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HALL OF THE AMERICAN PHILOSOPHICAL SOCIETY.

MAY 22-26, 1893.

1743—1893

PROCEEDINGS COMMEMORATIVE

OF THE

ONE HUNDRED AND FIFTIETH ANNIVERSARY

OF THE FOUNDATION OF THE

AMERICAN PHILOSOPHICAL SOCIETY

HELD AT PHILADELPHIA

FOR THE PROMOTION OF USEFUL KNOWLEDGE

MAY 22–26, 1893

PHILADELPHIA
1894

PRESS OF

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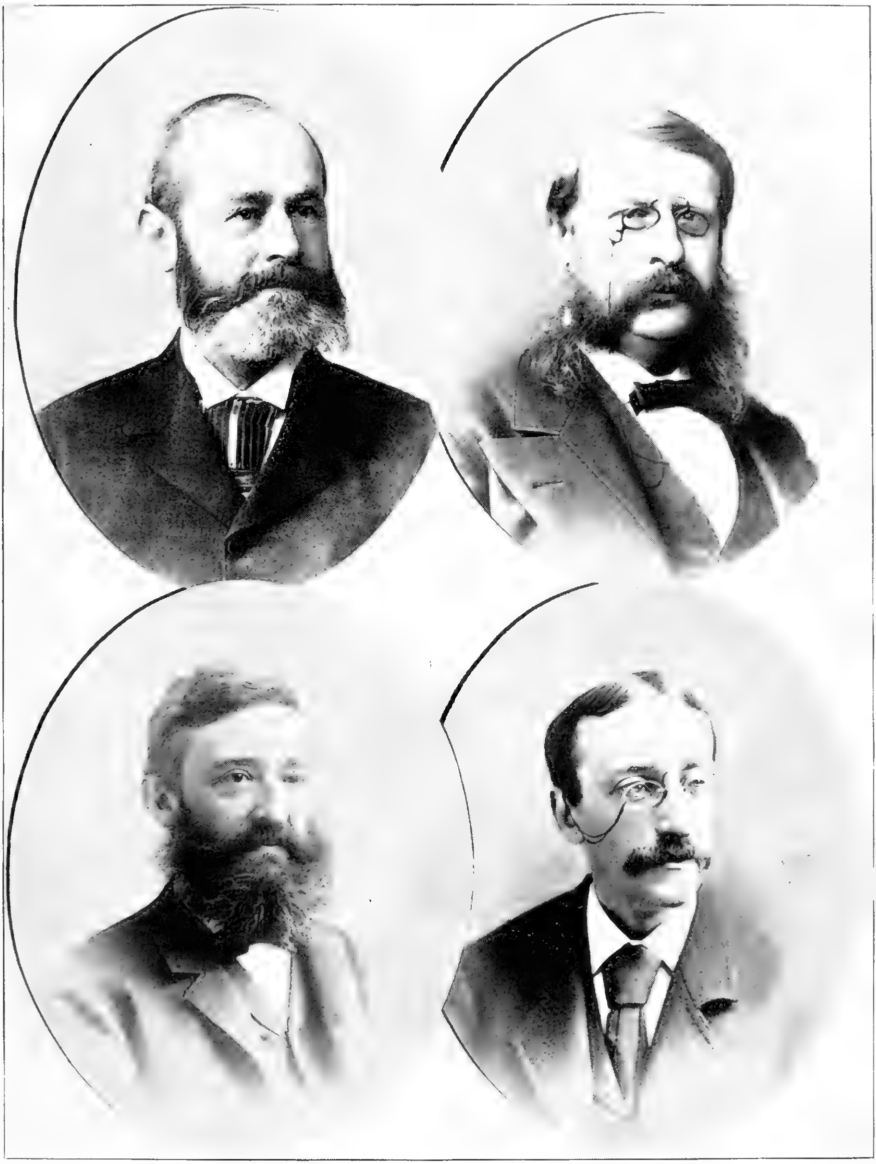

SECRETARIES:

2—DANIEL G. BRINTON,
4—GEORGE H. HORN,

1—GEORGE F. BARKER.
3—HENRY PHILLIPS, JR.

CURATORS:

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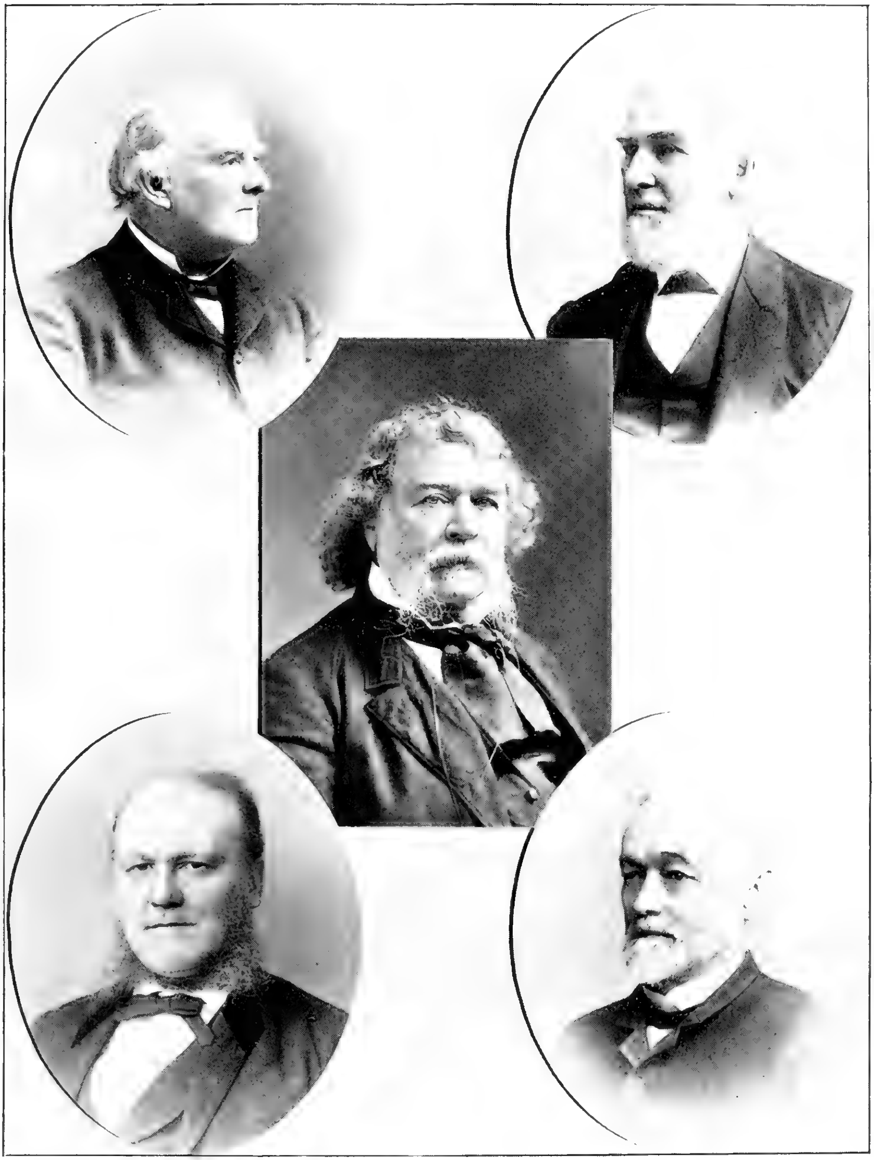

COUNCILORS:

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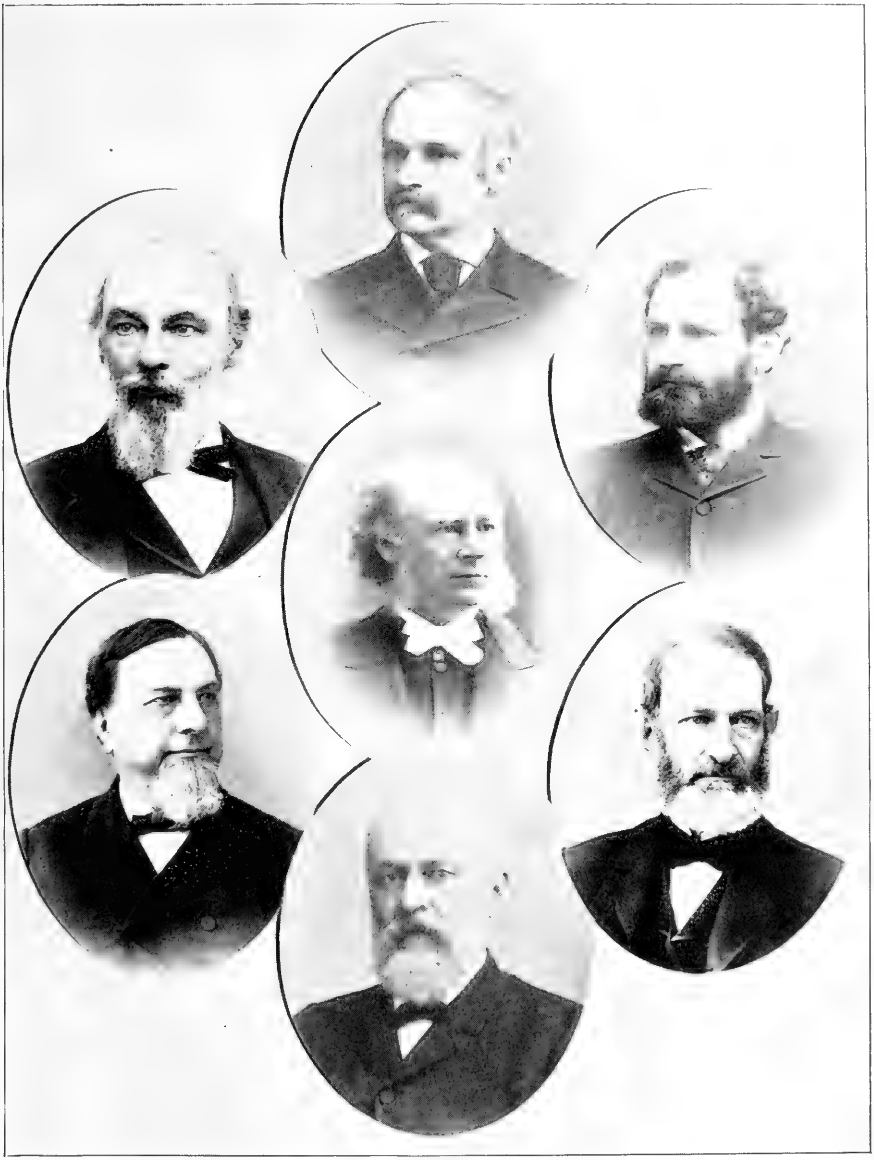
RICHARD WOOD, HENRY CAREY BAIRD.



COUNCILORS:

WILLIAM P. TATHAM, CHARLES S. WURTS, SAMUEL WAGNER.
GEORGE R. MOREHOUSE, WILLIAM C. CATTELL, THOMAS H. DUDLEY,
WILLIAM A. INGHAM.

1743 COMMEMORATION 1893

OF THE

ONE HUNDRED AND FIFTIETH ANNIVERSARY

OF THE FOUNDATION OF THE

AMERICAN PHILOSOPHICAL SOCIETY

HELD AT PHILADELPHIA

FOR THE PROMOTION OF USEFUL KNOWLEDGE,

May 22d to 26th, 1893.

At a stated meeting of the Board of Officers and Council of the Society, held on the 13th of May, 1892, Mr. Henry Phillips, Jr., offered the following Preambles and Resolutions, which were adopted:

Whereas, This Society did in the year 1843 celebrate the Centennial Anniversary of its foundation by a series of addresses, meetings, receptions, exercises, etc., upon the 25th, 26th, 27th, 28th, 29th and 30th days of May, the results of which were published in a special volume of over two hundred pages; and

Whereas, We are approaching the Sesqui-Centennial Anniversary of the same auspicious event; therefore, be it

Resolved, That the Society will celebrate the same in a worthy and becoming manner.

Resolved, That the President be authorized to appoint a Committee of five members to make all necessary arrangements for the same and with full power to act, and that the President be *ex officio* a member of said Committee.

At a stated meeting of the Society, held on May 20, 1892, the Preambles and Resolutions were considered by the Society, and unanimously agreed to.

The President appointed as such Committee, Mr. Henry Phillips, Jr., *Chairman*, and Messrs. J. Sergeant Price, Richard Vaux, Daniel G. Brinton, M.D., William V. Keating, M.D., Frederick Fraley, *ex officio.**

*On the 1st of May, 1893, the Chairman of the Committee was attacked by a sudden and serious illness, and being unable to carry on the duties of the position, Mr. J. Sergeant Price, at the request of the President of the Society, acted in such capacity.

ONE HUNDRED AND FIFTIETH ANNIVERSARY

OF THE FOUNDATION OF THE

AMERICAN PHILOSOPHICAL SOCIETY.

MONDAY, May 22, 1893, 8 P.M.

The Society was called to order by the President, Hon. Frederick Fraley, LL.D., who delivered the following address of welcome:

United Brethren (for so I think I can appropriately address you), it gives me great pleasure to welcome this goodly company which has come to us from abroad to the State of Pennsylvania and the city of Philadelphia, and to the ancient edifice in which we are now assembled.

I esteem it the crowning glory of a long life to be permitted to look upon this day. I have been a sojourner on earth for nearly ninety years, and I have looked upon this goodly world for the last seventy-five years with a full appreciation of what it contains and how much good it is possessed of to benefit mankind. Among those benefits I recognize the existence of our scientific institutions, which have gradually grown to be numerous in our territory, to be the correspondents of the older institutions abroad; and to have the opportunities occasionally of mingling in such assemblies as this for the promotion of the common objects they have at heart, for the general promotion of useful knowledge.

I hope that the occasion in which we have come to take part will be blessed, as our previous celebrations have been, with a unity of purpose, with the beginning of friendships that shall endure through life, with stimulus for the creation of new institutions of similar character, so that, as the years roll on, the circle of science will be completed and extended, and the benefits arising from a diffusion of useful knowledge will become more and more a blessing to the world at large.

It is difficult for me to find words with which I can pour out the fullness of my heart to you, my brethren, who are here around me, and I trust from the greetings which I have witnessed this evening, in the gratulations and friendships which have saluted my ears, that this occasion will be memorable in the history of our scientific life; and that if we have the advantages which seem to me to be promised to us from this gathering, when we shall separate at the close of the week there will be not only a union of hearts and a union of hands, but a union of common purposes and pursuits. Our country is so large, our population is so great, our resources of all kinds are so abundant, that everything which can stimulate the human intellect to labor, for the increase of knowledge and for the increase of happiness, lies all around us.

While you are here you will, I hope, accept and participate in those social enjoyments that will be tendered to you outside of the mere exercises of our meeting, and that you will visit our ancient University, the Girard College for orphans, the Drexel Institute, the United States Mint at Philadelphia, and, among others, those two hives of industry which bear testimony to the great improvements in the extension and perfection of steam machinery, in its application to naval purposes and to land transportation, the workshops of the Cramps and the "Baldwin's."

These opportunities are freely tendered to you, and our Committee of Arrangements will divide themselves into squads and take charge of you, so far as your individual preferences may choose, for visiting these different institutions.

Again renewing the cordial welcome that I have given you, I bid you now, gentlemen, Godspeed in the enterprises in which you may engage for the coming three days of this week, so that when the time comes for drawing upon us the curtain of separation, we will disperse with the conviction that we have added to our knowledge and to our friendships, and that we have done something for the benefit of our country and for the world at large.

It will be a great gratification to me personally, and I know that it will gratify our friends who are here assembled, if some of our guests will say a few words of congratulation to us, I may ask, and also give the views that they may take of such a celebration as we propose to hold.

Mayor Stuart, having been introduced by President Fraley, addressed the Society, as follows:

Mr. President, Guests and Members of the American Philosophical Society:—I had no idea when I came into the room to-night that I was to say anything in the way of welcoming the guests of this Society to Philadelphia. My good friend, Mr. Fraley, whom every Philadelphian loves and respects, has said far more to you in the few moments he has spoken than I could say if I were to speak for half an hour; but I have been requested, on behalf of the Committee, to say a few words of welcome to the distinguished guests who have honored our city to-day and this week by their presence, and in the name of the people of Philadelphia, who cherish the highest regard and respect for this ancient and useful Society, I extend to you a most heartfelt welcome, hoping that your visit among us will be as pleasant and agreeable to you all as I know your presence will be to us.

President Fraley next introduced Hon. Louis Vossion, Consul of France at Philadelphia, who presented the greetings of the University of Paris to the Society, as follows:

A La Société de Philsophie de Philadelphie—L'Université de Paris.

Messieurs:—L'Université de Paris est heureuse de saluer votre Société qui cultive, avec tant de succès, les Sciences philosophiques dans un pays que l'Europe considère trop souvent comme exclusivement occupé d'affaires industrielles et commerciales.

Il appartenait à l'État qui a compté parmi ses citoyens un philosophe pratique tel que Franklin de tenir haut et ferme le drapeau de la philosophie dans les États-Unis d'Amérique.

La France n'oublie pas que la Pensylvanie lui a envoyé ce grand patriote qui a noué entre votre jeune nation et la vieille France des relations d'affection et que c'est aux environs de Philadelphie que

La Fayette a scellé de son sang, dès sa première bataille, cette amitié impérissable.

Nous aimons aussi à nous rappeler que Franklin n'a pas seulement acquis à son pays les sympathies de la France, mais que par la dignité simple de sa vie, par ses paroles et par ses écrits, il nous a préparés à la liberté en nous montrant qu' une grande nation peut se gouverner elle-même.

Ces souvenirs ineffaçables vous assurent, Messieurs, de la sincérité des vœux que nous formons pour votre Société et pour la Grande République des États-Unis d'Amérique.

Le Recteur, Président du Conseil général,
Ereud.

Le Secrétaire,
Ernest Lavisse.

Prof. William B. Scott was next introduced, who, on behalf of the University of Princeton, New Jersey, read the following address:

Societati Philosophiæ Americanæ Universitas Princetoniensis.
S. P. D.

Cum hoc quidem semper decet eos qui scientias liberales amore, labore honore illustrauerint liberali in grata memoria haberi, sic enim debita immortalitas his rite tribuitur qui scientiam uiuificauerunt, tum in præsenti præcipue conuenit nos Præsidem et Professores Universitatis Princetoniensis lætos celebrare uobiscum sæculares ferias mox Philadelphiæ habendas atque hunc annum centesimum quinquagesimum Societatis Philosophiæ Americanæ conditæ commemoraturas.

Itaque nobis placuit inuitatui uestro amicissimo respondentibus Guilielmum Berryman Scott, qui apud nos Geologiam Palæontologiamque profitetur, diligere uicarium, cui insuper mandaruimus ut ipse pro nobis gratias et gratulationes coram reddat.

Datum Princetoniæ a. d. xiii Kal iun. [seal.]
Anno Salutis MDCCCXCIII.

The following address from the Naturwissenschaftliche Verein in Kiel was read:

Der Amerikanischen Philosophischen Gesellschaft zu Philadelphia zu ihrem Hundertfünfzig-jährigen Stiftungsfeste am 22 Mai, 1893, Gewidmet vom Naturwissenschaftlichen Verein in Kiel.

Ist unser Verein auch durch die räumliche Entfernung gehindert Ihrer Einladung gemäss einen Abgeordneten zu Ihrer Festfeier zu senden, so sind wir doch nicht verhindert, Ihnen unsere Grüsse und Wünsche über das Meer hin zu schicken.

Ihre Gesellschaft, so viel wir wissen eine Vereinigung mit der von Franklin begründeten Gesellschaft Junto, feiert fast genau zu gleicher Zeit wie eine der ältesten deutschen naturwissenschaftlichen Gesellschaften, diejenige zu Danzig, das hundertfünfzig-jährige Stiftungsfest.

In zahlreichen Bänden reichen Inhaltes haben diese beiden Gesellschaften die Naturforschung gefördert und der Verbreitung nützlicher Kenntnisse zum Besten der Menschheit gedient.

Fast zahllose Gesellschaften sind seitdem Ihrem Vorbilde gefolgt; Sie aber können Sich rühmen unser naturwissenschaftliches Zeitalter vorbereitet zu haben.

Wir senden Ihnen unsere besten Wünsche für das fernere Blühen und Gedeihen Ihrer Gesellschaft.

Der Naturwissenschaftliche Verein in Kiel.
Dr. G. Karsten, C. Reinbold, L. Weber.

Provost William Pepper being next introduced, presented on behalf of the University of Pennsylvania the following address:

Societati Philosophicæ Americanæ Universitas Pennsylvaniensis. S. P. D.

Magno cum gaudio litteris vestris nuper acceptis intelleximus appropinquare diem natalem Societatis Vestræ abhinc annos centum et quinquagenta conditæ; ad quem diem maxima lætitia concelebrandum nos non solum humanitas Vestra in convocando, sed etiam vel maxime id movet, quod Societatem et Universitatem meminimus ab uno conditore eodem fere tempore institutas, omnibus enim notum inter conditas eas annos intercessisse decem vel haud multo plures. His igitur jam Vobis conjunctos vinculis, tempore, quod et maximum, Franklinio conditore nunc cum maxime juvat illius hominis, decoris nostra communis, merita commemorare erga nos, civitatem nostram immo patriam universam, necnon operam egregie navatam in litteris scientiaque promovendis. Is enim est ille vir, cui inter nostrates pæne soli hoc contigerit, nullum opus in nostra urbe, quod ad bonum publicum spectet, non tetegisse, nullum, quod tetigerit, non auxisse, dignumque esse qui hanc laudem audiat, meliora sevisse quam speraverit vel etiam somniarit. Omnia quæ instituit ille, Bibliotheca Philadelphica, Valetudinarium Pennsylvaniense, Universitas Pennsylvaniensis, hodie, quod ad magnitudinem pertinet, adeo sunt aucta, quod ad utilitatem publicam, tantum ab inittiis illis parvis, ut nobis nunc videtur parumque sunt provecta quantum nemo, ne in somnio quidem fieri posse imaginaretur.

Nec solum habemus illum, cujus hodie mentionem debeamus facere: immo quam multi philosophi illustrissimi, Societatis socii, magna pars fuerunt rerum a Universitate prospere gestarum! Quis enim est civis noster quem dies hic faustus felix ad commemoranda non ipse ducat nomina hæc clarissima; Franklin, Bond, Bartram, Hopkinson, Coleman, Alison, inter fundatores venerabiles Vestros; —Rittenhouse, Smith, Ewing, Adrian, Morgan, Kuhn, Redman, Kinnersley, Barton, Coxe, Hare, Patterson, Rush, Wistar, Bache, Hornor, Wood, Price, Leidy, olim socii illustri Vestri, Curatores, Professoresque Universitatis nostræ honoratissimi! Et in præsenti eadem communitas atque necessitudo nos feliciter conjungit. Vobis igitur gloriam per annos centum et quinquagenta conservatam et auctam sincere gratulamus, optamusque ut illa in omnem posteritam vigeat ac floreat. Valete!

GUILELMUS PEPPER,
Præfectus.

Curatorum a secretis,
JESSE Y. BURK.

[SEAL.] WILLIAM PEPPER, M.D., LL.D.

Mr. Price, on behalf of the Committee, then read a number of telegrams received by the Society from various scientific societies.

ST. PETERSBURG, May 20, 1893.

TO THE AMERICAN PHILOSOPHICAL SOCIETY, PHILADELPHIA:

Russisches Geologisches Comité sendet seine beste Glückwünsche am bedeutungsvollen Tage Hundertfünfzig-jährigen Jubiläums der Gesellschaft. KARPINSKI.

MOSCOW, May 22, 1893.

TO THE AMERICAN PHILOSOPHICAL SOCIETY, PHILADELPHIA:

The Imperial Society of Friends of Natural Sciences, Anthropology and Ethnography, Moscow, congratulate cordially upon the great Anniversary, and send the best wishes for the future.

President, ANOUTCHIN.

Secretary, GONDATTI.

MOSCOW, May 21, 1893.

TO THE AMERICAN PHILOSOPHICAL SOCIETY, PHILADELPHIA:

Société Imperiale Naturalist, Moscow, presente felicitations a Société Philosoph occasion 150 Annivers de fondation.

President, SLOUDSKY.

ST. PETERSBURG, May 21, 1893.

TO THE AMERICAN PHILOSOPHICAL SOCIETY, PHILADELPHIA:

Imperial Russian Mineralogical Society congratulate Philosophical Society on 150 years of existence.

Director, JEREMEJEW.

Secretair, TSCHERNYSCHEW.

HELSINGFORS, May 22, 1893.

TO THE AMERICAN PHILOSOPHICAL SOCIETY, PHILADELPHIA:

Geographic Society of Finland and Societas pro Fauna et Flora Fennica beg to present their respects and congratulations on the memorable day. BERGBOM PALMEN.

The following list contains the names of the delegates appointed to represent the various societies and institutions responding to the Society's invitation:

Société Entomologique de Belgique, BRUXELLES, BELGIUM:
Capt. Casey, U.S.A., New York.

I. R. Accademia degli Agiati, ROVERETO, TYROL:
Henry Phillips, Jr., Philadelphia.

K. K. Military and Geographical Institute of VIENNA:
Capt. Karl Chevalier Rousseau d'Happoncourt,
Lieut. Col. Robert Daublebsky von Sterneck.

L' Université de Paris:
Hon. Louis Vossion, Consul of France at Philadelphia.

R. Università de Bologna, BOLOGNA, ITALY
Henry Phillips, Jr., Philadelphia.

University of Pisa, PISA, ITALY :
Henry Phillips, Jr., Philadelphia.

Royal Academy of PADUA :
Prof. John James Stevenson, Ph.D., New York.

R. Istituto di Studi Superiori, FLORENCE, ITALY :
Prof. Vincenzo Botta, New York.

R. Academia de la Historia, MADRID, SPAIN :
Henry Phillips, Jr., Philadelphia.

Royal Society, LONDON, ENG. :
Capt. W. de W. Abney, R. E., C. B., K. C. B.

Royal Statistical Society, LONDON, ENG. :

Royal Institution of Great Britain, LONDON, ENG. :
Sir Douglas Galton, K. C. B.

Royal Astronomical Society, LONDON, ENG. :
Isaac Roberts, D. Sc., F. R. S., F. R. A. S., F. G. S.

Royal Asiatic Society of Great Britain and Ireland, LONDON, ENG :
Prof. Charles R. Lanman, Cambridge, Mass.

Royal Society of Edinburgh, EDINBURGH, SCOTLAND :
Prof. Herbert Anson Newton, New Haven, Conn.

Canadian Institute, TORONTO, CANADA :

Nova Scotian Institute, HALIFAX, N. S. :

Harvard University, CAMBRIDGE, MASS. :
Prof. William W. Goodwin, LL.D.

Museum of Comparative Zoölogy, CAMBRIDGE, MASS. :
Prof. George Lincoln Goodale, LL.D.

Massachusetts Historical Society, BOSTON, MASS. :
Dr. Samuel A. Green.

American Academy of Arts and Sciences, BOSTON, MASS. :
Prof. Josiah P. Cooke, LL.D.,
Prof. Alpheus Hyatt, Cambridge, Mass.

Boston Society of Natural History, BOSTON, MASS. :
Prof. Samuel H. Scudder, Ph.D.

Institute of Technology, BOSTON, MASS. :
Prof. Thomas Messinger Drown.

American Antiquarian Society, WORCESTER, MASS. :
Hon. Henry C. Lea, LL.D., Philadelphia.

Providence Franklin Society, PROVIDENCE, R. I. :
Prof. Levi W. Russell.

New Haven Colony Historical Society, NEW HAVEN, CONN.:
Prof. James M. Hoppin, D.D.

Yale University, NEW HAVEN, CONN.:
Prof. Othniel C. Marsh, LL.D.

American Chemical Society, BROOKLYN, N. Y.:
Prof. George F. Barker, M.D., Philadelphia.

Columbia College, NEW YORK:
Prof. Charles F. Chandler, Ph.D.

American Geographical Society, NEW YORK:
Prof. William Libbey.

Mathematical Society, NEW YORK:
Prof. Henry B. Fine.

Oneida Co. Historical Society, UTICA, N. Y.:
Gen. Charles W. Darling.

College of New Jersey, PRINCETON, N. J.:
Prof. William B. Scott, Ph.D.

Lafayette College, EASTON, PA.:
President Ethelbert D. Warfield, LL.D.,
Prof. Francis A. March, LL.D.

Linnean Society, LANCASTER, PA.:
Prof. H. F. Bitner, Millersville, Pa.,
Prof. J. H. Roddy, "
Prof. S. M. Sener, Lancaster, Pa.

College of Pharmacy, PHILADELPHIA:
Charles Bullock.

Academy of Natural Sciences, PHILADELPHIA:
Gen. Isaac J. Wistar.

College of Physicians, PHILADELPHIA:
Dr. I. M. DaCosta.

Numismatic and Antiquarian Society, PHILADELPHIA:
Francis Jordan, Jr.

Engineers' Club, PHILADELPHIA:
Strickland Kneass.

Wagner Free Institute, PHILADELPHIA:
Joseph Wilcox.

University of Pennsylvania, PHILADELPHIA:
Provost William Pepper, M.D., LL.D.

Franklin Institute, PHILADELPHIA:
Dr. Edwin J. Houston.

Wistar Institute of Anatomy and Biology, PHILADELPHIA:
Charles C. Harrison.

Johns Hopkins University, BALTIMORE, MD.:
Prof. Ira D. Remsen.

Maryland Historical Society, BALTIMORE, MD.:
Rev. John G. Morris, D.D.

Anthropological Society, WASHINGTON, D.C.:
Col. Garrick Mallery, U.S.A.

U. S. Coast and Geodetic Survey, WASHINGTON, D.C.:
Prof. Charles A. Schott.

Smithsonian Institution, WASHINGTON, D.C.:
Prof. Samuel P. Langley, Ph.D., LL.D.,
Dr. George Brown Goode.

Georgia Historical Society, SAVANNAH, GA.:
Henry Phillips, Jr., Philadelphia.

University of Michigan, ANN ARBOR, MICH.:
Henry Phillips, Jr., Philadelphia.

University of Indiana, BLOOMINGTON, IND.:
Prof. John M. Coulter.

Chicago Academy of Sciences, CHICAGO, ILL.:
George H. Hough, LL.D.,
Charles G. Fuller, M.D.

Societies that sent congratulations, but regretted their inability to send delegates:

Geological Survey of India, CALCUTTA.
Asiatic Society of Japan, TOKYO.
Tokyo Library, TOKYO, JAPAN.
Royal Society of New South Wales, SYDNEY.
Royal Geographical Society, BRISBANE, AUSTRALIA.
Finska Litteratur-Sällskapet, HELSINGFORS.
K. Sächsische Meteorologische Institut, CHEMNITZ, SAXONY.
K. Sächsische Alterthumsverein, DRESDEN, SAXONY.
K. Norske Frederiks Universitet, CHRISTIANIA, NORWAY.
K. Norske Videnskabers Selskab, THRONDHJEM.
Anthropologische Gesellschaft, VIENNA, AUSTRIA.
Rheinische Friedrich-Wilhelms-Universität, BONN, PRUSSIA.
Naturhistorische Verein der Preussischen Rheinlande und Westphalens, BONN, PRUSSIA.
Verein für Erdkunde, METZ, GERMANY.
Württembergische Verein für Handelsgeographie, STUTTGART, GERMANY.
Senckenbergische Naturforschende Gesellschaft, FRANKFURT A. M.
Naturwissenschaftliche Verein für Schleswig-Holstein, KIEL.
Batavian Society, ROTTERDAM.

Académie Royale des Sciences, Bruxelles, Belgium.
Schweizerische Naturforschende Gesellschaft, Lausanne, Switzerland.
Académie des Sciences, Dijon, France.
Société de Geographie, Paris, France.
Oxford University, Oxford, England.
Royal Observatory, Edinburgh, Scotland.
Literary and Philosophical Society, Manchester, England.
University of California, Mount Hamilton, Cal.
Ohio Archæological and Historical Society, Columbus.
Georgetown College, West Washington, D. C.
Colorado Scientific Society, Denver.
Elisha Mitchell Scientific Society, Chapel Hill, N. C.
United States Naval Institute, Annapolis, Md.
United States Military Academy, West Point, N. Y.
American Museum of Natural History, New York.
University of North Carolina, Chapel Hill, N. C.

Philadelphia, Tuesday, May 23, 1893, 11 a.m.

The Society was called to order at 11 a.m. by the President,* Mr. Fraley, who delivered the following address:

Gentlemen:—In May, 1743, when Benjamin Franklin put forth his proposals for the establishment of an American Philosophical Society in Philadelphia, he found, according to his letter, that the population of the British Colonies in North America had reached to such proportions, and the examinations that had been made of their natural resources and the industry and thrift that attended the whole population, showed that it was a favorable time for bringing the scientific men of the country into unison, and to establish a Society having for its model the Royal Society of London.

What thoughts rise in our hearts when we contemplate the boldness of such an undertaking at such a time, and how naturally we realize the fact that the struggles of the Society for existence and progress were marked with all the usual infirmities that attend upon infancy!

During the last half of the eighteenth century, Europe was agitated by bloody and cruel wars, nation waging against nation,

* At this meeting General Isaac J. Wistar appeared, and, as a newly-elected member, was presented to the President, and took his seat.

threatening the overturn of existing institutions, and ultimately culminating in the establishment of modified institutions and a gradual approach more and more to democratic organizations. Our own country, emerging from its colonial state, had made a declaration of independence; had, by great courage, trials and sufferings, accomplished finally the result of the proposition for free government; and, before the close of the eighteenth century, that Constitution of the United States under which, with a few amendments, we now so happily live and are making such mighty progress as a great nation, was adopted.

Some of the men who participated in those early struggles in our country were enrolled as members of this Society, and, among them, without an attempt to enumerate all, we find of the signers of the Declaration of Independence, Benjamin Franklin, Thomas Jefferson, Robert Morris, Benjamin Rush and several others who were early members of our organization.

In 1769, there was a union of the two Societies for the promotion of useful knowledge in Philadelphia, and Benjamin Franklin became the first President, David Rittenhouse the second and Thomas Jefferson the third. Those who followed after have fairly illustrated what were the objects which were had in view by the founders of the Society, and how they were prosecuted by the early members; and with what success the great objects for the promotion of useful knowledge were aided, and to a great degree accomplished, through the instrumentality of the members of our Society.

While the wars which I have referred to disturbed the last half of the eighteenth century, science, invention, intellectual thought, with everything that contributes to the elevation and prosperity of mankind, were not neglected. The volumes written and printed during those fifty years, the activity in the development of the constitution of nature, in the empire of thought, the application of science to the useful arts and the wonderful achievements of those days, even when we contrast them with what is now going on around us, are wonderful in the extreme. *The Century of Inventions*, published by the Marquis of Worcester, illustrative of his investigations in the mechanical sciences, has formed to a certain extent the basis of the operations and thoughts of our mechanical minds. The simple steam engine which was in existence at the beginning of the eighteenth century, was gradually developed by new additions to its structure, promoting its safety and giving it more and more efficiency. By the attention given to mechanical science by the Earl of Stanhope, and above all by the genius of James Watt, the steam engine of those ancient days attained a perfection which seemed at the beginning of the nineteenth century to be such that there was nothing more for man to invent or to aspire to, to increase his powers.

But how does this wonderful invention stand at the present day? The old, simple-acting atmospheric engines, of which I saw some remains in my early childhood, have entirely disappeared, except perhaps in the museums of mechanical objects. The perfected engine of Watt began to be superseded early in the century by the invention of Oliver Evans, a citizen of Pennsylvania, who devised the high-pressure engine, imperfect in the first place in its structure, but wonderful in its effect. Among the examples of his engines, in contrast with those of Boulton and Watt, I may be permitted to call the attention of this meeting to the two engines which for a number of years stood side by side in the building of the Fairmount Water Works, which was erected for the purpose of containing the engines and supplying the city of Philadelphia with water. There was the complicated and ponderous engine of Boulton and Watt, with its walking beam and its great fly-wheel, with the improvements that had been made on the sun and planet movement for the accomplishment of the conversion of vertical power into rotary power. There was a little engine built by Oliver Evans, occupying a space of certainly not more than fifteen feet wide by twenty feet long, with its boiler and all its appendages working under a pressure of 150 pounds to the square inch and performing more work than the elaborately constructed and perfected engine of Boulton and Watt.

In this high-pressure engine of Oliver Evans is found the type of what are now called the compound steam engines of the present day, the steam entering one cylinder at a very high pressure, gradually emerges from that into a second under a diminished pressure, and going on until finally, I believe, it is now passed through at least four cylinders, and terminates at the end of its work under the pressure with which the Boulton and Watt engines were originally worked.

I do not think too much praise can be given to our mechanical inventors. Not only does the steam engine evidence the success of their inventive genius and their perfected labors, but the machinery by which cotton and wool and silk are carded, spun and woven into the beautiful fabrics of the present day, is the product of the last one hundred and fifty years. It will be recollected by my friends who are now here that it was very doubtful towards the close of the eighteenth century whether cotton could be so treated as to separate it from the seeds, to be carded and spun into threads and woven into fabric; but while this doubt was threatening that great product of nature, Whitney gave us the cotton gin, which separated successfully the seeds from the fibres of cotton, preparing it for the cards and introducing it through the gradually perfected machinery for drawing and spinning.

The English inventors and factory men had their genius stimulated to the same end, and the spinning jenny, the mule, and the more elaborate machinery invented by Richard Arkwright, came into use, and, by improvements on the original structures, have arrived at the perfection with which our factories are now equipped and perform their work.

If we turn to other branches of useful knowledge and of science, the first that make an impression on my mind are the wonderful discoveries in astronomy. The old plan of searching the heavens by imperfect instruments has given place to the magnificent telescope of the present day. Photography has come in to the aid of the astronomer, and while his telescope searches out the stars and keeps his instrument in continued harmony with their motion, photography copies the picture of the heavens and opens to us a world not only of knowledge but of imagination.

The chemistry of the world has also undergone great changes. The middle of the eighteenth century was illustrated by the discovery of oxygen gas by Dr. Priestly, and that discovery influenced the science of chemistry to a very great extent in the early years of its progress. But Sir Humphrey Davy and the other later chemical philosophers found out that there were other supporters of combustion than oxygen, and by the combination of those other supporters of combustion we get the basis with which it is possible to combine those gases in the manufacture of important acids.

The whole science of chemistry has been revolutionized, and now the chemists who survive and who received their instructions in the early years of the present century, not only cannot realize what the status of chemistry is at the present day, but are lost in amazement at the contemplation of the arts by which such revolution and such changes have been accomplished.

In mathematical science the development has, I think, been found equally progressive. We must recollect, in this connection, that while planets used to be discovered by accident and by the visual inspection of the starry heavens, this age has been celebrated by the discovery of a planet purely accomplished by mathematical computation. The great planet Neptune bears testimony to the accuracy of such mathematical formulæ, and perhaps it may not be too much to say that, as years roll around, other great planets may be added to our solar system and the study of the inferior ones will become more nearly perfect by the aid of improved telescopes and the application of photography, so that we may penetrate into the recesses of those planets and perhaps discover that, like our own, they are populated by intelligent beings pursuing, according to the blessings that may be vouchsafed them, the study of what they are capable of in the development of their condition; and possibly, if it is not too much a flight of fancy, that the inhabitants of the earth may develop some machine or instrument by which the gravity of our planet may be overcome and we may go on a voyage of discovery to Venus or Mars.

In medicine, what progress has been made? The old, simple methods followed by a physician, when he was called in to attend a patient, in endeavoring to ascertain the cause of the disease with his imperfect knowledge, reducing inflammation by bleeding, afraid to embark upon any capital surgical operation for fear of disastrous results, have been replaced with greater knowledge. Now the accomplished physician and surgeon steps in and in a very few hours or a very few days determines what is the affliction of his patient and applies the appropriate remedy for changing the constitution of the fluids of the body, and, if need be, courageously takes out his knife and extirpates a tumor, dissevers an arm, opens the throat or the body and by actual inspection of what is the matter lays open the whole case for the application of his remedy, and saves perhaps ten lives at the present day from the inroads of disease, where one life was saved at the beginning of our present century.

In geographical investigation what marvels have the explorations of our travelers exhibited? How more and more are we becoming familiar with the conditions of uncivilized life, the temperature of the regions it occupies, the products which are yielded by their soil, the direction in which their rivers run, and the whole phenomena of geographical investigation, beginning not only with the appearance of the topography of the earth, its mountains and valleys, but its meteorological conditions and the influences that those conditions have in modifying climatic influences, and either tending to the increase of the natural productions of the soil or interfering with their growth, and admonishing man that there are certain pastures upon which he cannot venture.

What is the geology of the present day as compared with that which prevailed one hundred and fifty years ago? The great geological surveys that have been going on, not only in Europe but in our own country, have developed an amount of knowledge as to the structure and contents of the rocks which strikes us all with admiration. One discovery after another is presented. Men are tracing the various stages of the earth through the fossils which the rocks contain, and while their speculations are not always conclusive on our judgment, yet they open to us fields for contemplation and thought which we all may pursue with intelligence and profit.

We are endeavoring now to unroll the history of the past by the excavations which reveal the ancient temples and the depositories of the knowledge of those who have passed into history, and day by day some tablet, or cylinder, or mummy, is brought forth and the contents of the cylinder or tablet and the wrappings of the mummy give us lessons in the history of man which compel us to say in our hearts: There is nothing new under the sun.

I have referred to photography. At the centennial celebration of this Society, in the year 1843, one of the papers which was presented was a sketch given by Dr. Paul B. Goddard of his investigations in what might be the outgrowth of photography from the daguerrotype process. At that time photography was in its embryo state; very little was known of it. The experiments which he described as to the possibility of transferring upon printed pages or metallic plates the impressions that were taken, showed the dawnings of this great art which, perhaps, I ought to dignify with a higher name and call it science. Look around you now, my friends, at the manifestations of this art which meet you at every step of your progress through the streets of a great metropolis. The familiar features of your friends and children, of the distinguished men of the country and the great natural objects which attract our attention, are brought forth with a precision and certainty that does not admit of a doubt of their recognition, and in many instances so rounded off by art that they as far excel the productions of the pencil or the brush as the monumental pictures which the God of Nature has planted on the surface of the earth in trees and flowers, valleys and mountains, rivers and lakes, excel those which it is possible by the skill of man in any other direction to produce.

Now we sit at home and we hear the clicking of the telegraph, and it brings us a message from three thousand miles distance in a very little time. We put our mouth to the instrument of the telephone and speak in a natural voice to a man at a hundred yards or a hundred miles or even a thousand miles distant, and there the voice is heard, the interrogatory is answered, and the answer is flashed back before one would think the words had escaped the lips of the interrogator.

So that other marvelous instrument, the phonograph, takes down the very tones of our voice, engraving the words on cylinders of wax, which may be laid by in the closet and after a long interval of time be taken from its recesses and placed again in the machine, and, if the man and his voice have disappeared from the earth and his spirit gone to the God who gave it, that voice can be reproduced and be heard, and the lessons of philosophy perhaps contained in the engraved words may be read for the remembrance of his fellow-beings and fellow-workers, and, more than that, may be preserved and read for the use of the future.

When I think of these marvelous inventions, and turn my thoughts next to what has been accomplished while I have been partaking in the affairs of the world and endeavoring to learn my own lessons of what is going on around me, I marvel more and more at the blessings which have thus been vouchsafed to me. I feel from my knowledge of the men who have grown up and been around me, and lived with me, and participated in the pursuits in which I have engaged, that all this glorious company has been educated up to a higher level than we had any reason to anticipate in our early life, and that we may safely cherish the hope that the good work which has been accomplished is not to terminate with our earthly career, but is to be enlarged, fortified, extended and multiplied for the blessing of the human race, and for the promotion of knowledge and prosperity throughout the earth.

Here I feel that I ought to stop, but I may give one more word, I think, of encouragement to what has been accomplished by your skill. The old methods of transferring power by means of cog-wheels and ratchets has given way to the utilization of power by means of the pulley and the belt. You enter a factory now and see whirling around you what appears to be simply a loose strap passed over a pulley, with ponderous masses of machinery driven for the production of objects that are useful to mankind, some of them of prime necessity, and all of them recognized as great coadjutors in the work of practical education.

In every large machine shop that we enter we see the evidences of the invention of instruments of precision by which the labors of the mechanician are rendered more easy and more perfect; the planing machine supersedes the old attempt to form a level surface by the application of the hand plane; the turning-lathe accomplishes the formation of very complex forms, far differing from the original cylinder or cone that was the marvelous product of the lathes of old; the gunstock, or the last for a shoe for the human foot, or any complicated form of object, is turned out as if by magic in the improved lathes of the present day, and thus enters into the general mass of useful objects and the evidences of profound invention and skill.

And now, my friends, while I have not especially referred to the history of the American Philosophical Society, I will give you a reason for it, in the fact that it has already been given to you with such marvelous fidelity and truth by the public press that I could add no words to make the record which they have transcribed more complete or full. But I will say in conclusion, that one of the most useful applications of knowledge that these two centuries have witnessed, is the progress of the printing press. In the hall of the child of this Society, the Franklin Institute of Pennsylvania, stands the original printing press of Benjamin Franklin. Contrast that old but powerful instrument of its day with the steam presses that are rattling with their machinery and the operation of their contrivances every hour through the existing busy day. Their work and the result of their labors seems even to exceed what we have witnessed by the utilization of light and electricity. Light and electricity contribute no doubt to the vitality of their existence, but I think one of the most marvelous things for study is to visit the interior of a large, well-equipped printing office of the present day, and see with what rapidity the notes of the stenographer are turned into the text which appears in the newspaper article of the next day or the magazine article of the next month, the ponderous chapter of the history of inventions, or the treatise on mathematics or chemistry or geology or any other of the kindred sciences; how the text is reduced to printed matter, the type set up, the matrix in which a whole cylinder of matter can be at once developed, formed and put on the whirling cylinders of the press and printed and sped on the wings of the wind throughout the universe.

Such, my friends, is the simple tribute that I am able to pay to this intelligent audience, and the testimony which I am constrained to bear that this earth is gradually growing better and wiser, and that men are beginning to understand more fully the objects for which they were created and to be more helpful to their fellowmen, to prepare us for that higher and more blessed immortality which is promised to the faithful.

President Fraley then presented Prof. Alpheus Hyatt, of the American Academy of Arts and Sciences, Boston, Mass., and spoke as follows:

The American Academy of Arts and Sciences, at Boston, is the sister of this institution, ours having been established in 1743 and the Boston Academy in 1780. They celebrated their centennial in 1880, and no doubt will emulate us in celebrating their one hundred and fiftieth anniversary in 1930; and when that time comes around they will make up the glorious record more fully of that which has been accomplished and also realize the truth of the motto which they bear on their seal.

Prof. Alpheus Hyatt, of the American Academy of Arts and Sciences, Boston, Mass., addressed the Society as follows:

Mr. President and Members of the American Philosophical Society:—I came this morning intending, of course, to listen to the two gentlemen who had been announced to speak, with no anticipation whatever that I should be called upon to give anything more than perhaps a mere statement of the subject of my paper.

I labor under the double disadvantage of having prepared therefor no specimens, having brought before you nothing to make my theme comprehensive, and also the final disadvantage of having no blackboard ; but I will do the best I can to make my point comprehensible.

The subject which I proposed to present to the Society is what I should call the "Phylogeny of an Acquired Characteristic," the history of one single characteristic followed out from its earliest inception in the type of cephalopods through various stages of its evolution to its final disappearance in the same type. The object is to give a solid basis to certain theories of evolution.

You all, of course, know that in the present treatment of the problem of evolution everything depends on having some specific object. It is well enough to speculate, it is well enough to state the Darwinian hypothesis, it is well enough to have this hypothesis or that point of view and to argue about them, but to come down to the facts which lie at the bottom of these, and to follow them through all the phases of their evolution is, of course, difficult and largely a matter of chance in every department of research.

In this case, one characteristic happens to be provable, and furnishes the subject which I have in hand for special investigation. The earliest shells, those which are primitive in shape, are cones like this. (Illustrating.) They are divided by partitions and have certain internal characteristics which distinguish them. The next shape is bent, as if I were to take this cone and bend it without crushing in one side. The next form is loosely coiled, as if I doubled this paper cone without depressing one side, the cone not coming in contact. The next stage of evolution is one in which the cone not only doubles on itself by growth, but doubles so closely that it actually flattens this inner side, and then, in place of being able to see these inside convolutions in the next state of evolution, they are concealed by the downward growth of the outside. So that the shell, growing gradually, first like a rope coiled up, and then eventually, if you can imagine the sides of the coil growing inwards as they progress, so as to cover up the interior, you would see the last or outside convolution with a depression like that (illustrating) in a horseshoe shape, on the inner side. These whorls, the first of them in the Devonian and Silurian period, are always rounded, so that the section is very much like a section of the end of that cone, it has no depression on the inside. Then, as the forms coil tighter and tighter, one whorl lying over the other, the inner whorl presses upon and obliges the outer whorl to form this depression on the inner side. When the shell gets old the whorl quits the spiral and grows out straight, and when that period begins in old age this depression, which is formed where the whorls close up, gradually disappears, so that in extreme old age you get a return to the rounded outline.

Thus you get throughout the earlier systems in the earth's history, throughout the Silurian and Devonian period, a transient condition. You will find that whenever this depression occurs it is always because one whorl laps over another. When, in the course of growth, the shell passes by the whorl, that bay or depression disappears, so that you get in every fossil the proof that this characteristic is a transient one, that when it occurred it was through the mechanical action of the growth of one whorl of the shell over another, as much so as a dent in a piece of putty when you put your fist in it; in other words, it is not in the organism and in any shape which would enable us to say it was inherited. The Weissman hypothesis is that evolution has taken place by other forces than those which modify the organization from the exterior. He says that no characteristic which is acquired in this way, mechanically, by growth or the action of the externals in any way on the animal, can be inherited. It is not inherited. It makes no impression on the organism so that it can be inherited.

We can get the history of this characteristic throughout the earlier periods and it justifies the hypothesis. It was supposed by me for several years to be one of the strongest points in favor of the hypothesis, that an acquired characteristic made no impression on the germ and was, in fact, non-inherited.

This last winter, following out an investigation begun in connection with the geological survey of Texas in the carboniferous deposits of that region, I was led to extend my investigation in regard to their development and general history. The result was the finding that in certain series of the carboniferous this characteristic was indubitably inherited. I found in the young of close-coiled carboniferous forms, shells which were unquestionably close coiled in their adult condition, that in the young of these there was a repetition of the characteristics of the adults of the Silurian and Devonian. In these very young forms the whorls do not touch when they first begin to grow, but are all open, as much so as if I bent this piece of paper this way and simply curled it in that shape. (Illustrating.) The young of these carboniferous forms are formed like that; the whorls do not touch. When you take a young cone like that and examine this portion of it you find this depression, which was purely mechanical in origin throughout the Silurian and Devonian, and dependent upon close coiling is here inherited before the whorls touch.

That, then, seems to be as far as possible, without demonstration by experiment, a clear case of the acquisition of a characteristic in the earlier periods of the evolution of a group, through the purely mechanical effect produced by the mode of growth of the shell, and then the inheriting of the same in the young of carboniferous forms before any of those mechanical causes which originated this characteristic could have their influence on the growth of the shell. While it was still young, still uncoiled, still like its ancestors in every way, it inherits this acquired character, which never appeared in them until later in life, and was retained in them only so long as the originating mechanical causes continued to bear on the shell during its growth.

Then to complete the history after the carboniferous, I have investigated the different forms to see if it were continuous. We find it is present in the same type throughout the jura, cretaceous and trias, and finally, examining the last existing forms, of which there are only four species, of nautiloids now living, the same characteristic is well developed in the young.

Then following up another line, taking the Ammonoids, which is the more complicated type, and which terminates in the cretaceous, we can pass through the entire group, and we find this characteristic increasing and becoming more and more important. Finally, we strike in the jura certain degraded forms, and ultimately in the cretaceous forms which are the reverse of those with which they began. Just as in old age we are in a measure the reverse of our adult period, just as in that condition we put on certain infantile characteristics, which are produced by the wear and tear of life, these types through their evolutionary history go back on their history, and part with characteristics that distinguish their higher development and become simpler. Instead of being coiled up they become uncoiled, having young which are coiled up and adults which are uncoiled, and in following this characteristic through that long reverse series of forms it is found to disappear precisely in accordance with certain laws, which show that in the degeneracy of types, as well as in the old age of individuals, there is a decrease and a final disuse of characteristics which have been introduced during the rise of the group.

The history of this characteristic follows the same law, and is precisely in accordance with the history of other parts of the animal, and precisely parallel with those which no one can deny to be hereditary. It will be very difficult for those who take the view that acquired characteristics cannot be inherited, to prove that this is not an acquired characteristic or that it is not inherited. It seems to me, as far as can be shown, without, of course, the direct demonstration of experiment, that it is an acquired characteristic of purely mechanical origin which becomes inherited in the carboniferous.

A Member: I should like to know what is the natural size of these shells.

Prof. Hyatt: They are of all sizes. The largest of those described perhaps are three inches in diameter, others when full grown being much larger. They are all of good size for observation.

Prof. Hubert A. Newton, of New Haven, Conn., representing the Royal Society of Edinburgh, next addressed the Society, as follows:

I have to apologize somewhat in that I came to the rooms not expecting to speak to you. I have, however, one point which I think will interest the members of this Society if they will give me a few minutes to develop it, and that is, the force which acts on the small bodies sent off from comets and which form our shooting stars.

There are in the comets so many questions that we cannot answer, so many curious and wonderful phenomena that are unexplained, that I am sure you will accept any explanation of any of them that seems plausible, as a matter of interest. From a comet there is continually driven off matter forming the tail, a light substance, and astronomers are agreed that the force that acts on the matter which forms the tail is a repulsive force from the sun acting inversely as the square of the distance, the force of the repulsion being greater than that of attraction.

Not only is this true, but different parts of that tail are acted upon by repulsive forces of different powers; otherwise the tail would form across the sky a single line instead of a broad, expanded mass of light such as we see. From the comet, however, there are driven off also, or there are separated other things entirely distinct from the tail, small bodies, which are not thus driven away, which are not visible, but follow along closely in the path of the comet, and whenever the occasion comes, that is when we go through a group of them, those give us our shooting stars.

The Biela comet, in the period about 1840, passed near to Jupiter. At that time it was turned pretty sharply out of its orbit, the inclination of the orbit being turned several degrees, and the node being carried forward also several degrees, represented by several days in the time at which we crossed the path of the comet.

After 1840 the bodies which formed the meteors that were met in 1872 and in 1885 were separated from one or other parts of the Biela comet. I say after 1840, because if they had been separated earlier they would have given us a different radiant in the skies, the one given by the Biela meteors of 1838. The radiant was changed, the node was changed, all to correspond to the new orbit, and these bodies could not have been turned in that way had they been before scattered, because the force that acted on them, the attraction of Jupiter, would have scattered the group instead of giving us that single compact group through which we passed in 1872 and 1885 in the course of four or five hours, and the bulk of them even in two hours.

In 1872, the comet was something like 200,000,000 miles away from the bodies that we met as we passed through them on the 27th of November, giving us a brilliant shower. Thirteen years later we passed through the group again, and then the comet was something like 300,000,000 miles ahead of the group. So that some of the particles, leaving the comet between 1840 and 1870, had gained and others between 1840 and 1885 had fallen behind.

What should separate those particles? What are the forces which carried off those particles so many miles—200,000,000 miles on the one hand and 300,000,000 miles on the other, in round numbers? The force that acts on them must be a force acting in one plane, that is, the plane of the orbit of the comet. Any force acting in other planes would have scattered the group and we would not have met them as a single definite group at the times named; but if it acts in the plane, only scattering them on the plane, they would be together as we saw them.

In that plane, it must be either an impulsive force acting once or it must be a constant force acting continually. The only bodies in that plane are the comets and the sun, and if the force is a continuous force it must be from the comet or from the sun. It is almost inconceivable to suppose that the comet could have sent them off, either impulsively or continuously, in such a way as to give us the distance of 200,000,000 and 300,000,000 miles in the course of thirty years; it would require far more than any velocity that we can give in our terrestrial experiments, and we have no reason to suppose that there is any such power of impulsion. Moreover, if the impulsion came from the comet, they would go in all directions and their character, as being in a plane, would have been entirely lost.

We are then thrown back on this one hypothesis, that the sun is the source of that force. In other words, we are led to extend the idea that I gave you in the beginning, and which is accepted by astronomers, that the material which goes off from the comet, after it leaves it, is subject to a force like that of attraction but differing in its intensity. In the case of the tail, it is a repulsive force. To satisfy these conditions of separation, part in one direction and part in the other, from the comet, we must have an attraction in the one case exceeding the attraction of gravitation and, in the other, an attraction less than the attraction of gravitation. In other words, these little bodies of hard matter that go off from the comet and follow very nearly in its train are acted on not in proportion to the force that steadily acts on the planets in their orbits.

I see no escape, myself, from this conclusion. What it means, I must leave to you to decide. Our experiments make it very improbable that the attraction of matter differs in any way from proportion to the mass. It looks to me as though the more natural explanation is that, in some way, the materials which go off from the comet carry with them a load of electricity, or something of that kind, by which they have a permanent repulsion or permanent attraction sufficient to change the orbit altogether, not in kind, but in a steady change, throwing them into a new orbit with a new period, and thus scattering them.

What that added force must be, we cannot very well tell, because it differs according to the place in the orbit where the disintegration takes place. If that disintegration takes place near the sun, it is one thing; if it takes place near Jupiter, it is another. It looks more to me as though there was a disintegration all along the line of the comet's orbit, giving us small particles with all sorts of loads of electricity and all sorts of differences of central attraction and differences of orbits, and thus they get widely scattered so as to give us the showers a long distance from the comet itself. The amount of this change would have to be something like the tenth part, possibly, or something less than that. I should think that all the phenomena could be explained by a change amounting to one-tenth of the attraction; that is, if the small particle carries a load of electricity such as to diminish the attraction to say nine-tenths of the original attractive force of the sun, or increase it to eleven-tenths, it will explain the phenomena.

If that is the explanation, we come to this further conclusion of interest, that the space through which these comets move is not such that the electricity which the particle carries can be lost. Another practical point would be that, in the discussion of the separation of these comet masses that through the telescope we see going on as the comets pass the sun, there might fairly be introduced an unknown correction of the force of central attraction.

A MEMBER: Have you gentlemen, who have made a study of this very interesting subject which you have been discoursing on, arrived at any hypothesis as to what broke up the Biela comet?

PROF. NEWTON: I can only answer as a working hypothesis, in my own mind, is that a mass, not surrounded by an atmosphere, coming down from the cold into a warmer region near the sun, becomes heated up, and in that heating there is a disintegration going on. If you put the pieces of a meteorite into a vacuum, and heat them, you will get gases that will be something like those which are thrown off from the tail of a comet, and the comet coming down near the sun, with the hot, scorching effect entirely undiminished by a thick atmosphere, would have pieces broken off, giving fresh surfaces. An immense amount of action of some sort follows, and those pieces would naturally go off under such excitement, carrying with them, as I conceive, a load of electricity. The process goes on in almost all our comets. It is not in Biela alone that we see comets going off to pieces. Scores of comets have shown that same breaking up under the telescope.

Adjourned.

In the afternoon the Society and guests attended a reception tendered by the Drexel Institute.

PHILADELPHIA, Wednesday, May 24, 1893, 11 A.M.

The Society was called to order at 11 A.M. by President Fraley, who presented Dr. Daniel C. Gilman, President of the Johns Hopkins University, who read an address on the "Present Aspects of Science in America."

After presenting the congratulations of the Johns Hopkins University to the American Philosophical Society, he proceeded to discuss the various agencies which are concerned in the advancement of knowledge, namely, museums and libraries, universities and colleges, scientific instruments and apparatus, agencies for the encouragement of research, and publications. Under each of these five heads, the speaker considered the actual condition of science in America, adding occasional historical illustrations. The paper included a sketch of the contributions made to each of the principal branches of natural science by American investigators.

President Fraley next introduced Rt. Rev. John J. Keane, President of the Catholic University of America, at Washington, who addressed the Society upon the subject of "Philosophy's Place Among the Sciences," as follows:

Mr. President and Fellow-members of the American Philosophical Society, Ladies and Gentlemen:—In the name of one of the very youngest of our American institutions of learning, I offer the tribute of my respect and reverence to the first association of the kind in our country. In our New World a century and a half is a very hoary old age, and a society that has with honor lived during that period can very well look down in a spirit of patriarchal dignity and superiority on every other institution that sets to work under its guidance and in pursuance of its example.

I say in the name of our young institution in Washington that to follow that guidance shall be our constant endeavor and our highest ambition. We have long since come to the conviction, so well stated just now by Dr. Gilman, that between science and religion there cannot be an antagonism, only we go a step farther than that which he indicated: We are not willing merely to regard science as the handmaid of religion, but we look upon science as the sister of religion; they are both from the same Father, and He has not made one the servant of the other; He has made them sisters one to the other, and it is in that spirit of sisterhood that in our institution they are to march hand in hand through the generations to come, and in doing that we are always going to keep our eye on the grand old association in Philadelphia. We are going to have its object of extending the boundaries of human knowledge and of bringing its treasures within the reach of the largest possible number, and in pursuance of that we shall always promise the tribute of our reverence and our loyalty to the grand old pioneer.

Yesterday, the keynote to this centennial celebration was given in the address of our venerable President. He showed us that the century and a half during which this Society has lived has been a period of progress along all the lines of human knowledge and of human activity. As lovers of mankind, we rejoice in that perspective and we give thanks to the Author of all good gifts, to the Father of Lights, who has so guided the researches of the past and led them to results that are so conducive to human utility.

To-day, as Americans, we look on that same perspective with honest pride, listening to the admirable presentation made by Dr. Gilman of what America has done in helping on that progress in the lines of science, and it could be shown by other specialists how America, in every other field of human thought and action, has taken her part nobly.

There is one department, however, in which it might be alleged that America has been rather in the background. America has added very little, comparatively, to the world's stock of philosophic thought. This is not owing to any want of philosophical ability or of what may be termed the philosophic spirit in our country, but it is because the energies of a new country have naturally been taken up in the tremendous development of her growth. Now that that growth is approaching its maturity, the natural tendency to philosophize asserts itself; but it behooves us, looking at the present and glancing forward to the future as far as we can, to provide that the philosophizing of the present and of the future shall chime with all the advance of human thought and of human knowledge.

We do not want a philosophy that will ignore any acquisition of human knowledge. Hence, it becomes of great importance that we should rightly estimate the relations that exist and must exist between science and philosophy.

In glancing over the sum of human knowledge, there are two things that strike us with almost equal force—we cannot but wonder at how little we know and we cannot but wonder at how much we know. Paschal has said very truly that that man has advanced but a short way in the road of knowledge who has not discovered that the amount which he does not know incomparably surpasses the amount he does know. There are still infinities of things that are beyond the reach of our ken, and yet we cannot but marvel at the amount of knowledge that we have drawn from the facts that are within our reach. The reason of that is because, as Schelling says, knowledge has two poles, the objective and the subjective poles, of cognition. The object of cognition may remain the same; the subjective conditions vary infinitely—subjective aptitudes, subjective fitnesses. The dewdrop has a message for the poet that the scientist may have no ears to hear, and the dewdrop has revelations for the physicist to which the poet may be absolutely impervious. The vibrations of air are one thing for Helmholtz; they are quite a different thing for Wagner. We remember how, in our childhood, we played with our kaleidoscopes and saw how the same little bits of broken glass, continuously assuming their varied forms, could give us infinities of beauty, and that was not, by any means, only a work of imagination. So the facts that stand before us are many sided in their phases, and every phase appeals to some aspect of human intelligence, and when we put into combination the endless variety of phases of things, and the endless variety of intellectual capabilities, then we come to understand how it is that, from the facts within our reach, the sum total of human intelligence has grown so tremendous.

This variety of human capabilities coming in contact with the intelligibility of things, is not only a legitimate and an unquestionable fact, but it is an ultimate fact, a fact whose consequences impose themselves upon us, not with a necessity that is regardless of distinction between true and false, but with the necessity of the truth. The consequences of that endless variety of human capabilities are in the sum total of knowledge an endless harmony, although in the comparison of individual fitnesses and individual intellectual activity it may often seem to lead to contradiction. Why should it lead to real or to apparent contradiction?

Even within the limits of severe knowledge, laying aside fancy and poetry, there is an immense difference between, leading to a divergence between, experimental observation and philosophic or speculative thought. Some minds are made for the one, some minds are made for the other. It is only the rarer minds, the immensely comprehensive minds, that seem capable of fully combining these two qualities in perfection. We know that this combination did exist in Aristotle—equally wonderful, equally admirable as a scientific observer and as a philosophic speculator; but in the average of men the one or the other fitness is very apt to predominate, and, if it is predominant, is apt to run into exclusiveness, and, if that tendency to exclusiveness be not counteracted, after awhile the scientific observer and the philosophic thinker may have drifted so far apart that they seem to be in conflict, in contradiction, that they may seem to find it impossible to come into agreement or even to find a common ground for argument.

When both gifts are combined in some great man, then it becomes evident to him, and his experience serves as a demonstration to others, that between the two—between the scientific and the philosophical—there cannot be a contradiction. But whenever the speculative or the experimental claims for itself exclusiveness, then the result is one-sidedness, and the one-sided thinker is apt to tumble over into chaos, or, what is almost equally bad, to rebound to an opposite extreme. So it is with individuals, so it is with epochs, with generations. Some great man puts the stamp of his mind on his epoch, and it is philosophic or it is positivist and scientific; and in the epoch even more than in the individual, because the epoch has time to work out the logic of things which may not be given to the individual, extremism or one-sidedness is certain to lead to a rebound, to a reaction that tends towards and may reach the opposite extreme.

During our century and a half, this has been made abundantly evident to the world. When our Society began, Kant was calmly investigating the value and the limits of human knowledge, working out what posterity recognized to be objective scepticism. It led to the rebound of extreme idealism, led by such men as Fichte, Schelling and Hegel, and that idealism went to such extremes as simply to bring philosophy into contempt. It led to the opposite rebound of materialism, reaching its climax in the positivism of Auguste Comte, and the extremes of that idealism have almost justified the extremes, also, of the empirical school.

At present we see a rebound from materialism and empiricism. The result is twofold. Wherever philosophic thought has grown languid and weak under the opiate influences of materialism and skepticism, wherever it merely has power to lift itself up and be heard, it seems to totter into mere agnosticism; but wherever, on the contrary, philosophic thought has retained some of the manly vigor which recognizes that the human intellect is not made for nescience but for knowledge, not made for darkness but for light, then philosophy stands up and asserts itself, asserts its right to remind science that it does not fill the whole world of human thinking, and demands that those relations between science and philosophy shall be remembered and shall be observed, upon which the reasonableness or utility of both equally depends.

What are those relations? Science works according to certain principles which it presupposes. These principles are very elementary. The whole is, and must be, greater than any of its parts. All the operations of nature take place, and must take place, in space and in time. Every effect presupposes, and must presuppose, a cause; and is, and must be, proportionate to its cause. Nature itself is a reality and not a fiction. It has in it those elements that make it possible for a man from facts to rise to laws and from laws to build up systems. All the notions of equality and inequality, of proportion and relation—all these things science works with, all these things science presupposes. Science did not make them, science did not discover them, science did not receive them even from mathematics. Mathematics, itself, presupposes them and works with them. Where do they come from? The scientist may accept these principles unconsciously, he may forget his debt to philosophy, but he does not by that forgetfulness cancel the debt.

More than that, when a science has done its best, and by the application of these principles has made and tested its methods, carried on its observations and then tested its results, all is not done. These single facts have to be woven, have to be fixed into the great mosaic of truth. Science stands side by side with other sciences, and the scientist in any department must every now and then, if he is loyal to human intelligence, look over the fence of his own narrow boundary, recognize the fields of thought that are beyond him, estimate the relation and agreement between his results and those which they are working out, and not merely try to estimate how it is as between him and his nearest neighbor in the departments of science, but how it is between him and them all.

Who is going to do this? No individual science can do it; no mere coming together of all the sciences can accomplish it. An arbiter is needed, an arbiter that can stand on a hilltop and survey all; and that arbiter of all the sciences—the one that stands on the hilltop and corrects blunders and utters notes of warning, and knows how, from hypotheses, to sift out certitudes and from mistakes to sift out truths, and to take all the little bits that each supplies and weave them in the harmony of truth—is philosophy; and the fact that her point of view is so much higher and so much more comprehensive than that of any science in particular, enables her to direct the sciences in their work and to point out any part of the great horizon in which the light is seen to be breaking forth.

Such is the natural relation between science and philosophy, the relation that they must have in the nature of things. How is it *de facto* in the age in which we live? It is a noteworthy fact that, in our age, so many scientific men are developing into philosophic thinkers. Wundt, after writing on physics, physiology and experimental psychology, gives us his system of philosophy. Mivart, while plying his scalpel, learns for himself and publishes to the world the deeper lessons from nature and the higher meaning of truth and the value and method of reasoning. From the physiological laboratory Du Bois Raymond surveys the Seven World Riddles, and Lewes launches out into the problems of life and mind.

These facts, simple indications of multitudes that might be enumerated, show that the most accurate scientific research is compatible with the profoundest philosophic thinking. Nay, more, it shows that science—when it is loyal to truth, when it is logical, when it is consistent, when it is human—must lead up to philosophic thinking. The same appears when we institute a comparison between the methods of science and of philosophy. First of all, let us observe that every science has its own specialties of method which no other science may share with it. The physicist has one method, the chemist has another, so have the biologist and the astronomer.

But these differences of detail in the methods of the individual sciences do not, by any means, prove any incompatibility between the sciences or their general methods. Apply the truth, and we recognize at once that, while there must exist distinctive differences between the methods of any science, or of all the sciences, and the methods of philosophy, these distinctive differences are no proof of incompatibility between philosophy and sciences or between their methods.

More than that, the method observed by all sciences is, in its ultimate analysis, generalization, which is a process of abstraction. Without generalization, without abstraction, it would be simply impossible to rise from the notion of fact to the notion of law. When the chemist finds that this oxygen, in this balloon, takes just so much of this hydrogen in this balloon in order to combine into water, he extends this proportion to all oxygen and all hydrogen, and to all experiments with them—past, present and to come—not by scientific observation, but by generalization, by abstraction, by the fundamental process of all thinking. When the physicist finds that this piece of spar gives double refraction, he concludes the same of all samples of that substance, and that without at all needing to experiment with the rest. When the physiologist finds that the blood in this man is composed of white and red corpuscles, he does not need to dissect all mankind in order to reach the conclusion that the blood of every man is composed in the same way. Thus we recognize that science is constantly making use of one great operation, which is the fundamental unity of all scientific method, and that is generalization, abstraction.

Then comes the mathematician, whose method means abstraction on a higher plane. He shows that two and two make four, whether it be two and two atoms, or two and two planets, or two and two ideas; and he applies his principles of number and weight and measure, his notions of quality and equality and proportion, to all things, and works out at his desk the system of the universe. It is a remarkable fact that the great fundamental, dominant principle of all physical science in our age, the conservation of force, was wrought out mathematically, by Leibnitz, one hundred and fifty years before it was proved experimentally by Joule.

One step more up that ladder of abstraction and we reach the operations of philosophy. It widens our view, giving us not merely the perspective of this science and of that science and of all sciences lying side by side, interlacing and working together in the production of the world's harmony, but it opens before us a perspective that embraces all things, a perspective embracing the infinite and the atom, with all the intervening grades of force and of life, the grand hierarchy of being, of causing, of becoming; therefore, the advance from science to philosophy is but an ascent from one grade of abstraction to another, without jar or hindrance, for those whose minds are keen enough for analysis and broad enough for synthesis.

Yet another motive which leads, or rather forces, the logical scientist into philosophy is the fact that problems exist and demand a solution which no amount of scientific research can solve. What is the origin of all? What is the aim of evolution? What is the nature of the human soul, its whence, its whither? What is the real value of human life? What are its duties, its rewards, its destiny? Any individual scientist may brush these questions aside, but there they stand, they confront mankind, they ever have confronted mankind, they ever have forced mankind to its highest and its deepest and its noblest thinking. They demand a reply, they prove with the very evidence of intuition that a reply to these problems is of greater importance than a reply to any of the problems ever started by physics or by chemistry; and just in proportion as special research drifts away from facing these problems they cry out all the more loudly in the ear of humanity and tell man that he dare not ignore them. The man who stands ankle deep in the rivulet may laugh at the shallowness of the little stream, but his merriment does not fathom the sea into which that stream and a thousand others are pouring; and to sound the depths of that all-comprising truth into which the separate branches of knowledge empty their threads of facts is the proper office of philosophy.

What system of philosophy is going to do this? What system of philosophy can we Americans at the close of the nineteenth century accept? It must be a philosophy that shall have an eye on the past and an eye on the future; that is to say, first, it must be a fair and balanced philosophy that shall avoid extremes, extremes which are fatal alike to empirical and to speculative thought. It must avoid one-sidedness, it must keep clear of materialism and of idealism, of skepticism and of dogmatism, of pantheism and of atheism; it must be balanced, it must be an all-around philosophy, it must be the *via media*. Secondly, it must be adaptable, it must be firm enough to hold fast to every addition which science may make to the sum total of human knowledge, fearless enough to welcome them all, knowing that fact can never contradict fact and that truth can never be in antagonism to truth; and it must be elastic enough to meet the result of philosophic research, holding on to what is, pressing on to what is to come. It must be, in the third place, a reflection of all those elements which in the development of thought persist because true.

We have men around us building up grand systems of philosophy and those systems die one after another, and yet, as the scientist shows us to-day the structure of the beings that lived ages and ages ago and left a substratum of fact after them, so these systems of thought that come and go and die leave something after them. No system of thought is totally false, though few systems of thought can claim to be totally true. And so our system of philosophy must be able to hold on to all that is true, no matter where it comes from, to hold on to the persistent, to hold on to that which is eternal because it is true.

May I be permitted in conclusion to ask your attention to what some may consider a singular fact in the world of thought at the close of the nineteenth century. Let me ask your attention to that grand old man whom we Catholics I think have a right to be proud of, Leo XIII, who on the one hand calls the world again to study the old scholastic philosophy, and, on the other hand, endows out of his own means astronomical observatories and laboratories of physics and of chemistry. That man is convinced that there is in that old philosophy a body of principles that are the truth, a body of principles that therefore are everlasting, a body of principles that therefore can guide science as well at the end of the nineteenth century as they did in the middle of the thirteenth. He shows that that philosophy is not a fossil, but a system of living principles ready to take in all that the scalpel, the retort and the lens can ever show us, and to teach all the wondrous progress of the science of the future how it is to weave itself into the great harmony of truth and is yet to shed its refulgence on the world. He shows us that it is possible for a system devised by Aristotle and developed by Aquinas to receive yet further development, and to answer yet or to help mankind to answer all the mighty problems in nature and above it that press upon the mind of man.

Shall not America do something towards helping the world to such a philosophy? America aims at giving to the world not only the best machines the world has ever seen, but the best men the world has ever seen ; Americans make the best men that civilization has yet produced. She is therefore to help the world on to the best thought that the world has ever yet beheld. I hope we recognize that human thought will not be at its best until scientific thought and philosophic thought are wedded together in proper harmony; and shall not this grand old Society, which has so beautifully guided America in her thinking and researches of the past, guide and help America in the study of that glorious problem which she in the future must help the world to solve?

Adjourned.

Wednesday, May 24—3 o'clock P.M. Reception by the Board of Directors of Girard College at the College.

9 o'clock P.M. Reception by the "Penn Club."

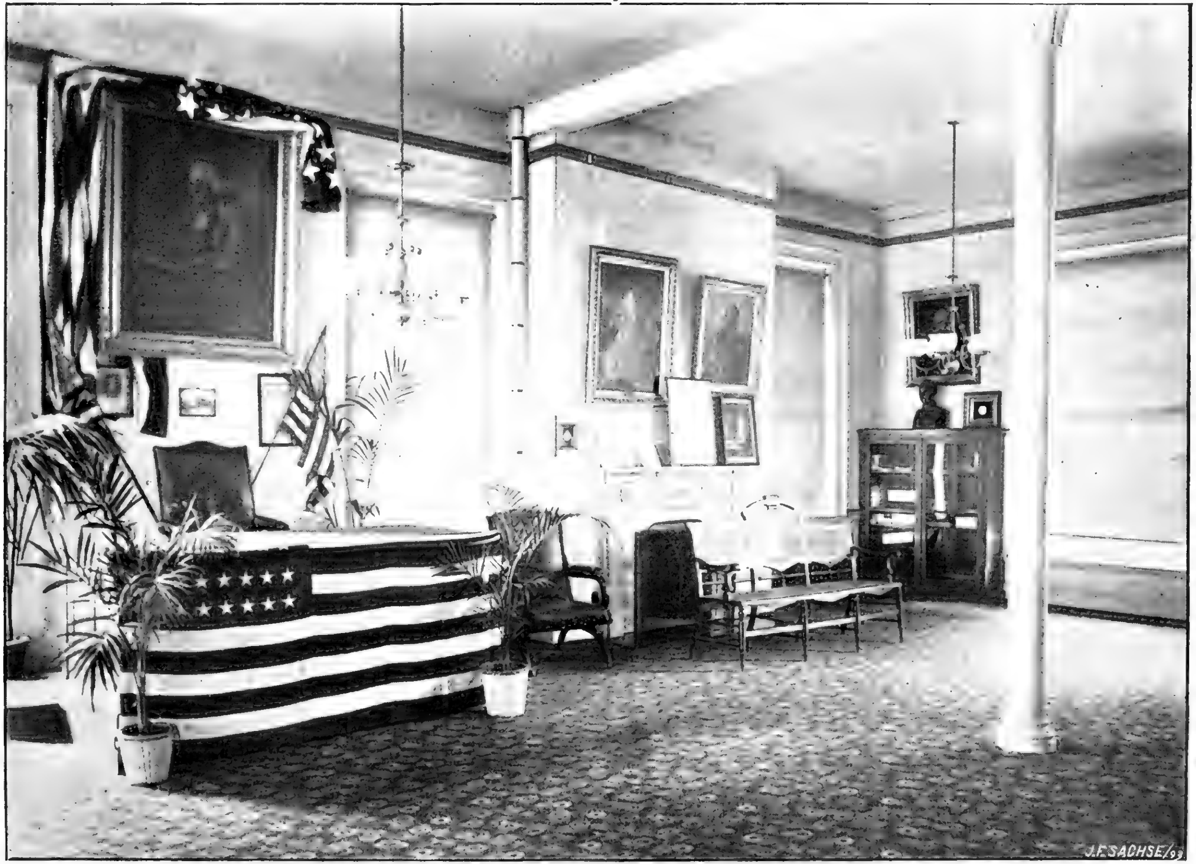
PHILADELPHIA, Thursday, May 25, 1893, 11 A.M.

The Society was called to order by Dr. Ruschenberger, who presided over the meeting.

Dr. Samuel A. Green having been introduced, read a paper on "Benjamin Franklin, Printer, Patriot and Philosopher," as follows:

At this anniversary meeting of the American Philosophical Society the name of the founder readily suggests itself; and for that reason I have taken as the subject of my paper the career of Benjamin Franklin, who was during his lifetime, with possibly a single exception, the most conspicuous character in American history.

Whether considered as a printer, a patriot, or a philosopher, Franklin challenges our highest regard and our deepest admiration. Taking him for all in all, in his moral and intellectual proportions, he is the most symmetrically developed man that this country has produced. In popular phrase he was a great all-round man, able to meet any emergency and ever ready to cope with any situation. In many ways he has left behind him the imprint of his mind and



MEETING ROOM, FACING SOUTH.

MAY 22-26, 1893.

BANQUETTING ROOM.

MAY 22-26, 1893.

of his work on the activities of the present day, to an extent that is unparalleled. To a large degree he had a knack of doing the right thing at the right time, which is epitomized by the American people as horse sense,—a quality which justly assigns him to a high place among men of worldly wisdom. He had a faculty of performing the most arduous labors on the most momentous occasions in such a quiet way that even his nearest friends often were entirely ignorant of his agency in the matter; and little did he care whether the credit of the deed came to him or went elsewhere. He seemed to turn off work of the highest order as easily as the sun shines or the rain falls, and just as unconsciously. A marked peculiarity with him was doing his whole duty on all occasions, without making a fuss about it. An estimate of his father's character, given in Franklin's own words, would apply equally well to himself: "His great excellence was his sound understanding, and his solid judgment in prudential matters, both in private and public affairs."

In order to trace some of these qualities towards their source, it is necessary to examine the causes at work during Franklin's early life, and even to go back still further and learn what influences had been brought to bear on his ancestors; since the influence of heredity must in this, as in every such case, be considered. It has been wittily said by a writer—so distinguished in many ways that I hardly know whether to speak of him as a poet or a physician, but whom all will recognize as "the Autocrat of the Breakfast Table" —that a man's education begins a hundred years before he is born. I am almost tempted to add that even then he is putting on only the finishing touches of his training. A man is a composite being, both in body and soul, with a long line of ancestry whose beginning it is impossible to trace; and every succeeding generation only helps to bind and weld together the various and innumerable qualities which make up his personality, though they be modified by countless circumstances that form his later education, and for which he alone is responsible. Of Franklin it may be said that he came of sturdy stock, none better in New England, poor in this world's goods, but rich in faith and the hope of immortality. On both sides of the family his ancestors, as far back as the records go, were pious folk, hard-working and God-fearing. They knew the value of time and money, and they also placed a high estimate on learning and wisdom. From such a source it fell to his lot to inherit life, and his heritage was better than silver or gold.

Benjamin Franklin was born on January 6, 1706,—according to the old style of reckoning time,—in a modest dwelling near the head of Milk street, Boston. Just across the way was the South Meeting-house, belonging to the Third Church of Christ, of which Franklin's parents were members, and at its services were constant attendants. In this sanctuary the little infant, on the day of his birth, was baptized by Samuel Willard, the minister, who duly entered the fact in the church record. With our modern ideas of sanitary precaution, it might now seem to us somewhat imprudent to take into the open air, even for a very short distance, a delicate *neonatus*, whose earthly pilgrimage was spanned by an existence of only a few hours, and to carry him to an unwarmed meeting-house, in the midst of a New England winter, even for the purpose of receiving the rite of Christian baptism; but our pious forefathers thought otherwise. At the same time, prayers were offered up for the speedy recovery of the mother; and the knowledge of this fact was a source of great comfort and consolation to the family household.

Benjamin's father, Josiah Franklin, was English-born,—coming from Northamptonshire, where the family had lived for many generations; the same county from which also the family of George Washington came. For a long period the men had been rigorous toilers, earning their livelihood by the sweat of their brow, and many of them were blacksmiths. Benjamin's mother, Abiah Folger, was a native of the island of Nantucket, and his father's second wife. Her father, Peter Folger, was a man of such distinguished probity that when he was acting as one of five commissioners appointed to measure and lay out the land on that island, it was decreed that any three out of the five might do the business provided he was one of them. What a commentary on his integrity, and what a tribute to his personal worth! The resemblance between the philosopher and Peter Folger, a later kinsman, as seen in his portrait, is very striking; and it may well have been said by his neighbors that in his younger days Benjamin favored his mother's family in looks.

Franklin's father owned a few books, mostly theological, and on these the lad used to browse, and pick up whatever he could in order to satisfy his inquiring mind, though he found it dry picking. There is no better exercise for a bright boy than to turn him loose in a library, and let him run, day after day and week after week, nibbling here and tasting there, as whim or fancy dictates.

Franklin's early surroundings were of a humble character, and his chances of brilliant success in life, as seen from a worldly point of view, were slim and discouraging. As a boy he played in the street, went barefooted in summer, fished from the wharves at flood tide, and snow-balled on the Common in winter; and he got into petty scrapes, just as other youngsters of that period did, and just as they ever will do, so long as boys are boys, because boyhood is brimful of human nature. He was no exception to the general run of youthful humanity, any further than that he was a bright, clever lad, with a good memory, and that he was fond of reading and always hated shams. He would never have been picked out of a group of urchins as one ordained to help mold the destiny of a new nation, or as one likely to stand before kings. But is it not written, "Seest thou a man diligent in business? he shall stand before kings"?

Early accustomed to habits of strict frugality, Franklin also imbibed those peculiar notions which laid the foundation of a remarkable and distinguished career. Brought up to work, he was not afraid of labor when apprenticed as a boy in the printing-office of his brother James, the owner and editor of *The New-England Courant*, where he often did a man's stint. His early advantages at school were very limited, being confined to a period of less than two years, and that, too, before he was eleven years of age. An apprenticeship in a printing office at any time is a good school of instruction, though one hundred and seventy-five years ago Franklin did not find it an agreeable one. His experience at that time, however, stood him in good stead on many later occasions.

The question naturally comes up, "What special influences were brought to bear on the young apprentice during the plastic period of his life which made him afterward the great philosopher and the sagacious statesman, and above all the apostle of common sense?"

This is answered in part by himself in his charming *Autobiography*, where he speaks of his fondness for reading, and of the difficulty he experienced during his younger days in getting the right kind of books. He mentions by title Defoe's *Essays on Projects*, and Cotton Mather's *Essays to do Good*, otherwise called *Bonifacius*, as two works which had a lasting influence on his after-life. Defoe's book is a very rare work, so rare, indeed, that its very existence has been doubted, and it has been even asserted positively that no such book was ever written; but the assertion is wrong. It has been said, too, that Franklin had in mind, when he wrote this part of his *Autobiography*, Defoe's *Complete English Tradesman*, and that he was then thinking of this work; but it was not so. The great printer in his younger days had handled too much type to make a mistake in the title of a book. Eight or nine years before his birth *An Essay upon Projects* was published in London, written by the same author who afterward wrote that prose epic *Robinson Crusoe*, which charmed us all so much in our boyhood. In the introduction to the Essay the author terms the age in which he wrote "the projecting age," and in the body of the work he refers to many schemes which have since crystallized into practical projects, and are now considered necessary institutions of the present age. Besides other subjects he refers to Banks, Highways, Assurances, Pension Offices or Savings Banks, Friendly Societies, and Academies, all which to-day are recognized as actual problems in business life. In his chapter on "Assurances" is found the origin of modern Fire Insurance companies; and in that on "Fools," or Idiots, there is more than a suggestion of Insane Asylums and other institutions for the care and comfort of persons who are mentally unsound. The Essay, or collection of Essays, is well written, and in style furnished a good model for the readers of that century, although now it would hardly be considered an attractive book for boys. It may be asserted, in the light of Franklin's statement, that this work gave the young philosopher a turn of thought which ever afterward he followed. In the treatment of the various subjects of the different chapters there is a decided flavor of practical wisdom for everyday use, which seems to have clung to Franklin during his whole life.

The other little book mentioned in the *Autobiography* was first published in the year 1710; and, as the author was settled as a colleague pastor over the church where the Franklin family afterward attended worship, it seems natural that the work should have been introduced at an early period into the Franklin household, where it surely found eager readers. The book is scarcely ever looked at nowadays, much less is it ever read; but it contains some grains of wheat scattered through the chaff. The following extracts from its pages are quite Franklinesque in their character:

Take a Catalogue of all your more **Distant Relatives**. . . . Think; *Wherein may I pursue the Good of such a Relative* (page 72)?

Have alwayes lying by you, a List of the *Poor* in your Neighbourhood (page 75).

You must not think of making the *Good* you do, a pouring of Water into a Pump, to draw out something for your selves (page 78).

Do Good unto those Neighbours, who will *Speak Ill* of you, after you have done it (page 80).

Often mention the Condition of the *Poor*, in your Conversation with the *Rich* (page 100).

The *Wind* feeds no body, yet it may turn the *Mill*, which will grind the *Corn*, that may Feed the *Poor* (page 101).

To *Bear Evil* is to *Do Good* (page 103).

One Small Man, thus *Nicking the Time* for it, may do wonders (page 179)!

At a very early period in his life Franklin had acquired a great mastery of language, and an excellent style in writing. It was clear and terse, and left no doubt as to the meaning he intended to convey. This high art is rare, and more easily recognized than described. In many ways it is the man himself, and shows him off from every point of view. It is never learned by rote, but comes largely by practice, and also by familiarity with the works of good writers. Franklin was a close reader, and in his boyhood devoured everything in the shape of a book within the reach of his limited means. He studied Locke's *Essay on the Human Understanding*,—a work to which many a man has acknowledged a debt of gratitude for its help in mental training. He had also read Bunyan's *Pilgrim's Progress*, and a stray volume of *The Spectator*, both excellent models for a young man to copy. In one of his Almanacks, Franklin says that Addison's "writings have contributed more to the improvement of the minds of the *British* nation, and polishing their manners, than those of any other *English* pen whatever." While yet a printer's apprentice he wrote articles for his brother's newspaper, the authorship of which was at first unknown to the editor; and he also wrote doggerel rhymes, in those days often called "varses," which he hawked about the streets of Boston and sold for a trifle. In this modest way he earned a few extra shillings and laid the foundation of a brilliant career. Who can say now that his success in after-life was not in some manner connected with the narrow circumstances of the young ballad-maker?

As at that time the drama was not regarded with favor by the good people of Boston, I have often wondered if Franklin in his boyhood had ever read any of Shakespeare's plays. The original settlers of Massachusetts abhorred playwrights, and looked with distrust upon everything connected with the theatrical stage. Even in his boyhood Franklin had such a keen appreciation of what is great and grand, and such a lively concern for all things human, that it would be of interest now to know that he, too, had paid silent homage at the shrine of the "sweet swan of Avon." In *The New-England Courant* of July 2, 1722, there is a bare allusion to "Shakespear's Works," which is probably the first time that the name of the great dramatist is mentioned in New England literature. It occurs in a list of books made by an anonymous correspondent, as belonging to himself, which would come handy "in writing on Subjects Natural, Moral, and Divine, and in cultivating those which seem the most Barren." The whole communication reads not unlike the effusions of the young printer, and may have been written by him.

The circumstances under which Franklin left home are too well known to be repeated here. Youthful indiscretions can never be defended successfully, but they may be forgotten, or passed over in silence.

From his native town Franklin went to Philadelphia, with no recommendations and an utter stranger; but fortunately before leaving home he had learned to set type. The knowledge of this art gave the friendless boy a self-reliance that proved to be of practical help, and laid the foundation of his future fame. During a long life he never forgot the fact that he was a printer first, and Minister Plenipotentiary from the United States of America to the Court of France afterward; and still later President of the State of Pennsylvania. In his last will and testament he sets forth these distinctive titles in the order given here; and in his own epitaph, which he wrote as a young man, he styles himself simply "Printer." This epitaph is a celebrated bit of literature, quaint and full of figurative expression, and has often been re-printed. It bears a remote resemblance to some lines at the end of a Funeral Elegy on John Foster, a graduate of Harvard College and the pioneer printer of Boston, who died on September 9, 1681. The Elegy was written by Joseph Capen, then a recent graduate of the same institution, and was first published as a broadside. Perhaps the lines suggested to Franklin his own epitaph. As a bright boy with an inquisitive turn of mind, he was familiar with the main incidents in the life of

Foster, who set up the first printing-press in Boston, and was probably the earliest engraver in New England.

After Franklin had become fairly domiciled at his new home in Philadelphia, one of his chief aims was to make himself useful not only to his fellow-artisans, but to the community at large. In divers ways he strove to raise the condition of young men, and to impress upon them the responsibilities of life and the duty they owed to others.

In the year 1732 Franklin began to publish *Poor Richard's Almanack*, which not only put money in his purse but made his name a household word throughout the land. It soon reached a wide circulation, and was kept up by him for twenty-five years. It was largely read by the people of the middle colonies and had great influence over the masses. From every available source he selected shrewd and homely maxims, and scattered them through the pages of the publication. So popular did these sayings become that they were reprinted on sheets, under the title of "The Way to Wealth," and circulated in England as well as in this country, and were even translated into French and sold in the streets of Paris. They are not so highly thought of now as they once were; and the more the pity. The present age likes show and style better than quiet ease and domestic comfort, and is sometimes called the gilded age, to distinguish it from one that is not veneered. The pseudonym of authorship on the title-page of the *Almanack* was Richard Saunders, and in quoting these maxims the public often used the expression, "as Poor Richard says," referring to the pseudonym; and in this way the name of Poor Richard has become inseparably connected with that of Franklin. During the latter part of the seventeenth century there had been printed in London an almanack by Richard Saunders, and Franklin, doubtless, there found the name. In fact his own title-page begins, "Poor Richard improved;" showing that it had some reference to a previous publication.

A curious circumstance, connected with the translation of these proverbs into French, may be worth narrating. The translator found a difficulty in rendering "Poor Richard" into his vernacular tongue, as *Richard* in French means a rich man; and to give a poor rich man as the author of the sayings was an absurdity on the face of it. So the translator compromised by rendering the name of the author as "Bon-homme Richard;" and Paul Jones' famous ship was so called in honor of the Boston printer and the Philadelphia philosopher.

Franklin never accepted results without carefully examining reasons, and even as a boy was slow to take statements on trust, always wanting to know the why and wherefore of things. By temperament he was a doubter; but in the end such persons make the best believers. Once drive away the mist of unbelief from their minds, and the whole heavens become clear. With the eye of faith they then see what has previously been denied to them. Franklin did not set up for a saint, or pretend to be what he was not; and his friends have never claimed that he was free from human failings. They have always looked with regret at his youthful errors, and would willingly blot them out; but he himself has freely confessed them all. It is on his own testimony alone that the world knows his worst faults. "To err is human, to forgive divine."

Franklin was a voluminous writer on a large variety of subjects, but of all his works the *Autobiography* has been the most widely circulated. This book was first published soon after his death, and has since passed through many editions. It has been translated into numerous languages and been read throughout Christendom, where it has charmed both the old and the young; and the demand for it still continues. For close, compact style and for general interest it has become almost a classic work in the English language. The bibliographical history of the book is somewhat peculiar, and makes a story worth telling.

Presumably an Autobiography, published after the death of the writer, would remain substantially unchanged; but it was not so with Franklin's. At four different times there have appeared in English four versions of the *Autobiography*, each one varying from the others,—though they have not always covered the same period of time,—thus making great and decided changes throughout the book. The explanation of this anomaly may be found in the following statement. The narrative was written at various times and places, and the author has given some of the circumstances under which it was prepared. The first part, coming down to his marriage in the year 1730, was written at Twyford, England, in 1771, while he was visiting at the house of his friend, Dr. Jonathan Shipley, Bishop of Saint Asaph, with whom he was on terms of close intimacy. It was begun for the gratification of his own family, and intended for them alone; but afterward it took a wider scope, and was then evidently meant for publication. He did not resume work upon it until 1784; but in the meantime the incomplete sketch had been shown to some of his friends, who urged him strongly to go on with it. The second part of these memoirs, written while Franklin was living at Passy, near Paris, is short and made up largely of his ideas on life rather than by the recital of events. When he began this portion of the narrative, he did not have the former part with him, which accounts for a break in the thread of the story. The third part was begun in August, 1788, while Franklin was in Philadelphia, and is brought down to the year 1757. This portion ended the Autobiography, as formerly printed in English. About a year after Franklin's death there was published in Paris a French translation of the first part of the memoirs. It is a little singular that the principal portion of the Autobiography, which was destined to have so great a popularity, should have been printed first in a foreign land and in a foreign tongue; and it has never been satisfactorily explained why this was so, nor is it known with certainty who made the translation from the English into the French.

In 1793, two years after the appearance of the Paris edition, two separate and distinct translations were made from it and published in London,—the one by the Messrs. Robinson, and the other by Mr. J. Parsons. Both editions appeared about the same time; and probably some rivalry between two publishing firms was at the bottom of it. They were English translations from a French translation of the original English; and yet, with the drawback of all these changes, the book has proved to be as charming as a novel.

In 1818 William Temple Franklin, while editing his grandfather's works, brought out another edition of the *Autobiography*, which seemed to have the mark of genuineness; and for half a century this version was the accepted one. But in 1868 even this edition had to yield to a fourth version, which gave the *ipsissima verba* of the great philosopher. During that year another edition was published from Franklin's original manuscript, which a short time previously had fallen into the hands of the Hon. John Bigelow, while he was United States Minister at the French Court; and by him it was carefully and critically annotated. This version now forms the standard edition of the *Autobiography*, and easily supersedes all former versions. It contains, moreover, six or eight additional pages of printed matter from Franklin's pen, which had never before appeared in English. It is also a curious fact in the history of the book that there are no less than five editions in French, all distinct and different translations.

The limits of this paper will not allow me to follow Franklin in his various wanderings either back to his native town or across the ocean to London, where he worked as a journeyman printer. Nor can I even mention the different projects he devised for improving the condition of all classes of mankind, from the highest to the lowest, and thereby adding to the comforts and pleasures of life. The recollection of his own narrow circumstances during his younger days always prompted him to help others similarly placed; and the famous line of Terence applied to him as truthfully as to any other man of the last century. In brief, it is enough to say that on all occasions and at all times his sympathies were with the people. In the great political contest which really began on the passage of the Stamp Act, and did not end until the Declaration of Peace in 1783, he was from the first on the side of the Colonists, and one of their main supports. During the War of the Revolution he was a venerable man, the senior of General Washington by more than twenty-five years, and the leaders all looked up to him for advice. In such an emergency it is young men for action, but old men for counsel; and on all occasions he was a wise counselor.

Franklin's services in Europe as one of the Commissioners of the United States were as essential to the success of the patriots as those of any military commander at home; and he gave as much time and thought to the public cause, and with as marked results, as if he had led legions of men on the battlefield. The pen is mightier than the sword, and the triumphs of diplomacy are equally important with those of generals who lead armies on to victory.

I regret that the space of time allowed forbids me to dwell, as I should like to do, on Franklin's brilliant career as a philosopher. From early boyhood his inquiring mind had led him to study the lessons of Nature and to learn the hidden meaning of her mysteries. It is easy to understand how, while yet a young man, his youthful imagination became excited over the wonders of the heavens, when the lightning flashed and the thunder pealed; and how he burned to find out the causes of the phenomena. By his ingenious experiments in the investigation of these matters, and by his brilliant discoveries made before he had reached the middle period of his life, he acquired throughout Europe a reputation as a philosopher; and the results of his labors were widely published in France and Germany, as well as in England. In his memoirs he gives a brief account of the way he was drawn into scientific studies, and how the seed was sown which brought forth the ripened fruit; but the preparation of the soil in which the seed was planted dates back to his childhood, when he was reading Defoe, Mather, and other writers, or even to an earlier period. For a full quarter of a century before the Revolutionary War broke out, he had gained such fame in Europe for his attainments, and was so widely known for his fairness, that, when acting as a diplomatist during the political troubles of the Colonies, great weight was always given to his opinions.

By the help of that subtle power which Franklin's genius first described, audible speech is now conveyed to far distant places, messages are sent instantaneously across the continent and under the seas, and the words of Puck have become a reality:

> "I'll put a girdle round about the earth
> In forty minutes."

Through the aid of this mysterious agency, dwellings and thoroughfares are illuminated, and means of transit multiplied in the streets of crowded cities, where it is made to take the place of the horse; and yet to-day mankind stands only on the threshold of its possibilities.

Whether the career of the practical printer or of the sagacious statesman or of the profound philosopher be considered, Franklin's life was certainly a remarkable one. It would be difficult, if not impossible, to name another man so distinguished in a triple character and so fully equipped in all his parts. By dint of genius alone, he arose to high eminence, and took his place with the great men of the age, where he was easily their peer, and where he maintained his rank until the day of his death.

One of Franklin's early acts, fraught with great benefit to scholarship, was the founding, one hundred and fifty years ago, of the American Philosophical Society, the oldest scientific body in America and one of the oldest in any country,—whose numerous publications, covering a broad variety of subjects and extending over a period of nearly its whole existence, have won for it a proud eminence, and given it high rank among the learned societies of the world.

On this interesting anniversary it falls to my lot to bring to you the felicitations of the Massachusetts Historical Society, which was founded in Franklin's native town and is the oldest association of its kind in the United States. The younger sister on this occasion sends her warmest greetings, and instructs me to express the hope that the same success and prosperity which have followed your growth during a long life of honor and usefulness may continue to abide with you, undiminished and unabated, for long generations to come.

The President next introduced Chevalier Rousseau d'Happoncourt, K. K. Navy, who presented the congratulations of the Imperial Royal Academy of Vienna to the American Philosophical Society, as follows:

SOCIETATI PHILOSOPHÆ PHILADELPHIENSI, CÆSAREÆ ACADEMIÆ LITTERARVM, VINDOBONENSIS, SODALES S.

Qvanti philosophiam qvam merito Cicero omnivm bonarvm artivm procreatricem et qvasi parentem esse dixit maiores vestri æstimaverint ex eo colligitvr qvod iam ante hos annos centvm et qvinqvaginta Beniamin Franklinio dvce et avspice illam qvæ nvnc vestris consiliis regitvr societatem condidervnt ad eam disciplinam excolendam et promovendam. Probe enim intellexerant singvlorvm hominvm doctorvm operam angvstis finibvs circvmscriptam esse iis avtem in vnvm corpvs conivnctis id effici vt lativs propagentvr stvdia ac permvltorvm animi ad satvs illos felicissimos excipiendos præparentvr. Ab his igitvr profecta initiis societas vestra non solvm de philosophia excolenda egregie mervit sed totam de rervm natvra doctrinam præclaris et laboriosis libris illvstravit lingvarvmqve mvltarvm origines et rationes feliciter indagavit atqve diligenter explanavit. Merito igitvr diem qvem vtpote natalem societatis vestræ vno et dimidio sæcvlo svmmo cvm honore peracto sollemniter agitis vobiscvm celebramvs congratvlantes optimisqve votis vos atqve institvtvm vestrvm proseqventes. Firmissimo enim vobiscvm conivncti svmvs vincvlo pio litterarvm amore et svmmo stvdio iis enixe cvltis omnivm hominvm salvtis promovendæ. Valete viri doctissimi nobisqve favete.

Dabamvs VINDOBONÆ Die iii, Mensis Mai,
Anni MDCCCLXXXXIII.

C. SUESS,
Cæs. Acad. Litt. Vindob., Totivs A Commentariis.

A. ARNETT,
Cæs. Acad. Litt. Vindob., Præses.

Reading the same to the meeting in German, as follows:

DIE MITGLIEDER DER K. UND K. AKADEMIE DER WISSENSCHAFTEN IN WIEN AN DIE PHILOSOPHISCHE GESELLSCHAFT IN PHILADELPHIA:

Wie sehr Euere Vorfahren die Philosophie gepflegt haben, von welcher Cicero sagt, dass sie Mutter und Amme aller Wissenschaft ist, folgt daraus, dass Euer gelehrtes Wirken schon vor 150 Jahren von Benjamin Franklin eingeleitet und seither durch Euch fortgesetzt wurde. Euere Vorfahren haben erkannt, dass auf dem Gebiete der Wissenschaft der Arbeit des Einzelnen enge Schranken gesetzt sind, dass aber eine Vereinigung mächtig zur Erzielung und Förderung des menschlichen Geistes beiträgt. In dieser Erkenntniss ist Euere Gesellschaft entstanden, welche nicht allein das Studium der Philosophie gefördert, sondern auch die Naturwissenschaften durch gründliche und vorzügliche Werke bereichert und Ursprung und Zusammenhang vieler Sprachen durch fleissige Arbeit glücklich gefunden hat. Wir fühlen uns daher gedrängt, die 150. Wiederkehr des Gründungstages Euerer Gesellschaft feierlich mit Euch zu begehen und beglückwünschen Euch und Euere so herrlich fortgeschrittene Anstalt. Wir sind mit Euch verbunden durch das gemeinsame Band der Liebe zur Wissenschaft, welche das Wohl der Menschheit in hohem Masse gefördert hat.

Lebet wohl und behaltet uns in Euerer Gunst.

SUESS,
Secretär.

ARNETT,
Präsident.

WIEN, 3. Mai, 1893.

Also a translation of the same made by himself, as follows:

THE MEMBERS OF THE IMPERIAL AND ROYAL ACADEMY OF SCIENCES IN VIENNA TO THE AMERICAN PHILOSOPHICAL SOCIETY, GREETING:

How much your predecessors cultivated philosophy, of which Cicero says that it "is the mother and nurse of all sciences," is shown by the fact that, so far back as 150 years ago, Benjamin Franklin introduced the study, which has since then been continued by you. Your predecessors recognized that in the domain of science narrow bounds are set to the pursuit of individuals, but a union becomes mighty in gathering and furthering what concerns the human mind. Recognizing this fact has your study arisen, which not alone encouraged the study of philosophy, but of the natural sciences as well, and by original publications, discussions and collections prove your active work.

We feel ourselves therefore called upon to join with you in the celebration of your One Hundred and Fiftieth Anniversary, and congratulate you and yours upon your grand progressive institution.

We are connected with you by the common bonds of love for knowledge, which has in a great measure helped the welfare of humanity.

Farewell, and keep us in your memory.

SUESS,
Secretary.

ARNETT,
President.

VIENNA, May 3, 1893.

The President next introduced Prof. J. M. Hoppin, who read to the Society an address on "The Philosophy of Art."

The subject of the paper which I have the honor to present is "The Philosophy of Art," and as this would seem to be in accord with the object of your venerable Society, devoted to philosophic inquiries, as well as in the line of my own pursuits, I have presumed on its fitness for this occasion. And, might I be allowed also to say, that the present is a favorable time to discuss art while we are having the great Exposition in which art holds so conspicuous a place. In looking at the buildings erected on the Fair grounds, at Chicago, I could not but think that architecture, at least, would receive a vigorous impulse in our land; for in these buildings there is an originality, a sense of creative power, a pregnant suggestion of something new, of a style more truly American than that of the Middle Ages and better suited to express the breadth and simplicity of our democratic ideas, which will doubtless be worked out by American genius into a national architecture of noble design, of which we need not be ashamed and can claim as our own. But my object at present is purely theoretic rather than practical. It will dwell more on the idea than on the expression of art.

The subject of the philosophy of art may be still more briefly comprehended in the term "Æsthetics." Æsthetics, from a Greek word of subtle meaning, was first used comparatively recently in Germany to signify the philosophic classification of those mental faculties with which we perceive and are pleasurably affected by the beauty of the world, and was thus made to comprise more than the term fairly means, viz., the whole theory, production and criticism of art; and yet this word, "æsthetics," happily emphasizes one important element of art—feeling, or the sense of delight in the perception of beauty—for art springs chiefly from the emotions and love, just as in the "terribleness" of Michael Angelo's nature averse to delights there was one spring of joy—the love of his art and beauty; and so, too, after the influence of the skeptical philosophy of the early part of the eighteenth century, that dried up the spiritual emotions, the new feeling for the beautiful opened by the movement of romantic literature, produced such works as *Faust* and *Wallenstein*.

The philosopher, Hegel, in treating æsthetics as a branch of psychology, set to work to explore the laws of spirit which constitute mind and to construe nature and art by means of universal ideas, on the principle assumed by the German transcendental philosophy of the subjectivity of all knowledge, regarding nature as the unconscious realization of spirit in time and space, and, in the same way, viewing the genesis of every human institution, science and art as spiritual expressions. He sought to trace through its various stages the philosophy of culture, and to develop *a priori* the history of human consciousness in its growth from the first crude ideas to the most advanced theories that shape our modern civilization. Civilization, in his application of philosophic analysis, is the mind realizing itself. Human consciousness perceives the ideal form which measures and moulds the phenomenal world, although this consciousness is not awaked at once, and only gradually awakes to find itself contemplating its ideal prototype, its absolute personality, which thus becomes self-consciousness; and this rousing of self-consciousness constitutes the intellectual progress of the race. It sees its ideas realized, or reflected, in art as well as nature, and makes at each step an advance in civilization. Hegel's philosophy was the revelation, in the world of time and space, of self-consciousness, of the personality of the absolute, of the advancement of humanity in the consciousness of its unity and perfection, of the gradual merging of the individual into the universal, which universal consciousness is the progress of thought from nature to spirit, from the sensual to the ideal, from the objective to the subjective; and, under this system, art is an expression of the spiritual, a manifestation, more or less clear, of the eternal idea which measures the outer and phenomenal, recognizing in the external world the image of itself and comparing all things to this inner form, this self-determined and abiding idea, which is the absolute, the ego, the rational totality of the race, the spiritual personality. The reality of things—art among them—is in the idea, while all else is show and changing phenomena. "The real world," says an Hegelian writer, "is the spiritual world; things exist because spirits experience them, and spirits experience them because, as parts of the complete life, it is their interest to be as manifold and wealthy in their self-realization as possible."

In a word, idealism, in which the world of nature and art is the evolution of spiritual existence—this is the basis, the road-bed, so to speak, in which Hegel's æsthetics is planted; and it must be confessed that it is an admirable foundation of art, going beneath the superficial theories now prevailing, most of which regard art as a mere fashion to catch, like a mirror, the flitting reflections of the outward, and to decorate life and amuse the senses; and also going beneath that false realism which lies in the physical merely, and not in the mind that contains the unchangeable types of beauty. Art, according to Hegel, is the discovery of the type-ideas upon which nature and all things are formed and which must be sought within, not without, so that self-apprehension is the artist's highest law, and that by which he seizes the universal, the absolute beauty. Nature acts as a medium of the manifestation of the ideas, or idea, of beauty, and is the objective form of a subjective fact. The artist studies nature, viewing it as an intermediary of the spiritual perfect truth, and not as perfect in itself; for perfection is in the idea consciously apprehended.

Mr. Stillman, in a recent article in the *Atlantic Monthly*, entitled "The Revival of Art," has favored this Hegelian theory of art, carrying it, however, so far as to make the artist wholly an idealist inspired by that beauty which he sees in his mind, and he seems to give but little value to the inspiration and study of nature, quoting Turner's saying that "nature puts him out."

The truth, I believe, would hold nature as that which mediates between and unites the ideal and the real, the subjective and the objective. The true idealist is he who has the deepest knowledge of nature, and who can use this knowledge in the formulation of his own conceptions.

But, even before Hegel, Schelling attempted to construct an æsthetic philosophy. His poetic temperament led him to look on nature as unconscious art, and to believe that material forms symbolize spiritual processes, so that in nature our ideals are expressed. He said that "artists were often unconscious philosophers and that the greatest philosophers were consummate artists."

Singularly enough, too, the pessimistic philosopher, Schopenhauer, set forth one of the most consistent, if but partial, theories of æsthetics of any of the school of the German idealists; for while himself belonging to this school, instead of Hegel's ego, or spiritual personality representing the absolute, he regarded the "world-will," or the concentrated power of all world-activities, as the capricious and accidental but real creator of the phenomenal world of nature, which "world-will" and its ideas we interpret by experience. Our intelligence, as also a creature of the *Weltgeist* or *Weltwille*, penetrates to the inner will of nature, and "reaches its perfection in the power of contemplation that sinks into the depths of nature, and which belongs, above all, to the temperament of the productive artist." Art, then, according to Schopenhauer, is "the embodiment of the essence of the 'world-will,' as seen or interpreted, by the artist's intelligence. The world-will has fashions of expressing itself, kinds and degrees of self-objectification, and these, in so far as contemplation can seize them, are ultimate types or ideas exemplified in space and time by individual objects." They are the embodiments of the world's desire, of the world's passion and longing, the forms of the whole world's will that exist. Art grasps these world-forms, these types of creation, action and desire, and exhibits them in artistic forms; for an example, architecture (as a commentator of this philosophy says) "portrays the blind nature-forces or longings of weight and resistance;" or, as I venture to add, the harmonious arrangement of matter and mass, paralleled by the scientific theory of the rhythmical disposal of molecular atoms. Art is the universal appreciation of the essence of the "world-will" from the point of view of an intelligent onlooker, above all, artist; and thus art, while embodying the world's desire or will, is not itself the victim of passion. Of all the arts, according to Schopenhauer, "music most universally and many-sidedly portrays the essence of the world-will, the soul of desire, the heart of this passionate, world-making, incomprehensible inner nature;" and listening to the longing and oft abrupt strains of Wagner's music, I have been sometimes startlingly reminded of Schopenhauer's "world-will," or desire, so wistful, passionate, objectless and chaotic, and finding its utterance in those weird and changeful harmonies. "The opposition between will and contemplation" reaches, indeed, its most systematic statement in the philosophy of Schopenhauer; but the difficulty remains that the "world-will" of Schopenhauer is at best "a simple desire and selfish striving," and the longing after perfection even is only an accidental and changing will, whereas human life has a spiritual centre (ψῦχή), as the material universe has a physical centre, from which ever-recurring influences and attractions spring, that tend to the recognition of unchangeable and eternal ideas of beauty—a will lying back of the phenomenal world in the spiritual; and in this Hegel is truer in his æsthetic philosophy than Schopenhauer.

Leaving these speculations of the German idealists, let me offer some thoughts, imperfect though they may be, on the philosophy of art as a good theme to theorize upon, and tending to promote the best interests of art, which is assuming, together with physical science and literature, its own great place in modern civilization as well as in modern education; and suffer me to follow out here for a moment this suggestion in regard to education. It might be taken for granted that the training of the knowing powers makes education mean nothing unless it mean the development of the intellectual faculties; but this surely is not all in education. There is left a portion of the being which is more peculiarly the region of æsthetic power, and in which are the sources of the beautiful; and how broad a region and how narrow the view which would suffer this part of our nature, the truly human part, to lie barren! It is the æsthetic power that reconstructs and makes all new; it is the creative power. It is that which gives one man's speech a freshness that another's of equal force of thought does not possess. Æsthetic culture should be introduced into education also, because art comprises so great a portion of the life of mind. It needed mind to build St. Peter's dome and to compose the music of Sebastian Bach, as truly as to compose the *Principia* or the *Mechanique Celeste;* and we are not confined to architects, musicians, painters and sculptors, but may reckon in as artists the poets who body forth ideas of beauty reflecting spiritual types. It is the province, too, of education to bring out the lovely perfection of truth, so that it shall meet the desires of the mind and be followed freely; yet as a people we have freedom much on our tongue, but not so much in our spirit. We have brought down everything to the dead level of the actual. It is the thing which answers the present use, the present success, and not the thing which should be, or the ideal; and while we would not weaken this noble, practical, American quality, we would counteract its current towards an utterly earthly conception of life and thought; and art would help in this struggle to deliver ourselves from the crass bondage of materialism and to give play to spiritual ideas. Art would likewise afford a counterpoise to certain narrowing tendencies in education by presenting truth in more natural and vital forms. The purely scientific process, it is true, comes first. The mind must learn to investigate and reason. First fact, then beauty. But the scientific process has its dangers unless guarded against, dealing as it does almost entirely with analysis, and may tend to lose the living synthesis of truth, and not to come, after all, to the unity of knowledge and the perfection of truth. Art through its intuition arrives often at truth's wholeness when science sees but in part. Art aims at unity, the beautiful whole, the perfect form of nature and spirit, and its influence is towards the introduction of a living variety into educational processes, so that young men may come out of the university not mere scholars, but men of broad, alert and independent minds, with the eye open to see the beauty and glory of the universe. But to return from this digression.

We sometimes hear it said that man is a religious animal, and yet it might just as well be said that man is an artistic animal—artistic in the constitution of his mind. Metaphysicians commonly divide mental faculties into reason, sensibility and will. This metaphysics —whose tendency is to view mind by sections, as it were, or as a congeries of faculties, each distinct from each, and which assigns its own value to different powers, giving to some an undue value—is apt to make the so-called intellectual faculty an exclusive object of consideration, losing sight of the truth that the mind is one and indivisible, that it acts as a whole, and that, in every act, all its energies enter, some more and some less; that there is a vital interplay of functions in mental acts, intellect in feeling and feeling in intellect, the rational nature resting on the moral and the moral moved to activity and choice by the sensibilities and imagination, so that, however convenient this metaphysical classification may be for the analysis and study of philosophical concepts, you cannot erect such distinctions in the inner spiritual substance of the mind, and to do this sometimes leads to grave errors; for you cannot really say that any one part of the mind is of more value than another and that any part of the mind can be ignored, or affirm that it does not belong to mind as mind, and therefore deserves no special attention. Shall we neglect that rich domain where lie the springs of feeling for the beautiful, the productive powers in the achievements of art? In this realm, called, in metaphysical language, the sensibility, is found mainly the domain of art, though it is by no means confined to this, since all the faculties are involved in art—reason, invention, will, the use of the intellectual and logical faculty that pervades a work of art, the judgment as well as feeling. But there is, nevertheless, a quality of sensibility, of emotional susceptivity, which is the mind's power of receiving impressions from the outward world and its beauty. This feeling is not a mere excitation of the senses, the sensual nature, but it is a mental susceptibility which not only feels but acts, and, when roused to act by impressions from objects, it becomes a power of self-differentiation, or a power of contemplating itself, a power capable of recognizing its own acts and impressions made on it, and of reproducing these impressions, being the correspondent within to the nature without; and it is thus a permanent quality, to which we give, with other elements combined, the name of *the æsthetic sense*, or, from the faculty through which this instinct chiefly operates, the perception or sense of the imagination. The imagination is the idealizing, the image-making power—the power that receives and communicates the form of things (*form-sinn*, as the Germans name it), even as the intellectual faculty receives and communicates the truth of things. This æsthetic power of the imagination, when acted upon by correspondent objects in nature that are sympathetic to man's spiritual conditions, seeks to reproduce the essential form of these objects, since they exist in the mind only in their forms—some philosophers deny any other real existence to objective matter—and on seeking thus to reproduce the forms of things, by a law of the mind it strives to reproduce the perfect form in which the mind delights and was made to delight. The mind's susceptibility to be impressed by the world of nature through the organ of the imagination, which not only receives but imparts impressions of objects, since it is full of energy and creative power, is the mind's function of form, and, necessarily, in a rational nature, of perfect form or beauty, and here dwell the ideas of beauty in the mind. If the imagination works simply in order to body forth the form of things as an "idealized imitation," to interpret nature in all its forms, it works artistically and its products are what are termed "art." The artist, in fact, is the poet; he is poet of another sort, who tells in line, form and color, as the poet in words, what nature tells him; and this is the more important because we ourselves are parts of this nature, inframed in her subtle organism. The artist, by his imaginative or *quasi* creative power, reconstructs nature, becomes nature's interpreter, and finds in nature the responsive image of the soul. Art is poetry, mainly poetry—I believe this.

We see thus in all mind, though in a less degree in most men, but especially, and sometimes supremely, in the artist, this æsthetic power, this artistic faculty, by which it must and will express itself in the sphere of art as surely as the mind must and will express itself in the sphere of knowledge, and, indeed, so related are the mental powers that, as we cannot keep out any of them from the æsthetic faculty, so we cannot keep out the æsthetic sense from any of these, and we cannot say—in the investigation of truth, the highest truth, which is moral—that the imagination, which is the organ of the sensibility, can be excluded, for here dwell the forms of truth and beauty. I am a Platonist. I believe art belongs to the spiritual powers, and is, in some sense, spontaneous—a law to itself. Schiller says: "The artist (meaning the poet or creator) is no doubt the son of his time. But ill is it for him if he be also its pupil or darling. A beneficent divinity snatches the suckling in time from his mother's breast, nourishes him on the milk of a better age and lets him ripen under distant Grecian heavens to his maturity. Then, when he has grown into manhood, he returns to his own country in the image of a stranger, not always to please it by his presence, but, terrible as the son of Agamemnon, to purify it. The substance of his work he will take from the present, but the form of it from a nobler time, yea, from beyond all time, out of the essential, invariable individuality of his own being." *

The highest conception of art is that it is the interpretation of the spirit in its varied forms, feelings and experiences, and of those eternal ideas of beauty that are in the soul and belong to absolute mind; but this admits, of course, of modification when other faculties and qualities of our nature—above all, the sensuous—come into view. The senses play their part in art, and a great deal of art is on this lower and not unnatural plane. What a world, that of color! Color has a strong, sensuous appeal, as in nature, but is sometimes too pronounced in art, as in the luxurious warmth of Rubens, the fiery tones of Raphael's greatest pupil, Giulio Romano, the violent contrasts of the Spanish school of painters.

Now to discuss this subject in a direct manner, What is art? But we can only approximate to a definition. It is impossible to give a rigid definition of art. It bursts from our formulas like an uncontrolled spring. It is indefinable because it is a truth rather than a term; and yet we may do something towards a definition by separating art from truths closely akin to it. Art, for example, is not nature, while it is nothing without nature, as Shakespeare says:

> "There is an art
> Which doth mend nature—change it rather, but
> The art itself is nature."

Nature, in a general way, is all that is not art—all that is created, not made. Nature is the substance, physical and spiritual, out of whose depths art arises like an exhalation of beauty. It comprises the forces at work to produce the phenomena of the world and their laws outside of human agency. Those phenomena in ourselves

* *Æsthetic Education of Mankind* (ninth letter).

and the world "which we do not originate but find" represent nature; those "which we do not find but originate" represent art. Thus the human element comes into art to mold nature to its purposes. Art, too, is not science. Science concerns itself with knowledge and the investigation of truth, and it may be said to be the law of knowing, dealing with the facts of the universe, its chief instrument being the reason whose special function is analysis. Art has also to do with knowledge, and art may aid in the search of truth; but it does not end in knowing. Art is, in fact, a science as far as its methods of *technique* are concerned, and it applies science to its own methods, but its end is farther on in the perfect and joy-giving work touching profounder emotions, rather than in scientific knowledge or the technical process. Art, in like manner, is not philosophy, nor religion, nor morality; and it does not pretend to overtop, oppose, usurp or meddle with these while keeping to its own sphere, and much confusion has been caused (and no one has done more of this than Mr. Ruskin) by mixing these; but the difference in such cases is obvious. Art, however, is no negative thing, but is a most positive reality, in that it implies the existence of natural material on which to work and out of which to create its results, requiring at the same time a principle of susceptive thought that understands and orders nature for its conscious ends. In every work of art, its original material of nature, the subjective idea which calls it forth, and the form which is complete in itself like a divine creation, are comprehended. This applies to all forms of art, even the most mechanical; and, first, the term doubtless meant the arts of bare existence, first of all, probably, the art of agriculture—the "coarse arts" as Emerson called them in contradistinction to the "fine arts"—so that the useful was the first idea, and, indeed, what is not intrinsically useful is worthless now in art, in the highest art, which belongs to the highest needs of being, and compared with which its commoner uses are as earth and clay. But as new methods of civilization arose, art came up into its more spiritual spheres. Nature was studied; her subtle laws of working were lovingly observed; finer natures were touched to finer issues; and the arts which have in them a thoughtful element, which spring from an idea, succeeded the arts of mere existence, until "art" won a peculiar meaning, limited to the production which has in it the love of perfect creation, of beauty, which Plato says is the most manifest and desirable of things. But while the artist represents the beautiful object that he sees in his mind's eye, and paints from this mental image, art is never simply a mental act. Hegel contended for this. Art, without the mediation of objective form, he said, was an empty thing. "The art-idea is not a mere conception —'*ist niemals ein Begriff*'—inasmuch as the latter is a frame into which different phenomena may fit, whereas the artistic idea must stand in the most intimate agreement with the particular form of the work." The subject must be conceived in the object; there must be the manifestation of the idea, which is its expression, as in nature, and which expression must accompany the conception. Expression, in fine, reveals the artist and is another word for his art; for if it be true that

> "Many are the poets sown by nature,
> Yet wanting the accomplishment of verse,"

it can hardly be said that the power of vision in the artist is ever unaccompanied by the power of expression, though the two may be unequally distributed. The bas reliefs on the pediment of the temple of Zeus, at Olympia, which Pausanias ascribes to the Attic sculptors, Alkamenes and Paionios, are conceived with the utmost dramatic power, but are stiffly and rudely executed; probably the conception was that of the great artist and the work that of the local artist. What wonderful power of expression, for another example, is in Rembrandt's painting of "Abraham's Sacrifice," now in the Hermitage, at St. Petersburg—the obedience of a servant, the heart-rending grief of a father, the mysterious awe which the celestial messenger inspires! Here the great artist is seen, and great artists exist because they cannot help being so any more than the roots of a willow-tree can help running to the water. Da Vinci and Correggio were predestined artists as truly as Isaiah and Martin Luther were predestined prophets and Dante and Tennyson predestined poets; for the spiritual conceptions and yearnings in them, the strivings for universal beauty, found their only expression in art-forms.

Art, therefore, if we should attempt to define the indefinable, might at least be described in its works as the power of representing, like a new creation, in form, line and color, the object presented to the mind, or, more specifically, to the imagination, which is awakened to act by a joyful and loving sympathy with nature in all her forms—it may be ugly as well as beautiful—but more especially with what is beautiful and perfect in nature, as that for which the mind was originally made or adapted.

1. Art, though having to do with the perceptive faculties and the senses, is spiritual in its essence and has its foundation in an inner susceptibility of the soul, which corresponds to outward forms. There is a power in the mind of receiving impressions corresponding to the power that impresses. There is more than this. The mind contains the very ideas, in their conceptual mold, in which the forms of natural objects are cast, and is fitted to comprehend them, so that art is the condition under which the sensibility for impression is excited when the object and subject become identified. The German philosopher, Lotze, indeed says that "the impression of beauty cannot be referred to a uniform standard in us, to a spiritual organization actually existing in all individuals, but to one that has first to be realized in each person by means of development, and realized in each only in an imperfect and one-sided way;" but, though this opinion of Lotze's may be true, that the perfect standard is not realized in every mind, or in the artist himself, yet for it to be realized at all, there must be the organization, the susceptibility in every mind as mind, and the imperfection of its development does not militate against the truth that there is an ideal condition, like the plate delicately prepared to receive impressions of objects, and without which the actualization of any form of beauty would be lost and objects would remain without form and void. A mountain is a pile of rocky matter of a certain geologic period, as science teaches, until thoughts of majesty, unity, power, are developed in its impingement on the ideal sense. The beauty of nature is only to him who appreciates it; but we are all of us inframed in this natural kosmos as an organism itself designed to be that through which the soul realizes its ideas, and without which the mind could not formulate them, and this is the most important part nature plays in art. In like manner the ethical sense is a permanent condition of the soul, but the ideas of justice, right, duty, are not developed except in the actual relations of our natural life.

Call the beautiful an intuition or not, man, I contend, has an æsthetic sense, the outcome of whose formulated ideas is art, and which is capable of recognizing and expressing the objective view and beauty of the universe. We are subjects of impressions which do not always find expression, and only do so when they impress with sufficient power to form distinct conceptions. We may feign an appreciation and enjoyment of nature that we do not feel. There is an æsthetic cant as nauseating as any other cant. The first hunter who saw Niagara was doubtless overpowered by its terrorizing sublimity, but, it may be, his uncultured mind soon recovered its ordinary apathy, and he saw nothing in the stupendous phenomenon to give him delight, and made his preparations to cook his dinner on the edge of the cataract as coolly as ever. With an Audubon it would have been different.

"If the eye had not been sunny
How could it look upon the sun?"

I have, however, guarded against the theory that art exists solely in the mind, solely in the idea, and that there is no intrinsic beauty in natural objects but what the mind creates in them.

2. Art is the interpretation of the significance and beauty of nature. The product of the subjective capacity when drawn forth by the beauty of nature becomes the language of art. Some think of nature only for scientific and practical uses, but "nature," says Canon Mozley, "has two revelations—that of use and that of beauty. The beauty is just as much a part of nature as the use; they are only different aspects of the self-same facts, the usefulness on one side is on the other beauty. The colors of the landscape, the tints of spring and autumn, the lines of twilight and dawn—all that might seem the superfluity of nature—are only her most necessary operations under another view; her ornament is another aspect of her work; and, in the act of laboring as a machine, she also sleeps as a picture. The same lines which serve as the measure of distance to regulate all our motions also make the beauty of perspective." But beyond this idea of Canon Mozley's, it is my belief that there is actual contrivance in nature for an appeal to the æsthetic sense. Mountains that surround a valley "like a chorus of hills," by their fusion of noblest forms with finest tints, speak directly to the mind, as do the powerful words of a chorus in a Greek drama; and there is found also in nature every secret, even the subtlest, for the result of beauty, so as to produce the effect of beauty and power on the mind of the beholder. This is nature's art. What Venetian blue is like the blue of the Rosenlaui glacier? What painting ever excelled the splendors of

"The fiery noon, and eve's one star?"

He who begins to study nature, who observes trees or a single leaf, who looks closely at the minute grass-spires under his feet that cover the whole earth, who notices the tricksy play of light and shadow, who watches the sky, "sometimes gentle, sometimes capricious, sometimes awful, never the same for two moments together, almost human in its passions, almost spiritual in its tenderness, almost divine in its infinity," he must believe that there is in nature that which is designed to convey thoughts to the human soul beyond those of mere sense. Art interprets this higher truth. "The aim of art," says Taine, "is to manifest the essence of things." Art, indeed, seeks for the means of the highest effects. It depends on a penetrative study of nature's principles, and here it still may be original. Here the Yankee artist has as good a chance as the Greek. Here American art may prove its claim to originality as truly as Dutch art has done. The artist, to be an interpreter, must have knowledge, whether gained by study or instinct. He goes lovingly where nature leads him, and enters this kingdom of art by becoming a little child, until, through long discipline and patient watching, he sees "the most essential quality of things;" he grows into such intimacy with nature that he comes to interpret the thoughts of nature and also the thoughts of the human heart. The group of the "Niobe" came out of the profoundest depth of human experience—there is, morally, nothing more suggestive than this sculpture in modern art—as the Greek poet, Meleager, in his poem on the "Niobe," believed and proved this in ancient art. There is a fragment of the Reformation in the works of the satiric, keen-eyed painter, Holbein. There is much of the splendid but corrupt sensuousness of the neo-pagan Renaissance period, under Christian forms of humanity, represented in Titian's voluptuous pictures; for art is a reflection of life and its multiform phases, fascinating or terrible as the ages march on, and of the life of the soul.

3. Art finds its laws and principles primarily in nature. It cannot go a step independently of these and remain art. Michael Angelo seemed to lose his creative power, and virtue went out of him the moment he left nature and began to work from a dry scheme of abstract form.

There is, for instance, the fundamental law of truth, which involves the idea upon which the universe was built. There must be a sensitive relation in the artist's mind to this law, without which art is artifice or sham. But art, as has been said, is not nature, nor does the artist, in Coleridge's words, "pick nature's pockets." Nature is inimitable; for how can a little square of painted canvas convey the infinitude of mountain scenery whose power is revealed like a divine inspiration? Yet nature in her commoner moods, if still inimitable, is genial and accessible. She is odd and humorous at times, with a fancifulness full of grotesque irony. She does not hide her winsome face. She invites us to sit at her feet and learn of her. She will herself teach us. We cannot follow her instructions too closely, nor imitate her too minutely. Not a leaf but is a map of the boldest and most complicated pattern. Nature furnished the originals of Greek forms of every sort. But the artist must go beneath the surface of things to the plastic laws of these forms, else imitation would be untrue. He must discover, as it were, nature's own law of creation. A picture is an illusion, but it is not a delusion, for its end is not imitation, which would be something unreal and an absurdity, but it is the production of similar effects of nature's beauty and power so as to speak to the mind in some sense as nature speaks. While the artist is not to leave nature and lapse into a dreamland of his own, while he is to seek truth, yet by his thought, by separating the natural object from its accidental circumstances and conceiving it as a whole, by so painting the tree, the flower, the man, that the true form is seen, that the type is brought out in which the properties of the species are developed and in which it is best fitted to discharge the functions for which it was made—this shows the highest skill; for here is the action of the artist's soul which gives to his works the appearance of fresh creations. This is the ideal in art. This is the law of mental selection and probably was coeval with the law of imitation even, and accompanied the earliest art, savage and archaic art, since no art, even the most primitive, could have been entirely imitative.

"In the effort to imitate the human figure the process of thought and sympathy becomes apparent; and where this process of controlling power begins there the ideal in art begins. Whenever this isolated position, or scene, or action of nature is taken, it cannot be truly represented unless by an act of thought it is connected with the whole. The idea, or the whole, to which it belongs as a part, must enter into it and transfuse it."*

Yet be it noted that the ideal does not exist without the real passing into it like a life, even as mind works on facts and molds

* A. S. Murray, *Hist. Gr. Sculpture.*

them, and this might be called "the idealized real." The real is the working basis of the ideal, even as the sculptor puts his thought first into a clay model and works from that. The poetic superstructure is grounded in the soil of the actual. "The beautiful is the real," was the Florentine sculptor Dupré's motto. Imitation is not the object of art, or is, at best, a low idea of it; yet how can a picture or sculpture be too true to nature? Were the best Greek sculptures? You may be sure that it was not the close imitation only in the old familiar story of the grapes that made the birds peck at them, but it was chiefly the truth. It was the real life of natural objects that the artist of poetic genius had caught. It was a picture and not a copy. A portrait—what is it worth if it be not real and rugged as life is; otherwise it would become like the many unauthentic portraits of Columbus—a specimen of what has been called "artistic subjectivity?" This realness is the test of artistic excellence. "The more nearly and truly a picture approaches the exact colors and forms of nature, the greater will be the effect." There is no excuse for false drawing. The healthy tendency of art, then, is to become more and more real, which is in the true line of progress. The vigorous revival of art in the Netherlands in the first half of the seventeenth century, which created the Flemish and Dutch schools, to which the names of Rembrandt, Franz Hals, Terburg, Jan Steen belong, was nothing more than a return to realistic art from the feeble conventionalism of decadent Italian classic art. But rashness in theory makes a one-sided development, and the attitude of the artistic mind should be ever that of a thoughtful receptivity. All great painters have been realistic painters, but that is not all that they were. They painted from an idea. Velazquez, the greatest of artists both in technique and expression, did not paint the architecture of a face, but its character, its character drawn from his creative conception of a man. So art must continue to have in it these two elements of the real and the ideal, or it will run into something analogous to that coarse realism in literature, whose works, viewed as works of art, are only pieces of loose real life, without unity and plan; or, on the other hand, that subjective school of poets illustrated by Dante Gabriel Rossetti, ravishing as it is, but neither of them complete in itself. Art would die out, since some essential quality of life would be lost. It would either drop the element of truth to nature or the element of thought. The canons of universal art must not be swamped in the turbid deluge of French realism; though in regard to French impressionism, which is the tendency of modern art, when not carried to an absurd extreme, I have a good word, as infusing new life into painting, catching the light and atmosphere of heaven, and promising a true advance in landscape art. But it is well to remember, in this realistic age, that art has a spiritual side allying it with poetry and with the loftiest achievements of the mind, in which the beauty that lives in the idea and in the universal and spiritual is expressed. All true art in every age catches a spark of this unfading glory of the beautiful; and yet I do not say that there is no true art which does not aim so high as this, as witnessed in the hundred forms of unambitious art, the crude but honest efforts of beginners, the drawing which aims only at correct imitation, the pictures of many realistic artists painting nature as it is and not so much in minute detail as in whole true impressions, the graphic illustrations of literature carried to such excellence at the present time, the rich field of decorative design which is mainly scientific—all this is pleasing and laudable and having its genuine place in art, but I speak now of art in its enduring forms, which, like the best poetry, is of "imagination all compact," and must spring from the love and idea of beauty. This innate sensitiveness of the Greek mind to *beauty* made it to differ from Egyptian, Roman, and almost every other national art, and constituted it the standard of art for all time. But the Greek sense of beauty was a thoughtful quality of a thoughtful people; since the sensual, strong in the Greek, was subordinated to the intellectual and moral in this finely attempered race. Its line of beauty was a line of strength. Beauty was another word for perfection. "Beauty with the Greek," says an English writer, "was neither little nor voluptuous; the soul's energies were not relaxed but exalted by its contemplation. The service of beauty was a service comprehending all idealisms in one, demanding the self-effacement of a laborious preparation, the self-restraint of a gradual achievement. They who pitched the goal of their aspiration so high knew that the paths leading up to it were rough, steep and long; they felt that perfect workmanship and perfect taste, being supremely precious, must be supremely difficult as well; *χαλεπὸν τό κᾶλον*, they said, the beautiful is hard to win and hard to keep."* Thus beauty, with the Greeks, was the manifestation of their ideal self-development, the working out of a pro-

* *Westminster Review.*

found principle of culture, and this made their art so noble; and it is this by which, in presence of their serious sculptures, our spirits grow calm, and we feel the truth and moral power of the Greek conception of beauty, raising us above our littleness into a region of higher thought and feeling.

So there are other laws of nature besides truth which enter into art, such, for example, as order, which belongs not only to the structure of the world, but of the mind and its structures; as unity, or that consistency of parts with the whole which gives delight in a beautiful object; as proportion, which is the outcome of a symmetric mind; moderation, which is the continence of conscious spiritual strength; grace, which flows from inward sympathy and freedom; character, or individuality, or expression, so variously named, which, indeed, is much the same as ideality, by which the artist expresses his own thought and personality, and by which also a distinctive spirit of the period and history of the work is stamped on it; and not to mention more of these laws, above all, the great law of form, to which everything in art comes, which is the highest intellectual expression of art, so that sculpture, perhaps, is the purest art manifestation; and it is by studying these laws that we come at the principles of art criticism, and through the ignorance of which there is often shown a want of judgment in matters of art, betokening false standards drawn, it may be, from metaphysics or political economy rather than nature, making to be measures of art productions such qualities as logic, difficulty, cost, prettiness, melodramatic effect, bulk, warm coloring, elaborate though senseless detail—instead of the true and invariable standards of nature, by a return to which through the clear instinct of æsthetic genius lies the only road to reform and advancement.

4. Art in its source is divine. The divine ideal has not been perfectly attained, but ever beckons on like a star. Nature is a projection of divine ideas of beauty into time and space; and the human mind, which could know nothing objectively unless the same existed subjectively in itself, can read these types of beauty, or, as Ruskin calls them, "the eternal canons of loveliness," in its consciousness. Ruskin classes among spiritual ideas typical of divine attributes such purely æsthetic conceptions as unity, perfection, infinity, order, repose, moderation, purity, truth. These are moral as well as æsthetic qualities; and I was greatly pleased to come

across this passage spoken to the students of Johns Hopkins University, from a poetic point of view, by an American poet—poet of the salt-sea marshes—Sidney Lanier: "Cannot one say to the young artist, whether working in stone, in color, in tone, or in character-forms of the novel: So far from dreading that your moral purpose will interfere with your beautiful creation, go forward in the clear conviction that unless you are suffused—soul and body, one might say—with that moral purpose that finds its largest expression in love; that is, the love of all things in their proper relation; unless you are suffused with this love, do not dare to meddle with beauty; in a word, unless you are suffused with true wisdom, goodness and love, abandon the hope that the ages will accept you as an artist." Would that Lanier could have lived longer to have outlived some superficial defects of style, to have chastened his luxuriant imagination, and to have carried out his own noble theory of art!

Thus art has a vital beauty belonging to divine things.

The total sensualization of art characterizing a great deal of our modern art, forgets the truth that, though art lies partly in the sphere of the senses, in which "ideas take their plastic embodiment," it has a spiritual source which makes the artist a priest of the divine. "The artist paints with the brain and not with the hands," said Michael Angelo contrary to Courbet's saying.

The noble young science of archæology, which has made such marvelous progress of late, but which, after all, is the serviceable handmaid of art and not art itself, this science, so helpful to art, so indefatigable in its research, so interested, and rightly, in the orientation of every exhumed stone, and so furiously combative in the claims of space occupied by the orchestra and proscenium of a Greek theatre—notwithstanding its brilliant discoveries, has served imperceptibly and unconsciously to set learning before beauty and thus obscure or render secondary the intrinsic idea of art.

Looking at these four principles, viz., that art has its foundation in an innate spiritual susceptibility which corresponds to outward objects and forms; that art is the interpretation of the idea, beauty and perfection of nature; that art finds its laws primarily in nature; and that art in its source is divine; we may judge somewhat, from these rough pillars, what is the vast scope of art, how it reaches into heaven as well as makes our own thought higher, our life sweeter and this earth lovelier. And when we come to consider further (which investigation I shall not, however, be able to follow out) the philosophical classification of art, this brings out more clearly its theoretic principles; for each form of art is grounded on a reason in the mental constitution, and depends primarily on the nature of the idea which strives for representation, so that every art has a body, as it were, in which its life freely develops itself, and in no other. The arts of expression by language differ from the arts of expression by form and color, and cannot be combined on the same lines of representation. Sculpture cannot perfect itself in the principles that apply to painting; and a familiar example of this is the beautiful gate of the Baptistry of San Giovanni, in which the sculptor, by trying to unite the plastic and the graphic elements, or not keeping them distinct, fails of the highest effect. Yet the principles of all the arts are, in a measure, interchangeable, just as the laws of construction in architecture, bringing into play such analytic qualities as order, mass and combination, may enter with effect into the composition of a picture and lend it unity of design and firmer tone.

One German writer classifies artistic forms into two—the mathematic and the organic; in this way art appears, as it were, a second nature, which represents and reviews her processes. Mr. Hay, in his *Science of Proportion in Greek Art*, goes so far as to say that "all fundamental beauty of form is derived from the vibrations of the musical chord, and is geometric or harmonic in its development, and cannot fail to be reducible to mathematical law." Rhythmic arts, at least, are governed by mathematical laws like architecture in its form in space, and music in its movement in time; poetry also partakes of this regulated character. On the other hand, the arts which represent life, free life, such as landscape, animal existence, and, above all, forms of human life in historic, *genre*, and portrait painting, and especially in sculpture, come under the class of organic art, which arts are essentially imitative, but at the same time they stand in connection with higher ideas. Yet here, too, it is difficult to draw distinctions. Painting expresses, above all, quality and character; and yet in music there is as truly quality as quantity of sound, character as well as harmony. Colors have a genuine resemblance to tone, and colors form an octave which produces concord or discord, and gives rise to as various sensations. Architecture, which is abstractly geometrical, becomes also highly expressive of thought, feeling and character, almost as much so as painting and sculpture.

Another classification separates all art into groups of technic, æsthetic and phonetic, the first being those that minister to the primary wants, the second to the æsthetic, and the third to those that express ideas by colors, forms and words—in fact, language. But, actually, no positive limits can be assigned to these varieties as a question of fact, and it is rather a matter of degree than of classification. While it is highly productive of thought to make this effort to classify, and is useful as bringing out more clearly the underlying principles of art, it is evident that a deep-grounded philosophic classification has not as yet been reached.

Dr. John G. Morris, having been next introduced, presented a paper on "The Nature and Design of the Historical Societies of Our Country, and the Invaluable Benefit They Have Conferred on the Community," which is as follows:

No one can reasonably object when a public speaker employs the heaven-inspired language of the Hebrew poet in illustration of a subject altogether secular and historical. In the loftiest strains which his language afforded, he invites all men of religious taste and piety to visit the magnificent house of worship at Jerusalem—to extend their walk around the impregnable walls and their massive abutments—to measure by the eye their height and thickness—to look upon the tall towers and their broad bulwarks—the ponderous gates of brass and all the other external wonders of that wonderful edifice—but the admiring visitor is invited to pass through the gates, and to contemplate the magnificent structures erected around the *sanctuary*, the grandest of all, and then to gaze with rapture on the unsurpassed splendor and ravishing architectural glories of that house of God—and why all this? Not merely to gratify a cultivated taste, but to tell it to the generation following—to write the history of it that subsequent ages might know what had been done by their fathers.

And this is the province of the historian of to-day, as it has been of all preceding times—to verify doubtful facts, to develop and record unwritten events, to correct popular errors, to authenticate disputed dates, to delineate the character, influence and deeds of illustrious men; in a word, "to walk about the towers thereof, to mark well her bulwarks and consider her palaces, that he may tell it to the generations following."

This is the design of all historical societies, and many of them have already contributed much to the consummation of it.

Allow me then, ye men of philosophy, on this auspicious day on which you will hear much of what your ancestors have told to the generations that came after them, and of what you are gathering for the benefit of those who will follow you, to speak of a theme closely allied to that which you cultivate. Philosophy and history are sisters, of whom *history* is the older, for history began in the primæval Eden. They tell us that some ancient writer has said that history is philosophy teaching by example; but history furnished the examples before philosophy or science could utilize them. Macaulay was of the same mind when he says: "History, as it lies at the root of all science, is also the first distinct product of man's spiritual nature; his earliest expression of what can be called thought. Before philosophy can teach by experience . . . . the experience must be gathered and intelligibly recorded." And that's history.

I have thought that it would not be inappropriate on this occasion to present a brief dissertation on "The Nature and Design of the Historical Societies of our Country, and the Invaluable Benefit They Have Conferred upon the Community." Of late years they have contributed marvelously to the illustration of our older history and are constantly piling up much rich material for future writers.

The design of such foundations is not primarily to write history so much as it is to collect, arrange, classify, describe and preserve authentic materials of whatever kinds they may be, out of which history may be written. It is true, societies may publish what an individual or a committee has elaborated, and many local histories and cognate papers or treatises have been thus published, but, after all, the main design is to collect the timber, stone, and everything else out of which the historic edifice is built by the master workman, and this most useful work our principal societies have diligently and successfully performed. They are composed of that class of men whom Bacon designates as "industrious persons who, by an exact and scrupulous diligence and observation, out of monuments, names, words, proverbs, traditions, private records and evidences, fragments of stories, passages of books, ... and the like, do save and recover much from the deluge of time."

A historical society should be a "snapper up of unconsidered trifles, and should not disdain to gather even the bubbles that float on the stream of current history, prizing them as the world will one day prize the gems into which they will be transferred by the magic of time." There are thousands of printed documents of one kind and another which few persons think of saving, but which if preserved and systematically arranged into sets become valuable for reference in a very few years, and this is a kind of work requiring painstaking and patience, rather than the expenditure of much money. The breaking up of private collections is the great opportunity of the historical librarians and members, who should always be on the alert for such chances. No scrap which contains a word or name or date of historic value should be allowed to be destroyed or to be thrown into the rag bag or sold to the gatherer of materials for the paper mill.

Whilst the American antiquarian must necessarily feel deeply concerned in whatever relates to the history of the aborigines of our country, and we all know to what extent that subject has been illustrated, especially in the Government publications, yet it is not the history of the Indians in our respective States that has engaged the special attention of our historical societies—though not entirely overlooked, especially by the societies in the Western and newer States—our main purpose is to rescue from oblivion the history of the first settlers of the country, the manners, habits, opinions, deeds, primitive institutions, the early establishments, their family papers, their schools and churches, parish records or newspapers and books, their roads, their country frolics, their holidays and diversions, their civil and social condition, their town meetings and country fairs, their old family pictures, their great men and noble women in every department of active life. It is literally carrying out the capital motto of the Maine Historical Society, "Antiquitatis monumenta colligere."

It is the province of the societies to collect and safely keep account of all these and of many other things. A historical society need and *should* not collect a library of miscellaneous books, nor spend any money on an ornamental picture gallery or a museum of curiosities which do not illustrate the history of the State. If such objects are donated to the society as decorations, and the society has room to exhibit them, they must not be refused, especially if with the donation provision is made for their safe keeping; but a general picture or a statuary gallery is a very different thing from a collection of historical portraits or other pictures representing great historical events. Such a collection it is desirable to have. Popular and miscellaneous books as well as most of the illustrated magazines and newspapers and quarterlies and monthlies must be sought for in libraries designed for more general use. A museum of household relics of colonial and Revolutionary times, of old documents, ornaments, dress, weapons, furniture and many other things, such as we have lately had exhibited in Baltimore, will teach more history in an hour than a mere fancy picture gallery, of whatever extent or estimated value, will do in a week.

What a fresh impetus has been given to the study of our national history within the last hundred years! It has been estimated by those capable of forming a correct judgment, that since the organization of the Government in 1789, under the Constitution, more than *two hundred* historical societies have been organized, the greater number of which continue in active existence. Most of them aim at the elucidation of the State or county or town in which they have been formed, and the principal means employed for accomplishing the object has been the collection of historical books, of manuscripts, of museums, of historical memorials—in some instances including the natural history of the region, and the printing of historical documents.

All these collections are rendered accessible to the public, and persons devoted to such studies have every desirable opportunity of gratifying their tastes, and every facility should be afforded. The *red tape* tying the documents should be short and the knot very loose. No student need go far to find everything that has been published concerning his own State, besides numerous valuable documents which have not yet been put in print, and to these he should have free access under liberal limitations. Of what use are such historic treasures to any body if they are to be locked up in a fireproof vault, and the use or exhibition of them environed with discouraging difficulties?

Several of the States, as Maryland and Georgia, and perhaps some others, have made their library rooms or vaults of their State societies, places of deposit of valuable State historical records, at least to some extent, and it would have been well if our own State of Maryland had adopted that wise precaution long ago. Many precious documents would have been saved which are now irrecoverably lost. This measure, of course, is not necessary where the capitol of the State has fireproof vaults in which such treasures may be safely kept, or where other measures of security are adopted, which is not the case in some State Houses we know.

Some State societies have called the attention of their Legislatures to the propriety of publishing the colonial and other early records, to which they have liberally responded, and a few of them have even gone so far as to send competent agents to Europe to secure copies of old papers or catalogues of them from the record offices. Private munificence, in several instances, has rendered the same service, of which we have a notable example in our own collection in Baltimore, as a gift from George Peabody, to whom we are indebted for other similar favors.

State societies have been established in more than half of the States, and they are designated *State* societies as different from *local* societies, either because they derive support from the State, or from the prominence which they give to the history of the State in their collections and printed contributions. Their place of meeting, their libraries and collections, and the principal seat of their operations are usually at the capital of the State or in the largest city, and hence they are distinguished as *State* societies.

There are some, also, which limit their collections to the *records of the church denominations* of their preference. Some of them have formed denominational libraries, and collections of ecclesiastical relics, manuscripts, pictures, Church journals, synodical proceedings, photographs of their clergy, histories of individual congregations or parishes, busts of some of their distinguished ministers, catechisms, hymn books, catalogues of their schools and colleges, reports of their benevolent and missionary societies, all the writings of their authors in this country, and even the old furniture of the fathers of their Churches. Two of the most notable of these denominational historical societies, embracing all and even more of the specific subjects enumerated, which come within my personal knowledge, are those of the *Moravians* at *Nazareth,* and of the *Lutherans* at *Gettysburg.* There are some other Church historical societies, but they are almost exclusively confined to the collection of books and manuscripts.

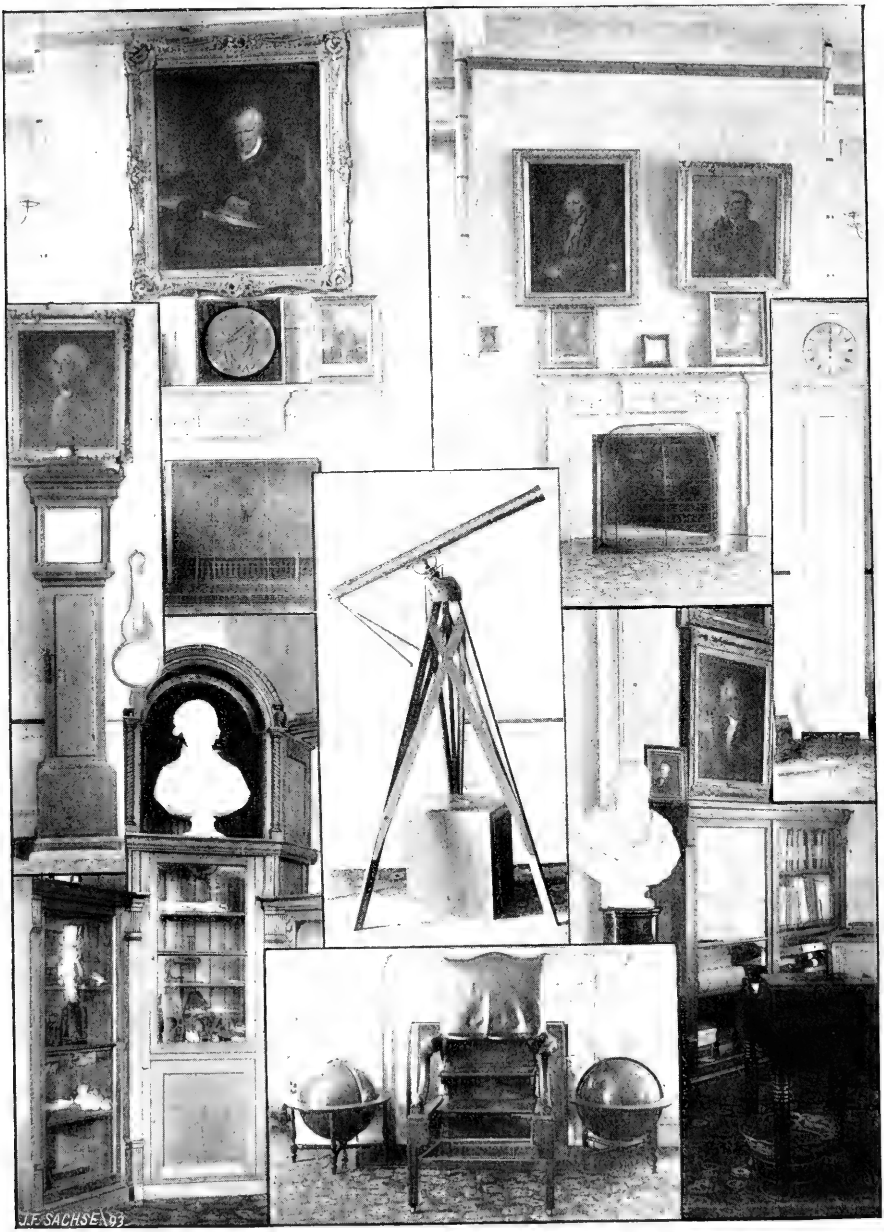
How are historical societies in general supported? Some have endowments or other property from which they draw interest or rent—such as those of Massachusetts, New York, Pennsylvania, and a few others. A few, such as Iowa, Minnesota and Wisconsin, and probably others, have special annual grants from their State Legislatures; a few are provided with apartments in the State capitol rent free, which is to that extent an appropriation, but the majority, I presume, are mainly supported by the membership fee, with occasional special contributions.

It is natural to presume that American energy would produce important and valuable *results* from such institutions. We, as a people, have never yet failed to bring something good out of material capable of being manipulated. The labors which most of these associations have performed are simply marvelous, and the good they have achieved is worthy of all admiration. Not only have many of them acquired by purchase, or donation, or bequest, splendid edifices, or, at least, most spacious and commodious buildings, in which they have gathered libraries, pamphlets, manuscripts, records, historical relics, museums of State antiquities and other treasures of priceless value, and have saved from destruction historical monographs, biographies and genealogies. They have enriched the literature of history with hundreds of volumes of useful books, containing many rare documents, of which but few knew anything before, but which are now open to all investigators, and many a precious book, which the poor student could not purchase, is now freely laid on the library table whenever he wishes to consult it. They have ransacked old depositories, and have rescued from dust and dampness and destruction many State and family records; they have unearthed many buried treasures of more value than heraldic escutcheons or baronial insignia. They have awakened an interest in historical research before unknown, or at least not concentrated and systematic; they have stimulated the zeal and encouraged the efforts of many a solitary student or obscure investigator; they have fostered the establishment of local and county societies in villages where intelligent persons cannot attend the meetings of the State societies.

But we dare not omit mentioning another result not less important, and that is, the formation of *ladies' societies* with the same general purpose in view. There are now eight or ten societies of Colonial Dames in this country, and although their researches are confined to the colonial period alone, yet they have done good service. They have not yet published the result of their studies, yet papers have been read, and it is presumed that the public will soon have the benefit of them. These patriotic American women are not out of place when hunting up the musty documents of early American history; their nimble fingers can gather the loose or tangled threads of ante-Revolutionary fragments, and weave them into beautiful historic tapestry.

But it is not only general American history that engages the diligent study of many of these investigators, but there is another branch which, of later years, has gained many ardent votaries, and that is, *family history* or *genealogy*. Old parish records, lists of emigrants, rolls of regiments, rosters of officers, old city directories and almanacs, and every conceivable ancient document that can throw a gleam of light on a family name, a disputed date, a place of residence, a clue to title or rank, is examined with painstaking assiduity. Those of us who have the management of historical libraries receive numerous letters making inquiries into family history. People from far and near want to know all about some relative concerning whom they know little themselves, but presuming that we know all about them, or can easily learn it. The investigation of some cases would require hours of patient labor, and to all excepting such all possible aid should be given.

I have playfully advised some of our resident investigators not to go too far back lest they might encounter ancestors whom they would not like to recognize, and in reply to that a bright lady from a neighboring county observed that she found the farther back she went the better her ancestors became, which pleased her vastly, for she thought some of those not far behind her were no better than they should have been. There are very few who go so far as it is said Dr. Johnson once did, although the same assertion is credited to some others; when he was asked about his ancestors he gruffly replied: "That all he knew about them was, that some of them were hung, and the rest should have been." But it is true that no one not engaged in a historical library can have any conception of the number and character of the people who are inquiring into the history of their forefathers. One fact will show the interest which this subject has awakened. Before the year 1845 the whole number of genealogical societies in New England alone was not over thirty, and twenty years after that there were 400, and since that the number



VIEWS IN MEETING ROOM.

HUMBOLDT (LAMBDIN.)
WASHINGTON (STUART.)
DUFFIELD CLOCK, 1768.
LAFAYETTE (HOUDON.)
AN ANCIENT TELESCOPE.
FRANKLIN'S CHAIR.
JEFFERSON (SULLY.)
RITTENHOUSE CLOCK, 1755.
FRANKLIN (MANCONI.)

has increased in other States also. It has been estimated that over 400 volumes, of 300 pages each, have been published by the various societies, and a much larger number of pamphlets and distinct family monographs.

The genealogies of not a few private families of distinction have been privately published, some of which are sent as donations to our libraries.

The existence of many ancient documents and relics of all other kinds which are locked up in the closets of many private families is shown on the occasion of public exhibitions for the benefit of some laudable object. We had a notable example of this in Baltimore during Easter week. There was a grand display of Revolutionary relics, and yet it is presumed that not half of similar articles existing in the State was sent to that exhibition, and the same may be said of some other States. We all remember what a collection was exhibited in the old State House, in Philadelphia, in 1876, and I believe all those objects were furnished by Pennsylvanians exclusively.

To maintain a historical completeness in this paper, this would be the place to notice the principal historical societies of our country. The number of them is so large, and their history is so extensive, that it would require a volume to describe them, so that not even a beginning can here be made.

Adjourned.

Thursday, May 25—4 to 6 o'clock P.M. Reception by the University of Pennsylvania at the Library Building of the University. In the afternoon the Society and guests attended a reception and garden party, given at Manheim Club House by Charlemagne Tower, Esq.

Friday, May 26, 1893, 11 a.m.

President Fraley introduced Capt. Rousseau D'Happoncourt, who read a paper "On Determination of Gravity by Means of a Pendulum Apparatus," which is as follows:

Die Bestrebungen, die Gestalt der Erde aus den Schwerebestimmungen abzuleiten, sind verhältnismässig neu, sie gehören fast ausschliesslich unserem Jahrhunderte an. Während die Gradmessungen sich allmählich innerhalb 2000 Jahren vom ersten Erkennen der Kugelgestalt der Erde bis zum heutigen Stande der Geodäsie entwickelten, lieferten die Schwerebestimmungen gleich nach ihrem Entstehen ein vollkommen verlässliches Beobachtungs-Materiale zur Bestimmung der gesuchten Erdgestalt, denn es standen denselben bereits die hochentwickelten Theorien der Geodäsie hilfreich zur Seite.

So kommt es denn auch, dass wir heute am Schlusse desselben Jahrhunderts, bei dem Studium über die Schwere auf der Erde, das am Anfange dieses Jahrhunderts geschaffene Materiale noch verwenden können, ja sogar fast ausschliesslich verwenden müssen, da ein neueres Materiale nur spärlich vorhanden ist, und dieses nicht immer das alte an Güte und Verlässlichkeit übertrifft.

Wir können in dem Bestreben, die Schwerebestimmungen der Geodäsie nutzbar zu machen, zwei Perioden: eine am Anfange und eine am Ende unseres Jahrhunderts, unterscheiden. Dieselben sind durch eine lange Pause von einander getrennt, während welcher nichts oder nur sehr wenig Brauchbares geleistet wurde.

In die erste Periode fallen jene zahlreichen vorzüglichen Schwerebestimmungen, welchen wir zum grössten Theile unser heutiges Wissen über die Erdgestalt, wie dieselbe aus Schwerebestimmungen sich ergibt, verdanken, und welche uns auch über die Vertheilung der Schwere auf der Erde überhaupt Aufschluss geben.

Die Namen jener Männer, welche dieses wichtige und werthvolle Materiale der Wissenschaft geliefert haben, sind wohl Allen geläufig.

Mit den grundlegenden Arbeiten Bessel's findet diese fruchtbare Periode ihren, man kann sagen plötzlichen Abschluss.

Erst durch die europäische Gradmessung, jetzt internationale Erdmessung, welche die Schwerebestimmungen in ihr Programm

KARL CHEVELIER ROUSSEAU D'HAPPONCOURT.

aufgenommen hat, entwickelte sich die zweite Periode dieser Arbeiten, in welcher wir uns eben befinden.

Wenn in Europa im Anfange dieser Periode die neueren Schweremessungen nur wenig gute Resultate lieferten, welche jenen der ersten Periode bezüglich der Genauigkeit nachstehen, so hatte dies seinen Grund darin, dass man glaubte, die so verlässlichen relativen Bestimmungen durch absolute ersetzen zu können. Mögen jedoch die absoluten Messungen noch so genau ausgeführt werden, immer haften denselben mehr, und meist auch grössere Fehler an, als den relativen; sie eignen sich demnach nur wenig oder gar nicht zur Erforschung von Details; denn die unvermeidlichen Fehler der absoluten Bestimmungen sind meist grösser, als die zu suchenden sehr kleinen Unterschiede. Ueberdies hafteten den verwendeten Apparaten Mängel an, durch welche die Ungenauigkeit der Resultate meist in ganz unbestimmbarer Weise vergrössert wurde.

Erst 1876 hat Peirce einen der wichtigsten dieser Mängel, nämlich das Mitschwingen des Stativs der Pendel-Apparate erkannt, und dem Einflusse desselben auf die Resultate Rechnung getragen.

Von dieser Zeit an war man bemüht, entweder den Einfluss des Stabilitäts-Mangels des Pendelstatives durch anderweitige Messungen zu ermitteln, und dieserwegen die gefundenen Resultate zu corrigiren, oder, was viel natürlicher ist, durch neue, bessere Constructionen der Apparate diesen schädlichen Einfluss gänzlich zu beseitigen.

Diese Bemühungen können bei uns als der eigentliche Beginn der zweiten Periode angesehen werden, in welcher neuester Zeit die relativen Schwerebestimmungen wieder den ihnen gebührenden ersten Platz einzunehmen beginnen.

Im Grossen und Ganzen sind es dieselben Ziele wie früher, die wir auch jetzt verfolgen, nämlich die Erforschung der wahren Erdgestalt; nur stehen uns gegenwärtig viele Erfahrungen zur Seite, die uns den Weg vorzeichnen, welchen wir zur Erreichung dieses Zieles einzuschlagen haben.

Früher suchte man wesentlich die Abplattung der als Ellipsoïd gedachten Erde zu bestimmen. Es hatten demnach die Messungen den Zweck, die Constanten eines schon vorher als Erdgestalt definirten analytischen Ausdruckes zu bestimmen. Strenge genommen genügten hiezu selbst nur zwei Bestimmungen; in jedem Falle war die Aufgabe durch eine verhältnismässig geringe Anzahl Beobachtungen lösbar.

Heute ist es nicht mehr die Abplattung allein, welche wir durch die Schwerebestimmungen ermitteln wollen, sondern es ist wesentlich der Verlauf des Geoïdes, welchen zu erforschen wir uns zur Aufgabe gestellt haben. Das Geoïd ist jedoch eine sehr unregelmässig verlaufende Fläche, welche sich bekanntlich durch keinen analytischen Ausdruck darstellen lässt.

Wir können demnach ihren Verlauf nur dadurch kennen lernen, dass wir die Coordinaten einer sehr grossen Anzahl von Punkten derselben bestimmen; und es ist daher im Gegensatze zu den früheren Bemühungen jetzt nothwendig, auf einer möglichst grossen Zahl über die ganze Erde gleichmässig und dicht vertheilter Orte die Intensität der Schwerkraft kennen zu lernen.

Wieder sind es die relativen Bestimmungen, welchen der grösste Antheil an der Lösung dieser umfangreichen Aufgabe zufällt, und es treten die absoluten Bestimmungen immer mehr in den Hintergrund; denn die Geodäsie verlangt nur die Vergleichung der Intensität der Schwerkraft für möglichst viele Punkte der Erdoberfläche, keineswegs jedoch eine sehr grosse Genauigkeit in der Bestimmung ihres absoluten Werthes. Wir können den Werth der Beschleunigung (g) der Schwere um 100 Einheiten der 5. Decimale ändern, ohne dass dadurch die Resultate der Vergleichung, auf die es ankommt, merklich afficirt werden.

Ob zwar wir daher den absoluten Werth der Schwere im Allgemeinen schon als bekannt ansehen können, so sollen doch dieserwegen die Bestimmungen desselben noch nicht als abgeschlossen betrachtet werden, umsoweniger, als die bisherigen Angaben für denselben noch beträchtlich von einander abweichen. Dies zeigte sich deutlich durch eine in neuester Zeit ausgeführte Untersuchung. Es wurden nämlich von Wien ausgehend, sehr genaue relative Schwerebestimmungen auf mehreren Orten ausgeführt, auf denen der absolute Werth der Schwere früher schon bestimmt war. Die grosse Verlässlichkeit der Resultate dieser relativen Bestimmungen zeigte sich gelegentlich einer Wiederholung derselben, mit verschiedenen Apparaten, zu verschiedenen Zeiten, und durch verschiedene Beobachter, welche das gleiche Resultat ergab.

Wären die verschiedenen absoluten Bestimmungen vollkommen richtig, so müssten die von ihnen mittels der gemessenen Unterschiede für Wien, geographisches Institut, abgeleiteten Werthe alle gleich sein.

Die Länge des Sekundenpendels Lw. für Wien, geographisches Institut, ergibt sich jedoch aus den Bestimmungen von:

							mm.
1.	Peters	in	Berlin,	1870,	mit Lw.	=	993.745
2.	Lorenzoni	"	Padua,	1885,	"	=	.756
3.	Anton	"	Berlin,	1878,	"	=	.760
4.	Peters	"	Altona,	1869,	"	=	.763
5.	Mahlke	"	Hamburg,	1891,	"	=	.782
6.	Peirce,	"	Berlin,	1876,	"	=	.791
7.	Bessel,	"	Berlin,	1835,	"	=	.804
8.	Biot,	"	Padua,	1820,	"	=	.805
9.	Sabine,	"	Altona,	1828,	"	=	.810
10.	Oppolzer,	"	Wien, (Türkenschanze)	1884,	"	=	.834
11.	Defforges,	"	Paris,	1884,	"	=	.835
12.	Orff,	"	München,	1877,	"	=	.837

Wie wir sehen, zeigen die Resultate nicht unbedeutende Differenzen, welche von systematischen Fehlern herzurühren scheinen. Der Unvollkommenheit der Vergleiche der zu den absoluten Bestimmungen verwendeten Maassstäbe, dürfte ein erhelicher Antheil an denselben zuzuschreiben sein.

Es zeigt sich demnach die Nothwendigkeit, dass dieses fast ausschliesslich in das Gebiet der Physik gehörende Problem, die absoluten Bestimmungen der Intensität der Schwerkraft, nach möglichst verschiedenen Methoden der Lösung zugeführt werde. Hiebei ist es ganz gleichgiltig, an welchen Orten die Bestimmungen vorgenommen werden, da die erhaltenen Resultate stets mittels relativer Bestimmungen untereinander scharf verglichen werden können.

Mit dem Bestreben, den Verlauf der Geoïdfläche aus den Schwerebestimmungen ableiten zu können, ist die Lösung mancher schwierigen Aufgaben eng verbunden.

Sowohl die Discussion der älteren Pendelbeobachtungen, als auch die Ergebnisse neuerer Bestimmungen haben uns nämlich belehrt, dass der Verlauf der Schwerkraft auf der Erdoberfläche kein regelmässiger sei; dass sowohl lokale als auch regionale Störungen derselben vorkommen und es erscheint unerlässlich, das Wesen derselben genau kennen zu lernen.

Wir kennen heute noch sehr wenig den Einfluss, welchen die Continente und Meere, die Gebirge, Hoch- und Tiefebenen, sowie die verschiedenen geologischen Formationen auf die Schwere ausüben.

Die Reductionen, mittels welchen die Beobachtungen nothwendigerweise vergleichbar gemacht werden müssen, sind uns gleichfalls nicht vollkommen bekannt, wenigstens weichen diesbezüglich die Meinungen noch sehr voneinander ab; endlich gibt es noch eine ganze Reihe von höchst interressanten, doch noch unerforschten Problemen, welche mehr in das Gebiet der Geophysik gehören, die jedoch gleichfalls nur durch Schwerebestimmungen gelöst werden können; so z. B. das Verhalten der Schwere beim Eindringen in die Erde, also in den Schachten der Bergwerke, Tunnels, etc. Erst an drei Örtlichkeiten sind über diese interressante Aufgabe Versuche unternommen worden, nämlich in den Bergwerken zu Harton in England, Pribram in Böhmen, und Freiberg in Sachsen.

Wie wir sehen, ist die durch Schwerebestimmungen zu lösende Aufgabe eine sehr grosse; denn abgesehen von den sehr zahlreichen über die ganze Erde vertheilten Beobachtungen, welche uns das Materiale zur Bestimmung des Verlaufes der Geoïdfläche zu liefern bestimmt sind, benöthigen wir auch eine grosse, nach Tausenden zählende Zahl meist dicht beieinander gelegener Beobachtungs-Stationen, zur gründlichen Erforschung der mit dieser Aufgabe im Zusammenhange stehenden Probleme.

Mit den bis vor kurzer Zeit im Gebrauche gestandenen Apparaten dieses Ziel zu erreichen, war aussichtslos, denn die Beobachtungen waren sehr mühsam und zeitraubend, daher auch sehr kostspielig.

Mit Hilfe des neuen Sterneck'schen Pendelapparates, der in vielen Staaten bereits in Verwendung ist, ist es möglich, mit Aussicht auf Erfolg, die Erreichung dieses Zieles anzustreben, indem die Beobachtungen bei sehr grosser Genauigkeit wesentlich vereinfacht sind, und überall, auch auf schwer zugänglichen Orten leicht ausgeführt werden können.

Mit demselben war es in jüngster Zeit ermöglicht, dass in Österreich Ungarn seitens des k. u. k. militär-geographischen Institutes die ersten detaillirten Untersuchungen über das Verhalten der Schwere in verschiedenen Terrain- und geologischen Formen ausgeführt werden konnten.

Es wurden die Alpen, die Karpaten, die ungarische Tiefebene, das Bihíar-Gebirge und noch andere interressante Örtlichkeiten mit einer Reihe von mehreren hundert enganeinander liegenden Schwerestationen durchguert und hiedurch viele wichtige und interressante Aufschlüsse über das Verhalten der Schwere erzielt.

Massendefecte und Massenanhäufungen under der Erdoberfläche wurden constatirt, systematische Unterschiede der Schwere über primäre Formen und Sedimenten aufgefunden, etc.

Jedes einzelne verhältnismässig leicht und schnell auf diesem noch unerforschten Gebiete zu erwerbende Resultat ist interressant, lehrreich und wichtig, u. z. nicht nur für die Geodäsie, sondern auch für Geophysik und Geologie; ja es kann heutzutage das Pendel auch als ein unerlässliches geologisches Instrument angesehen werden.

Derartige Apparate wurden bereits in grosser Anzahl von Wien aus nach vielen Staaten geliefert; bei jedem einzelnen wurden die Constanten und die Schwingungszeiten der Pendel genau ermittelt, und zwar an jenem Orte in Wien, wo Oppolzer den absoluten Werth der Schwere sehr genau bestimmt hat. Hiedurch ist eine grosse Vereinheitlichung bezüglich der Angaben für die Schwere angebahnt.

Gewiss wird sich binnen kurzer Zeit unser Wissen über diese und ähnliche Verhältnisse klären, umsomehr, wenn einmal, was in nächster Zeit zu erwarten ist, in mehreren Staaten an verschiedenen Orten ähnliche Detailstudien ausgeführt sein werden. Durch dieselben werden wir erst im Stande sein das zahlreiche über die ganze Erde vertheilte Beobachtungs-Materiale richtig zu verwerthen.

Dieses zu beschaffen, ist gegenwärtig die wesentlichste Aufgabe. Denn das von unseren Vorfahren ererbte Materiale, aus dem Anfange dieses Jahrhunderts ist viel zu spärlich und nicht immer strenge vergleichbar.

Es muss ein neues, gleichmässig über die ganze Erde vertheiltes, gleichwerthiges, Tausende von Stationen umfassendes Materiale zum Zwecke der Erforschung der wahren Erdgestalt geschaffen werden.

Wenn auch zu hoffen is, dass bei dem regen Interresse, welches sich gegenwärtig, nach so langer Zeit, allerorten für die Schweremessungen wieder kundgibt, auf dem Festlande bei allen Culturstaaten in nicht allzu langer Zeit sehr zahlreiche Messungen ausgeführt sein werden, so repräsentirt die hiedurch untersuchte Fläche doch nur einen geringen Theil der gesammten Erdoberfläche. Der weitaus grösste Theil derselben ist uns nur durch weite Reisen zugänglich, die Ausführung der Beobachtungen daher für den Einzelnen viel zu zeitraubend und kostspielig.

In richtiger Erkenntniss dieser Verhältnisse und stets bestrebt die Reisen Sr. Majestät Kriegsschiffe auch der Wissenschaft möglichst nutzbar zu machen, hat sich die k. u. k. Österreichisch-ungarische Kriegs-Marine-Verwaltung aus eigener Initiative bewogen gefunden, die Schwerebestimmungen in das Reise-Programm der Kriegsschiffe aufzunehmen.

Es wurden zu diesem Zwecke zwei Sterneck'sche Pendelapparate angeschafft und Seeoffiziere im k. u. k. militär-geographischen Institute mit der Ausführung der Schwerebestimmungen gründlich vertraut gemacht. Gegenwärtig befinden sich bereits zwei Schiffe mit completten Apparaten ausgerüstet in den ostasiatischen Gewässern, und ist die Ausrüstung eines dritten Schiffes für das mittelländische Meer bereits im Zuge.

Auf zahlreichen Stationen werden Beobachtungen ausgeführt werden, und lässt das grosse Interresse der Seeoffiziere an der Sache, die gute Schulung derselben, sowie die Einfachheit des Apparates und der Beobachtungen den besten Erfolg erhoffen.

Hiemit hat die k. u. k. Kriegs-Marine den richtigen Weg gezeigt, auf welchem es möglish ist, in relativ kurzer Zeit das für die Wissenschaft nothwendige, reichhaltige Materiale zu beschaffen.

Möge ihre Initiative auf die anderen seefahrenden Nationen anregend wirken, und eine baldige allgemeine Betheiligung an diesem Unternehmen zur Folge haben. Dann können wir hoffen, trotz der vielen Schwierigkeiten doch das angestrebte schöne Ziel zu erreichen, denn was der Einzelne nicht vermag, gelingt leicht mit vereinten Kräften.

R. v. STERNECK, *Oberstlieutenant.*

WIEN, im Januar 1893.

Chevalier D'Happoncourt then read the following translation prepared by himself:

The attempts which have been made to ascertain the figure of the earth from determinations of gravity are of comparatively recent date, and belong almost exclusively to the present century. The measurement of the lengths of degrees of the meridian has gradually developed itself during 2000 years, from the first discovery of the rotundity of the earth up to the present position of the science of geodesy, but gravity observations, from the time of their commencement, have supplied fairly reliable data for the determination of the earth's figure, for they were already assisted by the highly developed theories of geodesy.

Thus it comes about that even now, at the close of the same century, we can still use, for the study of gravity on the earth, the material obtained at the beginning of this century; indeed, it is almost all that we can use, for new material only exists to a small extent, and this does not always exceed the old data in quality and trustworthiness.

In the attempts to make gravity determinations useful to geodesy, two periods are to be distinguished; one at the beginning, and one at the end of our century. These are separated from each other by a long interval, during which nothing, or very little of any use, was accomplished.

In the first period are included those numerous and excellent determinations of gravity to which we owe, for the most part, our present knowledge of the figure of the earth as indicated by gravity determinations, and which also afford us information as to the distribution of gravity over the earth generally.

The names of those men who have furnished these important and valuable materials to science are well known to every one.

This fertile period comes, we may say, to a sudden termination with the fundamental investigations of Bessel.

The second period of these inquiries, which brings us down to the present time, was developed, first, by the measurement of degrees of the meridian in Europe, which has now become the international measurement of the earth, and has included gravity determinations in its programme.

During the second period of these inquiries, the determinations of gravity in Europe have yielded but few good results, inferior to those of the first period as regards accuracy, because it was supposed that the relative determinations which were previously employed, and which are so trustworthy, might be replaced by absolute measurements. But however accurately *absolute* measurements are carried out, they are always affected by numerous, and for the most part also by greater, errors than the relative ones; they are therefore but little, if at all, suited for the investigation of details; for the unavoidable errors of the absolute determinations are mostly larger than the very small differences which they are intended to ascertain. Moreover, there exist in the apparatus employed defects by which the inaccuracy of the results is increased in a way which it is generally quite impossible to determine.

In 1876, Peirce first perceived one of the most important of these defects, viz., the oscillation of the framework of the pendulum apparatus, and took that in account upon the results he obtained.

From this time it has been endeavored either to deduce the influence of the want of stability of the pendulum framework by further measurements, and by these means to correct the results obtained, or, what is more natural, to remove altogether this injurious effect by a better construction of the apparatus.

We may regard these efforts as the beginning of the really valuable work of the second period, in which *relative* determinations of gravity resumed the first place, which properly belongs to them.

On the whole, we still pursue the same object as before, viz., the investigation of the true figure of the earth, but we have now the advantage of much experience which indicates to us the line that we should follow for the attainment of the object in view.

Formerly, we really endeavored to determine the difference between the longest and shortest diameters of the earth, which was considered to be an ellipsoid. Accordingly the object of the measurements was to determine the constants of an analytical expression, previously defined as the figure of the earth. Theoretically speaking, two determinations were quite sufficient for this purpose; and in any case the problem could be solved by a relatively limited number of observations.

At the present day it is not only the oblateness that we wish to deduce by determinations of gravity, but it is really the shape of the geoid which we have set ourselves the task of investigating. The geoid is, however, a surface which is very irregular in shape, and which we know will not admit of representation by any analytical expression.

Thus we can only ascertain its course by the determination of the coördinates of a very large number of points; and it is therefore now necessary, contrary to former efforts, to ascertain the intensity of the force of gravity at as great a number of places as possible, uniformly and closely arranged over the whole earth.

It is, again, the relative determinations to which the greatest share in the solution of this comprehensive problem falls, and the *absolute* determinations continually recede into the background; for geodesy requires only the comparison of the intensity of the force of gravity at as many points of the earth's surface as possible, but in no wise very great accuracy in the determination of their absolute value. We may change the value of the acceleration (g) of gravity by 100 units of the fifth decimal, without thereby perceptibly affecting the results of the comparison on which it depends.

Although, therefore, we may regard the absolute value of gravity in general as already known, yet we must not on this account consider its determination as definitely set at rest, especially as the results hitherto obtained still differ considerably from each other. This is clearly shown by the following investigation, carried out quite recently. Starting from Vienna, very accurate relative determinations of gravity were carried out at many stations at which the absolute value had been already previously determined.

The thorough trustworthiness of the results of these relative determinations was proved on the occasion of their repetition with different apparatus, at different times, and by different observers, which led to the same result.

If the various absolute determinations had been perfectly correct, the results deduced from them by means of the differences determined for Vienna Geographical Institute must all be the same.

The results are as follows, expressed in the lengths of the seconds pendulum L.W., for Vienna Geographical Institute, as deduced from absolute determinations by

							MM.
1.	Peters	in	Berlin,	1870,	L.W.	=	993.745
2.	Lorenzoni	"	Padua,	1885,	"	=	.756
3.	Anton	"	Berlin,	1878,	"	=	.760
4.	Peters	"	Altona,	1869,	"	=	.763
5.	Mahlke	"	Hamburg,	1891,	"	=	.782
6.	Peirce	"	Berlin,	1876,	"	=	.791
7.	Bessel	"	Berlin,	1835,	"	=	.804
8.	Biot	"	Padua,	1820,	"	=	.805
9.	Sabine	"	Altona,	1828,	"	=	.810
10.	Oppolzer	"	Vienna, (Türkenschanze)	1884,	"	=	.834
11.	Defforges	"	Paris,	1884,	"	=	.835
12.	Orff	"	Munich,	1877,	"	=	.837

As we see, the results exhibit some important differences, which appear to be attributable to systematic errors. We may put down some of them to imperfection of the comparisons of the scales used for the absolute determinations.

This shows the necessity of referring this problem, viz., the *absolute* determination of the intensity of the force of gravity, which belongs almost exclusively to the domain of physics, to as many different methods of solution as possible. For this purpose it does not matter at which places the determinations are made, as the results obtained can always be closely compared with each other by means of relative determinations.

The solution of many difficult problems is closely connected with the endeavor to ascertain the form of the geoïd surface by means of gravity determinations.

The discussion of the older pendulum observations, as well as the results of more recent determinations, have taught us that the distribution of the force of gravity on the surface of the earth is not regular, but that local and regional disturbances occur, and it appears indispensable to ascertain their nature accurately.

Even at the present time we know little about the influence which the continents and seas, the mountains, plateaus and low plains, as well as the various geological formations, exert upon gravity.

The reductions which must necessarily be applied to the observations, in order to make them comparable with each other, are not thoroughly understood; at least, opinions about them still differ considerably. Lastly, there is still a whole series of highly interesting but yet unexamined problems, which belong more to the domain of terrestrial physics, but which can also only be solved by determinations of gravity; so, for instance, the behavior of gravity beneath the surface of the earth, such as in the shafts of mines, in tunnels, etc. Experiments have been undertaken in this interesting problem in only three localities in Europe, viz., in the mines at Harton in England, Pribram in Bohemia, and Freiberg in Saxony.

As we see, the problem to be solved by determinations of gravity is a very serious one; for, apart from the very numerous observations distributed over the whole earth which are available for furnishing materials for the determination of the form of the surface of the geoid, we require for the thorough investigation of the problems in connection with this subject, a large number of observing stations, amounting to thousands, and in close proximity to each other. It was impracticable to attain this end with the apparatus in use up to a short time ago, for the observations were very troublesome, and required much time, and were consequently costly.

By the help of Sterneck's new pendulum apparatus, which is already in use in many countries, it is possible to aspire to the attainment of this object with a prospect of success, as observations are materially simplified and yet possess very great accuracy and can be easily made everywhere, even at places which are difficult of access.

With this apparatus it was practicable, quite recently, for the Vienna Military-Geographical Institute to carry out in Austro-Hungary the first detailed investigations on the distribution of gravity in various soils and geological formations.

A series of several hundred closely connected gravity stations was established in the Alps, the Carpathians, the Hungarian lowlands, the Bihar mountains, and other interesting localities, and by this means many important and interesting results relating to the distribution of gravity were obtained.

The existence both of deficiency and of excess of mass beneath the surface of the earth was proved; systematic differences of gravity over primary formations and sedimentary deposits were discovered, etc.

Every individual result which is relatively easily and quickly obtainable in this yet unexplored domain is interesting, instructive and important, not only as regards geodesy, but also for terrestrial physics and geology; in fact, the pendulum may, at the present day, be regarded as an indispensable geological instrument.

Instruments of this pattern are already supplied in great numbers from Vienna to several countries; the constants of each, and the vibration times of the pendulums, are accurately determined at the place, in Vienna, where Oppolzer has very accurately determined the absolute value of gravity. By this means, a great uniformity of results is effected.

Within a short time, our knowledge of these and similar conditions will certainly be more definite if similar detailed experiments are carried out at different places in several countries, which may shortly be expected. By these means we shall, for the first time, be in a position to utilize properly the numerous data distributed over the whole earth.

This is the most essential task at the present day; for the materials inherited from our predecessors since the commencement of the present century are far too scanty and are not always strictly comparable with each other.

For the purpose of determining the true figure of the earth, we must obtain a mass of new material of uniform character, uniformly distributed over the whole earth, and representing thousands of stations.

If, as it is to be hoped—owing to the keen interest which, after so great a lapse of time, is again exhibited on all sides with regard to determinations of gravity—very numerous measurements are undertaken at no very distant period by all civilized countries on the continent of Europe, the area thus investigated only represents a small portion of the whole surface of the globe. By far the greatest part of the globe is only accessible by distant voyages, and the execution of the observations by means of private persons would take too much time and money.

The Austro-Hungarian Admiralty has always had a true perception of the circumstances above mentioned, and has taken the initiative by including observations of gravity among the duties to be performed by ships at foreign stations, in order to make the voyages of the ships belonging to their navy as useful to science as possible. For this purpose two of Sterneck's pendulum instruments have been procured, and the officers of the navy have been made thoroughly familiar, at the Vienna Military Geographical Institute, with the carrying out of gravity determinations. At the present time, there are already two ships in the China seas which are furnished with complete apparatus, and the equipment of a third vessel for the Mediterranean is already in progress.

Observations will be taken at numerous stations, and we may fairly hope for very good results, from the great interest the officers have taken in the subject and their good education, as well as from the simplicity of the apparatus and of the observations themselves.

The Ministry of Marine has thus shown the right way by which it is possible to secure for science, in a relatively short space of time, a copious amount of necessary data.

I may, in conclusion, express the hope that their initiative may stir up other maritime powers and result in a speedy, general participation in this undertaking. We may then hope that, in spite of the many difficulties, the important object in view may soon be attained; for what individuals cannot do may be easily accomplished by united forces.

(Signed) R. v. STERNECK, *Oberst Lieutenant.*

VIENNA, January, 1893.

President Fraley next introduced Dr. Isaac Roberts, who addressed the Society as follows:

I am delegated by the Royal Astronomical Society of England to convey to you their hearty good wishes on this anniversary of your Society, and hope that your career in the future will be even more prosperous than in the past.

I have brought with me a few specimens of the work that has been done in England, so that those present at the meeting may have an opportunity of judging somewhat of the way in which we work there. The subject involves a series of photographs, and the most convenient place for exhibiting them happens to be at the back of this room; it is therefore probable that the audience will desire to turn their backs on you, Mr. President, for a while, so that they may see on the photographs the references which I may have to make, and, with your permission, I shall have to be within reach of the photographs so that I may point them out.

My remarks may be entitled, "Illustrations of Progress Made During Recent Years in Astronomical Science." I am rather at a disadvantage in not knowing to what extent the field of astronomical science has been exhibited to you at the meetings which have preceded this one, and I therefore feel the risk that I incur of repeating much of what may have been already laid before you in form and substance better than I can submit it. I shall, therefore, assume that reference to the progress made in astronomical science between the time of the foundation of this Society and about the year 1850 may by me be omitted.

The selection of the year 1850 as the time for the commencement of my narrative will be appreciated, because it was in that year that your illustrious countryman, George P. Bond, produced with the fifteen-inch Harvard refractor, a very successful photograph of the moon, which was exhibited at the great Exhibition in London, in 1851. Another of your illustrious countrymen, Dr. J. W. Draper, of New York, had, as early as the year 1840, taken photographs of the moon, and in the subsequent year he succeeded in the application of the photographic method to the delineation of the solar spectrum. Bond also, in 1850, photographed, with the fifteen-inch Harvard refractor, the bright stars Castor and Vega, and, in 1857, initiated the photography of double stars.

Of course, in England and in France, celestial photography was successfully carried on concurrently with similar work in America, and it would be difficult to assign a sharp line of demarcation which would place any one of these countries far in advance of the others in the keen but noble efforts to enlarge the boundaries of knowledge by the application of the newly-discovered powers of photography. Warren De la Rue, in England, in 1853, produced excellent photographs of the moon, and, in 1858, instituted the method of photographing sun spots, which was effected continuously until 1872. In France, Foucault and Fizeau also photographed the sun, in 1845; and in America, Rutherford, in 1864, made an important step in advance by the construction of a telescope with an objective of eleven and a half inches aperture, corrected, not for visual observation, but exclusively for photographic work. This was improved, in the year 1885, by the brothers Henry, of Paris, who constructed a photo-telescope of thirteen inches aperture, and with it succeeded in photographing stars of the sixteenth magnitude, in May, of that year; and it so happened that I also had a reflecting telescope made, having an aperture of twenty inches, with which I commenced, in May, 1885, to chart the stars in the Northern hemisphere of the sky on a scale about double that adopted by Argelander. But Dr. Gill, the Director of the Cape Observatory, and the late Admiral Mouchez, Director of the Paris Observatory, proposed and admirably carried into execution a scheme of charting the stars by photographic instruments of identical aperture, focal length and chromatic corrections as those adopted in the Paris instrument made by the Henrys. There are now eighteen of those telescopes in observatories, situated in different parts of the world, regularly engaged in taking photographs of the sky, so as to produce a great chart of all the stars down to the fourteenth magnitude. Therefore, the charting which I had commenced is superseded by a more efficient method, and my twenty-inch reflector, practically, is turned to use in photographing nebulæ and clusters of stars, an employment for which it is better adapted than the thirteen-inch photo-refractors used in the charting.

The merits of the reflector in photographing faint stars and faint nebulosity was pointed out by Dr. Common, in England, in the year 1883, and my experience since fully confirms his. I must not here attempt even a cursory description of the great work done during recent years in the photographing of solar, stellar and nebular

ERRATA in the Orientation and Order of the Plates.

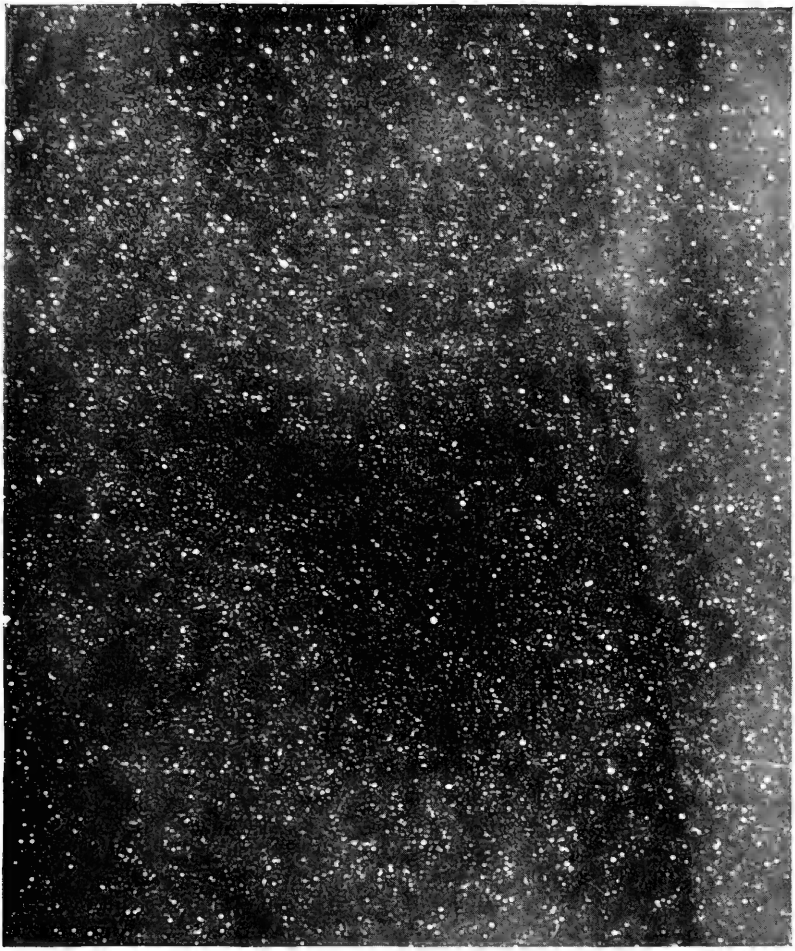
PLATES i., iv., viii., ix., xi., xii., xiii.—*North* point at the bottom; *South* at the top; *West* to the left hand; *East* to the right hand. This corresponds to the orientation of the object as viewed in an astronomical telescope.

PLATES v., vi., x.—*North* point at top; *South* at bottom; *East* to the left hand; *West* to the right hand.

PLATE ii.—*For* M 13 Herculis *read* M 15 Pegasi. *North* point is midway between bottom and left hand; *South* midway between top and right hand; *West* between top and left hand; *East* between bottom and right hand.

PLATE iii.—*For* M 15 Pegasi *read* M 13 Herculis. *North* point is at right-hand side; *South* at the left hand; *West* at the bottom; *East* at the top.

PLATE vii.—*North* point is midway between bottom and left-hand side; *South* between top and right hand; *West* between top and left hand; *East* between bottom and right hand.



STARS IN CYGNUS.

Plate I (Roberts).

M. No. 13, Herculis.

Plate II (Roberts).

spectra. The field is too extensive and the ardent workers too numerous for inclusion in this brief statement. I shall, therefore, as the representative of the Royal Astronomical Society of England, introduce to your notice a selection of thirteen photographs, which are copies of some which have been presented to the Society and described at the meetings of the Fellows at various times during the past seven years, and I may be permitted to add, that they represent the fullest information we yet possess concerning the objects they portray.

The first (Pl. i.) is a photograph of the stars in the Milky Way in Cygnus. When you examine it closely, you will find it is almost covered with stars, not one of them visible to the sight without the aid of the telescope, many of them invisible even with powerful telescopes. This is an area of the sky that would be covered by one of your smallest silver coins, held between the finger and thumb, at arm's length, between the eye and the sky; the area of sky covered by such a piece would be about equal to what this photograph represents. The centre of the photograph is in R. A. 19 h. 45 m., decl. N. 35 deg. 30 m., and covers a sky area of about 2 deg. 3 m. by 1 deg. 45 m. It has been enlarged from the negative to a scale of 26 seconds of arc to 1 millimeter, and was taken with the twenty-inch reflector, on August 14, 1887, with an exposure of sixty minutes. A photograph comparable with this, was taken by the brothers Henry, in Paris, in August, 1885, with the thirteen-inch photo-refractor, and was one of the early marvels of celestial photography. It showed about 3000 stars on the sky area just described, but the photograph taken with my twenty-inch reflector, and now exhibited, shows no less than 16,000 stars on the same coincident area of the sky. Allowing for difference in aperture between the two telescopes, there is still a wide margin in favor of the reflector for this kind of work.

The next photograph (Pl. ii.) is known as M. 15, in the constellation Pegasus, in R. A. 21 h. 25 m., decl. N. 11 deg. 41 m. The scale is 6 seconds of arc to 1 millimeter, and the field is 18 minutes of arc in diameter. The photograph was taken with the twenty-inch reflector, on November 4, 1890, with an exposure of two hours, and shows a fine example of a globular cluster, but the written descriptions of it, from eye observations, do it scant justice, and there are no drawings available for comparison. The photograph shows the central part of the cluster to be involved in nebulosity, as is also the case with other globular clusters. Surrounding the cluster are curves and festoons of stars, which is a characteristic of these objects. Eye observations do not reveal the existence of the involved nebulosity which, on the plate, is sufficiently dense to obscure the stars, though they are visible through the nebulosity on the negative.

The next photograph (Pl. iii.) is of the cluster known as M. 13, in the constellation Hercules, and is in R. A. 16 h. 38 m., decl. N. 36 deg. 39 m. The scale is 6 seconds of arc to 1 millimeter, and the field or circle is 18 minutes of arc in diameter. The photograph was taken with the twenty-inch reflector and an exposure of one hour, on May 22, 1887, and delineates one of the finest globular clusters in the heavens, containing thousands of stars densely packed together at the centre and with curvilinear streams of stars radiating from it. Lord Rosse detected three dark lanes or rifts in its interior, forming something like the letter Y, which is distinctly shown on the photograph and more strikingly visible on the negative. No drawing can possibly do justice to an object like this, which is portrayed by photography in one hour. Moreover, it shows the cluster involved in nebulosity obscuring the stars at the centre, a fact which observers had hitherto failed to perceive.

The next photograph (Pl. iv.) is known as Herschel VI., No. 33 and No. 34, in Perseus, having R. A. 2 h. 11 m., decl. N. 56 deg. 38 m. The scale is 24 seconds of arc to 1 millimeter, and the photograph covers the sky area of 1 deg. 54 m. by 1 deg. 38 m. It was taken with the twenty-inch reflector, on January 13, 1890, with an exposure of three hours. These gorgeous clusters, in the sword-hand of Perseus, reveal one of the most brilliant objects in the heavens. To chart their component stars by eye observations and measurements would be an exceedingly protracted task, and even then it would only be imperfectly done. The photograph gives a perfectly accurate picture of these thousands of stars in a very short time, the relative position and magnitude of each one being correctly delineated, so as to form a reliable basis for future investigation concerning their variability and relative movements.

Next (Pl. v.) is a photograph of the ring nebula, M. 57 Lyræ. It is in R. A. 18 h. 49 m., decl. N. 32 deg. 52 m. The scale is 4 seconds of arc to 1 millimeter, and the diameter of the field is 12 minutes of arc. The photograph was taken July 27, 1891, with the twenty-inch reflector and an exposure of thirty minutes. The nebula is the best known and brightest of the class of annular

Crab Nebulæ, M. 1, Tauri.

Plate VI (Roberts).

SPIRAL NEBULA, M. No. 51, CANUM.

Plate VII (*Roberts*).

Nebulæ in Ursa Major.

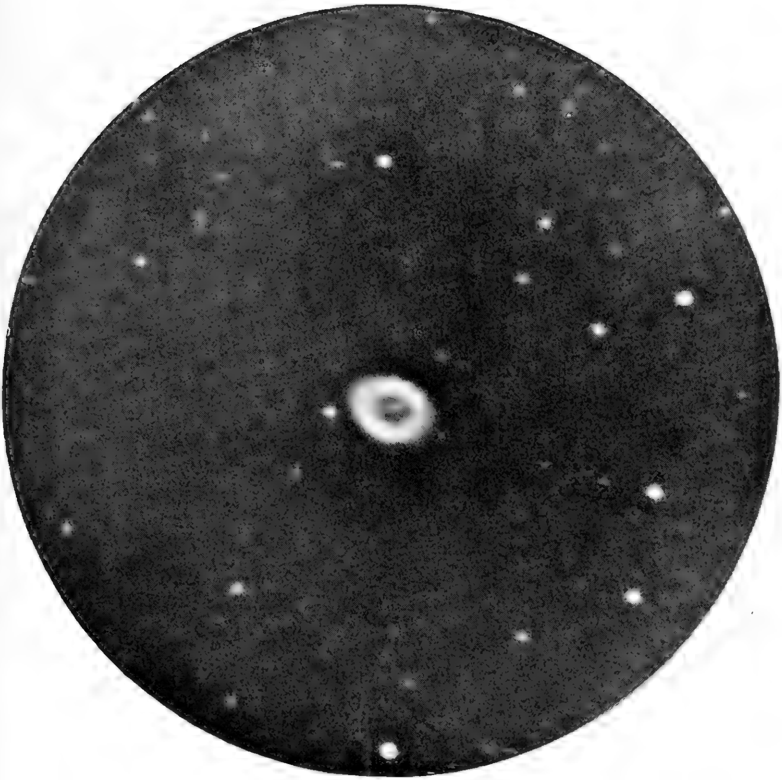
Plate VIII (Roberts).

Cluster M. 15, Pegasi.

Plate III (Roberts).

Herschel VI, Nos. 33 and 34.

Plate IV (Roberts).



Ring Nebula, M. 57, Lyræ.

Plate V (Roberts).

nebulæ, and the photograph confirms in general outline the observations of Herschel and Lord Rosse, but there is no indication of the filamentous projections shown on one of the drawings. On the other hand, the central star inside the ring is conspicuous on the photograph though not shown on the drawings.

The next photograph (Pl. vi.) is that of the crab nebula, M. 1, in the constellation Taurus. This nebula is in R. A. 5 h. 28 m., decl. N. 21 deg. 57 m. The scale is 8 seconds of arc to 1 millimeter, and the field is 24 minutes of arc in diameter. The photograph was taken with the twenty-inch reflector, on February 2, 1892, and an exposure of three hours. In Lord Rosse's drawing, which is familiar as a popular illustration, the nebula somewhat resembles a pineapple, with hair-like appendages; but the photograph shows it to be irregular, oval in outline, with a deep indentation on the following side, and immediately opposite to this is a protuberance of faint nebulosity. The nebula, generally, is very bright and granular in structure, with patches of unequal density involved, and the outer margin is faint and ill-defined.

Next is the photograph (Pl. vii.) of the spiral nebula, M. 51 Canum. This nebula is in R. A. 13 h. 25 m., decl. N. 47 deg. 45 m. The scale is 8 seconds of arc to 1 millimeter, and the field is 24 minutes of arc in diameter. It was taken with the twenty-inch reflector, April 28, 1889, with an exposure of four hours. This nebula is the most striking of the spiral form, and the published drawings of it by Lassell and Lord Rosse are, perhaps, the best known and in outline are in fair agreement with the photographs. Both the drawings, however, fail to give an adequate idea of the real structure of this remarkable object, which is here correctly depicted for the first time. The stars and condensed patches of nebulosity follow closely all the whorls of the nebula, and are strikingly seen on the photograph, though only imperfectly shown on the drawings.

Next is the photograph (Pl. viii.) of the nebulæ, M. 81, 82, and a nebulous star in Ursa Major, with centre in R. A. 9 h. 46 m., decl. N. 69 deg. 39 m. The area of the sky included is about 1 deg. 16 m. by 1 deg. 4 m. The scale is 16 seconds of arc to 1 millimeter. The photograph was taken with the twenty-inch reflector, March 31, 1889, with an exposure of three hours and thirty minutes. The nebula south is M. 81, which is on this photograph shown for the first time to be a spiral with a dense nucleus.

The nebula on the north is M. 82, and appears as a bright ray, due to its being viewed edgewise from our position on the earth. A nebulous star is also visible on the south, near the edge of the plate.

Next is the photograph (Pl. ix.) of the dumb-bell nebula in Vulpecula. It is in R. A. 19 h. 55 m., decl. N. 22 deg. 25 m. It covers a sky area of 1 deg. 26 m. by 1 deg. 13 m. The scale is 18 seconds of arc to 1 millimeter. It was taken with the twenty-inch reflector, on October 3, 1888, with an exposure of three hours. The drawings of the nebula by Herschel and Lord Rosse are familiar as illustrations in text-books, but when they are compared with the photograph they fail to show the outlines and details which it reveals. The brighter part is not shown in the shape of a dumb-bell, strictly, but as a vast, globular mass, surrounded by a wide, nebulous ring, which is seen as a projection at both sides and encroaching on the globular mass, which is also broken up into flocculent patches.

Next is the photograph (Pl. x.) of the nebulæ in the Pleiades. The sky area shown is 1 deg. 26 m. by 1 deg. 13 m., on a scale of 18 seconds of arc to 1 millimeter. The photograph was taken with the twenty-inch reflector, December 8, 1888, with an exposure of four hours. The stars visible to the eye in the Pleiades are five in number, and in 1859 Tempel discovered that the star *Merope* was involved in faint nebulosity. Some further traces of nebulous light in the group were suspected in a vague, indefinite way, by Weiss and other observers using large telescopes. In 1885, the Henrys obtained a photograph which showed a trace of nebulosity near three of the bright stars ; namely, three streamers across *Merope*, and a little projection from *Maia*, also a horn-like projection from *Electra*. My first photograph—taken in December, 1886, with three hours' exposure—proved the existence of extensive nebulous patches and streamers scattered over the whole group and probably forming parts of one vast nebula. The present photograph exhibits these features as far as they are at present known.

Next are two photographs (Pls. xi. and xii.) of the great nebula in Orion. The sky area covered is 1 deg. 16 m. by 1 deg. 4 m., on a scale of 16 seconds of arc to 1 millimeter. Pl. xi. was taken with the twenty-inch reflector, December 24, 1888, with an exposure of eighty-one minutes. The other (Pl. xii.), with an exposure of three hours and twenty-five minutes, was taken on February 4, 1889,

DUMBBELL NEBULA M. 27, VULPECULÆ.

Plate IX (Roberts).

Nebulæ in the Pleiades.

Plate X (Roberts).

GREAT NEBULÆ IN ORION.

Plate XI (Roberts).

Great Nebulæ in Orion.

Plate XII (Roberts).

Great Nebula in Andromeda.

Plate XIII (Roberts).

shows the structure and details of the central nebulosity with greater clearness than the first. The second shows vastly more extensive nebulosity than the first, but the central part is too dense on the negative to print on the paper enlargement. The stars and all details of the central nebulosity are, nevertheless, clearly visible on the negative. These two photographs, when correlated with each other, show the great nebula more completely and truly than it was previously known; and, though many drawings have been made and ably discussed by Prof. Holden in his elaborate monograph on the Orion nebula, they only show how utterly untrustworthy eye observations are. The first photograph of this object was obtained by Dr. Draper, in 1880, with an eleven-inch refractor, his best one being obtained in March, 1882, with an exposure of 137 minutes. The next advance was by Dr. Common, in 1883, with his three-foot reflector and an exposure of 37 minutes. This, in turn, has been much distanced by the present photograph, which shows an enormous extension of nebulosity and much delicate detail not before seen.

On the photograph of the great nebula in Andromeda (Pl. xiii.), the sky area covered is 1 deg. 54 m. by 1 deg. 38 m., on a scale of 24 seconds of arc to 1 millimeter, and was taken with the twenty-inch reflector, December 29, 1888, with an exposure of four hours. The nebula is one of the largest in the heavens, and has been known ever since the invention of the telescope as a long, oval nebulosity, ill-defined at the margin. Bond, in 1847, and Trouvelot, later, with the fifteen-inch Harvard refractor, detected two large, longitudinal rifts on one side of it. No advance was made beyond this until my photograph, taken on October 10, 1887, revealed its true form for the first time. The nebula is shown to be symmetrically oval and encompassed by elliptical rings, separated by dark divisions extending completely around it. There are a great many stars involved, apparently, in the nebula, which the photograph shows in their true relative positions, together with the structure and details of the nebulosity.

In conclusion, I shall only be uttering a truism when I say that we are yet only at the threshold of knowledge of the stellar universe, though the progress made during the past ten years encourages us to hope that ere the Two Hundredth Anniversary of the Philosophical Society of Philadelphia shall be held much will be known concerning the movements of the solar system in space, the general drift of the stars, the changes in star clusters and in nebulæ, together with solutions more or less complete of many other questions that are now obscure to us. The material which we are now laboriously accumulating will then be available in reliable form to unravel the knowledge that is now beyond our grasp.

May I ask you, Mr. President, to accept these photographs for the library of the American Philosophical Society, with the best wishes of the Royal Astronomical Society of England; and, if you can make them available to those who are teaching the science among you, so that they may be able to make, say, lantern slides for lecture illustrations from them, they are entirely at your service, subject only to such restrictions as you and the Council may choose to exercise.

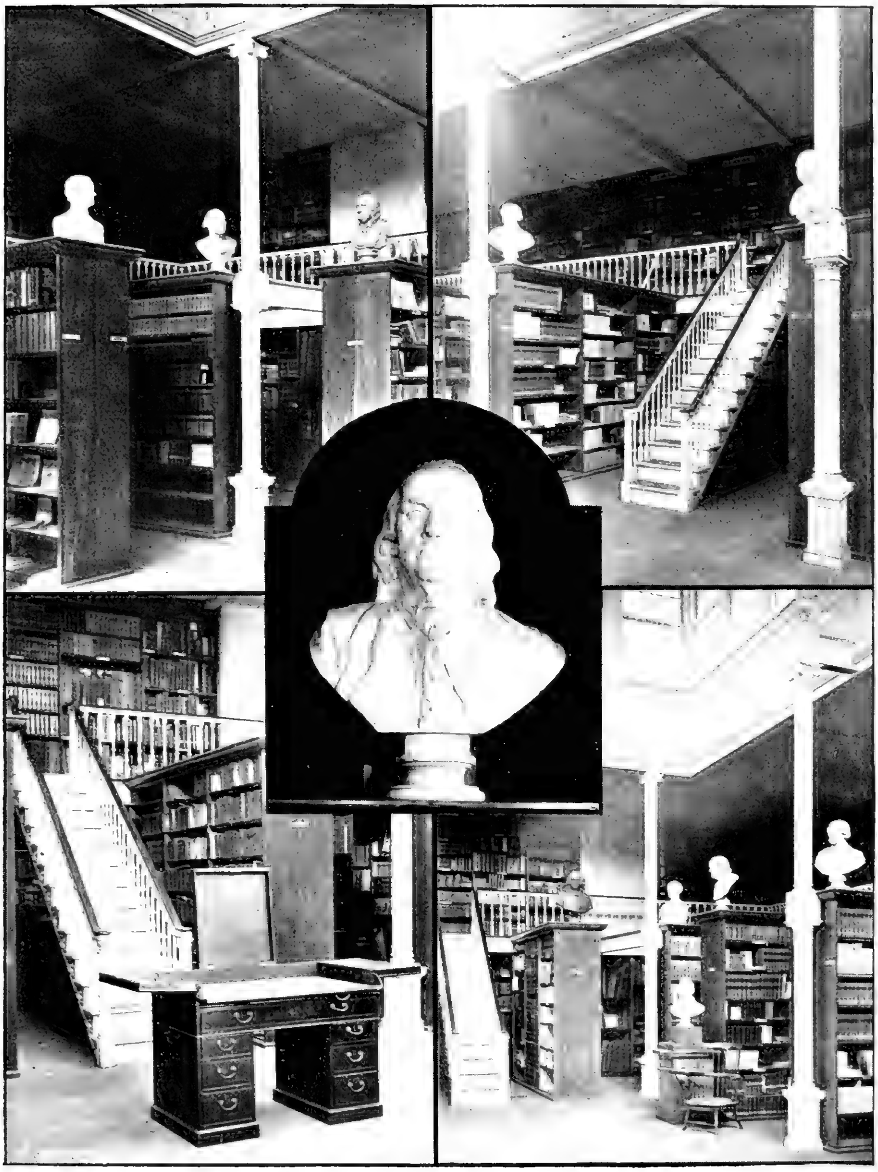
PRESIDENT FRALEY: I accept them on behalf of and with the thanks of the American Philosophical Society.

Prof. George F. Barker next read to the Society a paper on "Electrical Progress since 1743."

Mr. President and Gentlemen:—I take great pleasure in responding to the invitation of the Committee of Arrangements to prepare for the Sesquicentennial Anniversary of the American Philosophical Society a paper upon the development of electrical science since 1743, with especial reference to the part taken in this development by the members of this Society.

Surrounded as we are to-day with the numberless applications which have been made of electricity to the wants of man, it is not easy to go back one hundred and fifty years and to realize the actual condition of the science of electricity at that early date. It is true that Gilbert had already shown, in his remarkable book, *De Magnete*, published in 1600,* that "not only amber and agate attract small bodies, but diamond, sapphire, carbuncle, opal, amethyst, Bristol gem, beryl, crystal, glass, glass of antimony, spar of various kinds, sulphur, mastic and sealing wax" do so also. He had already invented the words, "electricity" and "electrical," and had differentiated between electric and magnetic forces by

* *De Magnete, Magneticisque Corporibus et de Magno magnete tellure,* Londini, Anno MDC.



VIEWS IN THE LIBRARY.
FRANKLIN (HOUDON)

showing that the electric force attracts all light bodies while the magnetic force attracts iron only. If, now, to these observations of Gilbert we add those of Von Guericke, in 1672,* that electrical repulsion exists as well as attraction ; of Boyle, the same year,† that the attraction between the electrified body and the light body is mutual; and that of Newton, in 1675,‡, that the electric action will pass through glass, we have before us an epitome of electric science at the close of the seventeenth century.

But the era of activity had begun. The light and sound of the electric spark were observed as early as 1708, by Wall,§ and their resemblance to lightning suggested. Hawksbee noticed, in 1709,‖ the light which is produced when mercury is shaken in a glass tube, and had improved on the electrical machine of Von Guericke by using a globe of glass in place of one of sulphur. Gray, in 1729,¶ discovered the property of conduction, and divided bodies into *electrics per se* and *non-electrics* or *conductors*. Dufay discovered, in 1733, "that there are two kinds of electricity, very different from one another; one of which I call *vitreous*, the other *resinous*, electricity. The characteristic of these two electricities is that they repel themselves and attract each other." **

This, then, constituted substantially the whole of the electrical knowledge of the world when the American Philosophical Society was established. Franklin, himself, took up the subject a few years later. He tells us that, "in 1746, being at Boston, I met there with a Dr. Spence, who was lately arrived from Scotland, and showed me some electrical experiments. They were imperfectly performed, as he was not very expert; but, being on a subject quite new to me, they equally surprised and pleased me. Soon after my return to Philadelphia, our library company received from Mr. Peter Collinson, F.R.S., of London, a present of a glass tube, with some account of the use of it in making such experiments. I eagerly seized the opportunity of repeating what I had seen at Boston, and, by much practice, acquired great readiness in performing

* *Experimenta Magdeburgica*, Amsterdam, 1672, lib. iv, c. 15.

† *Boyle's Works*, Vol. iv, p. 352 (edition of 1772, published in London in six volumes).

‡ *Philosophical Transactions*, 1675. Wiedemann, "*Lehre von der Electricität*," Vol. i, p. 4, 1882.

§ *Phil. Trans.*, v, 409, 1708.

‖ *Physico-mechanical Experiments*, 1709.

¶ *Phil. Trans.*, vii, 449, 1727.

** *Mémoires de l'Academie des Sciences*, 1733, p. 457.

those also which we had an account of from England, adding a number of new ones. I say much practice, for my house was continually full for some time with persons who came to see these new wonders. To divide a little this incumbrance among my friends, I caused a number of similar tubes to be blown in our glass house, with which they furnished themselves, so that we had, at length, several performers. Among these, the principal was Mr. Kinnersly, an ingenious neighbor, who, being out of business, I encouraged to undertake showing the experiments for money, and drew up for him two lectures in which the experiments were ranged in such order and accompanied with explanations in such method as that the foregoing should assist in comprehending the following. He procured an elegant apparatus for this purpose, in which all the little machines that I had roughly made for myself were neatly formed by instrument makers." * He continues: "Obliged as we were to Mr. Collinson for the present of the tube, etc., I thought it right he should be informed of our success in using it, and wrote him several letters containing accounts of our experiments."†

Franklin's first letter to Collinson is dated July 11, 1747. In it he says: "We rub our tubes with buckskin and observe always to keep the same side to the tube and never to sully the tube by handling; thus they work readily and easily, without the least fatigue, especially if kept in tight pasteboard cases, lined with flannel and fitting close to the tube." In a footnote he adds, "Our tubes are made here of green glass, 27 or 30 inches long, as big as can be grasped."

* *Memoirs of the Life and Writings of Benjamin Franklin, LL.D., F.R.S.* Written by himself to a late period and continued to the time of his death by his grandson, William Temple Franklin. Third edition, in six volumes. London, 1818. Vol. i, p. 237.

† *New Experiments and Observations on Electricity*, made at Philadelphia, in America, by Benjamin Franklin, LL.D and F.R.S. London, 1769. Franklin himself says of these letters: "Mr. Collinson gave them to *Cave* for publication in his *Gentlemen's Magazine;* but he chose to print them separately in a pamphlet and Dr. Fothergill wrote the Preface." In this Preface Dr. Fothergill says: "The experiments which our author relates are most of them peculiar to himself; they are conducted with judgment and the inferences from them plain and conclusive; though sometimes proposed under the terms of suppositions and conjectures. . . . .

"He exhibits to our consideration an invisible, subtle matter, disseminated through all nature in various proportions equally unobserved, and, whilst all those bodies to which it peculiarly adheres are alike charged with it, inoffensive.

"He shows, however, that if an unequal distribution is by any means brought about; if there is a coacervation in one part of space, a less proportion, vacuity or want in another; by the near approach of a body capable of conducting the coacervated part to the emptier space, it becomes, perhaps, the most formidable and irresistible agent in the universe. Animals are in an instant struck breathless, bodies almost impervious by any force yet known are perforated, and metals fused by it in a moment."

The precise form of the electrical machine used by Franklin appears to be a matter of some doubt. Parts of several machines are known, all reputed to have belonged to Franklin. Three or four quite similar frames are in existence, all provided with multiplying wheels for giving rotation to the electric used, which was mounted upon an axis placed above the wheel. One of these frames is in possession of the Franklin Institute, another is owned by the University of Pennsylvania, and a third is in the physical cabinet of the College of New Jersey, at Princeton. In only the first of these, however, is the electrical portion preserved. The electric is a glass globe, having a leather cushion for its rubber and provided with a curved rod for the collector. Moreover, these frames or stands all resemble very closely that which is described and figured as "the cylindrical machine as constructed by Franklin," in Snow Harris' *Frictional Electricity*.* But, as shown, this latter machine is provided with a cylinder as the electric, and not a globe. Again, in January, 1879, Miss Mary D. Fox presented to the University of Pennsylvania several pieces of electrical apparatus, said to have belonged to Franklin, and to have been deposited at the house of her father, George Fox, at Champlost, to whom they were bequeathed by William Temple Franklin, the grandson of Benjamin Franklin, together with many of his valuable papers, now in possession of the American Philosophical Society.† One of these pieces of apparatus I have the pleasure of exhibiting. It is evidently the collector (or prime conductor, as it was formerly called) of an electrical machine; and, as is evident from its construction, could have been used only with a machine provided with a plate electric.

In the earliest electrical machine, made in 1672 by Von Guericke, the electric consisted of a globe of sulphur, mounted on a horizontal axis and rubbed with the hand. In 1709, Hawksbee replaced the sulphur globe by one of glass. Franklin, in his first letter to Collinson, thus speaks of his electrical machine: "Our spheres are fixed on iron axes which pass through them. At one end of the axis there is a small handle with which you turn the sphere like a common grindstone. This we find very commodious, as the machine takes up but little room, is portable and may be en-

* *A Treatise on Frictional Electricity in Theory and Practice*, by Sir William Snow Harris, F.R.S., London, 1867, p. 104.

† See *Proceedings Amer. Philos. Soc.*, i, 253, July 17, 1840. "The Franklin papers were bequeathed by will to George Fox, father of C. P. Fox, by Temple Franklin, grandson of Benjamin Franklin."

closed in a tight box when not in use. 'Tis true the sphere does not turn so swift as when the great wheel is used; but swiftness we think of little importance, since a few turns will charge the vial sufficiently." He adds, in a footnote: "This simple and easily made machine was a contrivance of Mr. Syng's."

The addition of a metallic collector to the globe machine was made by Boze in 1742,* and the use of a leather cushion as the rubber was introduced by Winkler in 1744.† And, although Hawksbee had used a cylindrical electric, yet it did not come into use apparently until Wilson again made use of it in 1752.‡ It was not until 1756 that De la Fond § made a machine having a plate electric; in which he was closely followed by Ingenhaus (1764),|| Cuthbertson (1770),¶ and Le Roy (1772).** The addition of a multiplying wheel is generally attributed to Nollet, in 1746.††

In this connection, it is interesting to note that, with the electrical apparatus given to the University by Miss Fox, there was a set of copper-plate impressions of certain experiments in heat and electricity. As these engravings could not be identified with any of the researches made by Franklin, it was for some time doubtful what their origin was and what their connection with Franklin himself. Finally, several years later, in looking over the very complete antiquarian scientific library of Prof. H. Carrington Bolton, of New York, the writer observed that *facsimiles* of these plates served as the illustrations of a book entitled, "*Recherches Physiques sur le Feu.* Par M. Marat, Docteur en Médecine et Médecin des Gardes du Corps de Monseigneur le Comte d'Artois. À Paris, Rue Dauphine, MDCCLXXX, pp. 204 avec VI planches." Thus establishing the fact of scientific intercourse between Franklin and Marat, afterwards one of the chief actors in the French Revolution.‡‡

* *Die Electricität nach ihrer Entdeckung und Forgang*, etc., Wittenberg, 1744.

† *Gedanken von den Eigenschaften . . . . nebst Beschreibung zweyer neuen electrischen Maschinen*, Leipzig, 1744.

‡ *A Treatise on Electricity*, London, 1752.

§ *Précis des Phénomènes Électriques*, 1756, 2d ed., p. 47.

|| *Phil. Trans.*, xiv, 598, 1779.

¶ Harris' *Frictional Electricity*, p. 68.

** *Mémoires de l'Academie*, Première Partie, p 499, 1772.

†† *Leçons de Physique*, Paris, 1767.

‡‡ In a memorandum made at Passy, December 13, 1778, Franklin says: "Received a parcel from an unknown philosopher [afterwards discovered to be *Marat*, of subsequent notorious memory], who submits to my consideration a memoir on the subject of *elementary fire*, containing experiments in a dark chamber. It seems to be well written, and is in English, with a little tincture of French idiom. I wish to see the experiments, without which I cannot well judge of it" (*Memoirs*, Vol. ii, p. 90).

It appears, then, that in scarcely more than a year Franklin had mastered the theory and practice of electrical science and had become an investigator. In his letter to Collinson of July 11, 1747, he describes an experiment showing "the wonderful effect of pointed bodies both in *drawing off* and in *throwing off* the electrical fire." Moreover, it is in this first scientific letter that he propounds his theory of electricity. "We say B (and bodies like circumstanced) is electrified *positively;* A, *negatively.* Or, rather, B is electrified *plus;* A, *minus.* And we daily, in our experiments, electrize bodies *plus* or *minus,* as we think proper. To electrize *plus* or *minus,* no more needs to be known than this, that the parts of the tube or sphere that are rubbed do, in the instant of the friction, attract the electrical fire and therefore take it from the thing rubbing; the same parts, immediately as the friction upon them ceases, are disposed to give the fire they have received to any body that has less."

In 1745, Kleist,* and, in 1746, Cuneus,† had observed the phenomena of electrical condensation, and Muschenbroek had constructed the Leyden jar. The experiments of Franklin, made in 1747, showed that "at the same time that the wire and top (inside) of the bottle is electrified *positively* or *plus,* the bottom of the bottle (outside) is electrified *negatively* or *minus* in exact proportion; *i. e.*, whatever quantity of electrical fire is thrown in at top, an equal quantity goes out of the bottom." "None can be thrown into the top when none can get out at the bottom." . . . . "Again, when the bottle is electrified, but little of the electrical fire can be *drawn out* at the top by touching the wire unless an equal quantity can at the same time *get in* at the bottom." By these and similar experiments he completely analyzed the phenomena in question. He continues: "So wonderfully are these two states of electricity, the *plus* and *minus,* combined and balanced in this miraculous bottle, situated and related to each other in a manner that I can by no means comprehend! If it were possible that a bottle should in one part contain a quantity of air strongly comprest, and in another part a perfect vacuum, we know that the equilibrium would be instantly restored *within.* But here we have a bottle containing at the same time a *plenum* of electrical fire and a vacuum of the same fire; and yet the equilibrium cannot be restored between them but

* *Versuche u. Abh. d. Naturf. Gesellsch.*, Danzig, 1745, Vol. ii, p. 408.

† *Mémoires de l'Academie des Sciences*, 1746, p. 2.

by a communication without; though the *plenum* presses violently to expand and the hungry vacuum seems to attract as violently in order to be filled."

Again, Franklin was the first to prove that the phenomena of condensation have their seat in the dielectric and not in the metallic coatings. "The whole force of the bottle and power of giving a shock," he says, "is in THE GLASS ITSELF; the non-electrics, in contact with the two surfaces, serving only to *give* and *receive* to and from the several parts of the glass; that is, to give to one side and take away from the other." This opinion he supports by striking and conclusive experiments. "It is amazing," he continues, "to observe in how small a portion of glass a great electrical force may lie. A thin glass bubble, about an inch diameter, weighing only six grains, being half filled with water, partly gilt on the outside and furnished with a wire hook, gives, when electrified, as great a shock as a man can well bear. As the glass is thickest near the orifice, I suppose the lower half—which, being gilt, was electrified and gave the shock—did not exceed two grains; for it appeared, when broke, much thinner than the upper half." . . . . "Allowing that there is no more electrical fire in a bottle after charging than before, how great must be the quantity in this small portion of glass! It seems as if it were of its very substance and essence. Perhaps if that due quantity of electrical fire, so obstinately retained by glass, could be separated from it, it would no longer be glass; it might lose its transparency, or its brittleness, or its elasticity. Experiments may possibly be invented hereafter to discover this." Can we state to-day, in any clearer language, the electrical condition in the Leyden jar?

At the close of this investigation, he writes as follows: "Chagrined a little that we have been hitherto able to produce nothing in this way of use to mankind; and the hot weather coming on, when electrical experiments are not so agreeable, it is proposed to put an end to them for this season somewhat humorously in a party of pleasure on the banks of *Skuylkil.* Spirits, at the same time, are to be fired by a spark sent from side to side through the river, without any other conductor than the water; an experiment which we some time since performed to the amazement of many. A turkey is to be killed for our dinner by the *electrical shock* and roasted by the *electrical jack* before a fire kindled by the electrified bottle; when the healths of all the famous electricians in *England*, *Holland*, *France* and *Germany* are to be drank in *electrified bumpers* under the discharge of guns from the *electrical battery*."

It was in 1749 that Franklin came to the conclusion that lightning and the electrical fire are identical. "To determine the question," he says,* "whether the clouds that contain lightning are electrified or not, I would propose an experiment to be try'd where it may be done conveniently. On the top of some high tower or steeple place a kind of centry box big enough to contain a man and an electrical stand. From the middle of the stand let an iron rod rise and pass, bending, out of the door and then upright twenty or thirty feet, pointed very sharp at the end. If the electrical stand be kept clean and dry, a man, standing on it when such clouds are passing low, might be electrified and afford sparks, the rod drawing fire to him from a cloud. If any danger to the man should be apprehended (though I think there would be none), let him stand on the floor of his box and now and then bring near to the rod the loop of a wire that has one end fastened to the leads, he holding it by a wax handle; so the sparks, if the rod is electrified, will strike from the rod to the wire and not affect him."

On the 10th of May, 1752, M. D'Alibard, the translator of Franklin's letters to Collinson, placed in a garden at Marly, near Paris, a pointed bar of iron, forty feet high, supported upon an electrical base. At twenty minutes past two in the afternoon, a storm cloud passed over the rod, and the observers drew sparks from it and obtained with it all the common electrical phenomena.†

Shortly after, M. DeLor, who had repeated many of Franklin's experiments before the king, Louis XV, raised at his house, in Paris, a bar of iron ninety-nine feet high, placed upon a cake of resin two feet square and three inches thick. On the 18th of May between four and five in the afternoon, a storm cloud passed over the bar, and M. DeLor drew sparks from the bar which produced the same noise, the same fire, and the same crackling; the longest of these sparks being nine lines.

On July 20, Canton erected upon his house in London, a tin tube between three and four feet in length, fixed to the top of a glass one of about eighteen inches. To the upper end of the tin tube, which was not so high as a stack of chimnies on the same

* *New Observations and Experiments on Electricity*, p. 66.

† See the letter of the Abbe Mazeas, *New Experiments and Observations on Electricity*, p. 107.

house, he fastened three needles with some wire; a tin cover being soldered to the lower end to keep the rain from the glass tube, which was set upright in a block of wood. No electrification appeared upon this apparatus during the storm until after the third thunder-clap. Then, on applying his knuckle to the edge of the cover, Canton felt and heard an electrical spark, the length of which was about half an inch; the experiment being repeated four or five times in the space of a minute.

On August 12, Mr. Wilson, of Chelmsford, in Essex, during a thunder-storm, about noon, observed several electrical snaps from an iron curtain rod, one end of which he had put into the neck of a glass phial held in the hand, and to the other end of which he had fastened three needles. The sparks were taken from the rod to the finger of one hand, the other hand supporting the rod.

In communicating these experiments of Canton and Wilson to the Royal Society,* Watson says: "After the communications which we have received from several of our correspondents in different parts of the continent, acquainting us with the success of their experiments last summer in endeavoring to extract the electricity from the atmosphere during a thunder-storm, in consequence of Mr. Franklin's hypothesis, it may be thought extraordinary that no accounts have been yet laid before you of our success here from the same experiments." And he then proceeds to state that, "though several members of the Royal Society, as well as myself, did, upon the first advices from *France*, prepare and set up the necessary apparatus for this purpose," they were defeated in their expectations because of the uncommon coolness and dampness of the air in London; only one thunder-storm, that of July 20, having occurred during the season.

The celebrated kite experiment was made during the summer of 1752, in Philadelphia. Dr. Franklin, himself, thus describes it: "Make a small cross of two light strips of cedar, the arms so long as to reach to the four corners of a large, thin silk handkerchief when extended; tie the corners of the handkerchief to the extremities of the cross, so you have the body of the kite; which, being properly accommodated with a tail, loop and string, will rise in the air like those made of paper; but this, being of silk, is fitter to bear the wet and wind of a thunder gust without tearing. To

* *Phil. Trans.*, xlvii, 1752. See also *New Experiments and Observations on Electricity*, p. 109.

the top of the upright stick of the cross is to be fixed a very sharp-pointed wire, rising a foot or more above the wood. To the end of the twine, next the hand, is to be tied a silk ribbon, and where the silk and twine join a key may be fastened. This kite is to be raised when a thunder gust appears to be coming on, and the person who holds the string must stand within a door or window, or under some cover, so that the silk ribbon may not be wet; and care must be taken that the twine does not touch the frame of the door or window. As soon as any of the thunder clouds come over the kite, the pointed wire will draw the electric fire from them, and the kite, with all the twine, will be electrified, and the loose filaments of the twine will stand out every way and be attracted by an approaching finger. And when the rain has wet the kite and twine so that it can conduct the electric fire freely, you will find it stream out plentifully from the key on the approach of your knuckle. At this key the phial may be charged; and, from electric fire thus obtained, spirits may be kindled and all the other electric experiments be performed which are usually done by the help of a rubbed glass globe or tube, and thereby the sameness of the electric matter with that of lightening completely demonstrated." *

"In September, 1752, I erected an iron rod to draw the lightening down into my house," Franklin writes to Collinson, a year later, "in order to make some experiments on it with two bells, to give notice when the rod should be electrify'd, a contrivance obvious to every electrician. I found the bells rang sometimes when there was no lightning or thunder, but only a dark cloud over the rod; that sometimes, after a flash of lightning, they would suddenly stop, and at other times, when they had not rang before, they would, after a flash, suddenly begin to ring; that the electricity was sometimes very faint, so that when a small spark was obtain'd another could not be got for some time after; at other times the sparks would follow extremely quick; and once I had a continual stream from bell to bell the size of a crow quill. Even during the same gust there were considerable variations." The following winter he charged two phials, one with lightning from the iron rod, the other, equally, by the electric glass globe, and suspended a cork ball between the wires issuing from the top. He observed the cork ball play briskly between them, proving the

**New Experiments and Observations on Electricity*, p. 111. Letter of date October 19, 1752 charge from the clouds to be negative. Subsequent experiments showed that while in general the charge from the clouds is negative, it is sometimes positive.

In 1749, Franklin applied his knowledge of the power of points to the practical protection of buildings. He says: "If those things are so [*i. e.*, 'if the fire of electricity and that of lightning be the same'] may not the knowledge of this power of points be of use to mankind in preserving houses, churches, ships, etc., from the stroke of lightning by directing us to fix on the highest points of those edifices upright rods of iron, made sharp as a needle, and gilt to prevent rusting, and from the foot of those rods a wire down the outside of the building into the ground, or down round one of the shrouds of a ship and down her side till it reaches the water? Would not these pointed rods probably draw the electrical fire silently out of a cloud before it came nigh enough to strike, and thereby secure us from that most sudden and terrible mischief?"

In 1753, Franklin formally recommended that pointed rods be placed on buildings to prevent their being struck by lightning. But the suggestion does not seem to have come very rapidly into favor, since in a subsequent letter to Kinnersley, written from London, in 1762, Franklin says: "You seem to think highly of the importance of this discovery, as do many others on our side of the water. Here it is very little regarded; so little that though it is now seven or eight years since it was made public, I have not heard of a single house as yet attempted to be secured by it."* In 1777, at a meeting of the Royal Society Wilson protested against the pointed conductors of Franklin, and endeavored to prove the superior advantages of knobs to points, and the greater safety to be derived from blunt as compared with sharp lightning conductors. His experiments attracted considerable attention and evoked sharp discussion; and during this discussion "the pointed lightning conductors were taken down from the queen's palace." † They were never replaced, notwithstanding the condemnation of the pretended improvement by the Royal Society in their reports in favor of pointed conductors, and their being consequently generally employed for the protection of the powder magazines throughout the country. On being urged to reply to Wilson's assertions, Franklin

* *New Experiments and Observations on Electricity*, p. 416.
† *Memoirs*, Vol. ii, p. 79.

replied: "I have never entered into any controversy in defense of my philosophical opinions. I leave them to take their chance in the world. If they are *right*, truth and experience will support them; if *wrong*, they ought to be refuted and rejected. Disputes are apt to sour one's temper, and disturb one's quiet. I have no private interest in the reception of my inventions by the world, having never made, nor propose to make, the least profit by any of them. The king's changing his pointed conductors for blunt ones is, therefore, a matter of small importance to me. If I had a wish about it, it would be that he had rejected them altogether as ineffectual. For it is only since he thought himself and family safe from the thunder of heaven that he dared to use his own thunder in destroying his innocent subjects."*

These scientific and political conditions acting together, gave rise to the well-known and pointed epigram:

"While you, Great George, for safety hunt,
And sharp conductors change for blunt,
The empire's out of joint.
Franklin a wiser course pursues,
And all your thunder fearless views
By keeping to the *point*."

It was in recognition of the importance and value of Franklin's electrical investigations that the Royal Society not only elected him a member of that learned body, but also awarded to him the Copley gold medal. †

Of similar interest are Franklin's experiments on the physiologi-

* *Memoirs*, Vol. ii, p 81.

† Franklin's own account of the action of the Royal Society is as follows: "Dr. Wright, an English physician, when at Paris, wrote to a friend who was of the Royal Society an account of the high esteem my experiments were in among the learned abroad, and of their wonder that my writings had been so little noticed in England. The Society on this resumed the consideration of the letters that had been read to them; and the celebrated Dr. Watson drew up a summary account of them and of all I had afterwards sent to England on the subject; which he accompanied with some praise of the writer. This summary was then printed in their Transactions; and some members of the Society in London, particularly the very ingenious Mr. Canton, having verified the experiment of procuring lightning from the clouds by a pointed rod, and acquainted them with the success, they soon made me more than amends for the slight with which they had before treated me. Without my having made any application for that honor, they chose me a member, and voted that I should be excused the customary payments, which would have amounted to twenty-five guineas; and ever since have given me their Transactions gratis. They also presented me with the gold medal of Sir Godfrey Copley for the year 1753, the delivery of which was accompanied by a very handsome speech of the President, Lord Macclesfield, wherein I was highly honored" (*Memoirs*, Vol. i, p. 241).

cal action of the electric discharge. In a letter to the Royal Society he gives an account of these experiments.* "He made first several experiments on fowls, and found that two large, thin glass jars gilt, holding each about six gallons, were sufficient, when fully charged, to kill common hens outright; but the turkeys, though thrown into violent convulsions, and then lying as dead for some minutes, would recover in less than a quarter of an hour. However, having added three other such to the former two, though not fully charged, he killed a turkey of about ten pounds weight, and believes that they would have killed a much larger. He conceited, as himself says, that the birds killed in this manner eat uncommonly tender." "In making these experiments he found that a man could, without great detriment, bear a much greater shock than he had imagined; for he inadvertently received the stroke of two of these jars through his arms and body, when they were very nearly fully charged. It seemed to him an universal blow throughout the body from head to foot, and was followed by a violent, quick trembling in the trunk, which went off gradually in a few seconds. It was some minutes before he could recollect his thoughts, so as to know what was the matter; for he did not see the flash, though his eye was on the spot of the prime conductor from whence it struck the back of his hand; nor did he hear the crack, though the bystanders said it was a loud one; nor did he particularly feel the stroke on his hand, though he afterward found it had raised a swelling there of the bigness of half a pistol bullet. His arms and the back of the neck felt somewhat numbed the remainder of the evening, and his breast was sore for a week after, as if it had been bruised. From this experiment may be seen the danger, even under the greatest caution, to the operator, when making these experiments with large jars, for it is not to be doubted but several of these fully charged would as certainly, by increasing them in proportion to the size, kill a man as they before did a turkey."

With reference to the practical application of these experiments, Franklin subsequently wrote the following letter to MM. Dubourg and D'Alibard: † "My answer to your questions concerning the mode of rendering meat tender by electricity, can only be founded upon conjecture; for I have not experiments enough to warrant the

* *New Experiments and Observations*, p. 253.
† *Memoirs*, Vol. vi, p. 228.

facts. All that I can say at present is that I think electricity might be employed for this purpose; and I shall state what follows as the observations or reasons which make me presume so. It has been observed that lightning by rarefying and reducing into vapor the moisture contained in solid wood, in an oak for instance, has forcibly separated its fibres and broken it into small splinters; that by penetrating completely the hardest metals, as iron, it has separated the parts in an instant so as to convert a perfect solid into a state of fluidity; it is not then improbable that the same subtile matter passing through the bodies of animals with rapidity should possess sufficient force to produce an effect nearly similar.

"The flesh of animals killed in the usual manner is firm, hard, and not in a very eatable state because the particles adhere too forcibly to each other. At a certain period the cohesion is weakened, and in its progress towards putrefaction, which tends to produce a total separation, the flesh becomes what we call tender, or is in that state most proper to be used as our food.

"It has frequently been remarked that animals killed by lightning putrefy immediately. This cannot be invariably the case, since a quantity of lightning sufficient to kill may not be sufficient to tear and divide the fibres and particles of flesh, and reduce them to that tender state which is the prelude to putrefaction. Hence it is that some animals killed in this manner will keep longer than others. But the putrefaction sometimes proceeds with surprising celerity. A respectable person assured me that he once knew a remarkable instance of this. A whole flock of sheep in Scotland being closely assembled under a tree, were killed by a flash of lightning; and it being rather late in the evening, the proprietor, desirous of saving something, sent persons early the next morning to flay them; but the putrefaction was such and the stench so abominable that they had not the courage to execute their orders, and the bodies were accordingly buried in their skins. It is not unreasonable to presume that between the period of their death and that of their putrefaction a time intervened in which the flesh might be only tender, and only sufficiently so to be served at table. Add to this that persons who have eaten of fowls killed by our feeble imitation of lightning (electricity) and dressed immediately, have asserted that the flesh was remarkably tender. . . . .

"As this kind of death is nevertheless more sudden and consequently less severe than any other, if this should operate as a motive with compassionate persons to employ it for animals sacrificed for their use, they may conduct the process thus:

"Having prepared a battery of six large glass jars (each from twenty to twenty-four pints) as for the Leyden experiment, and having established a communication as usual from the interior surface of each with the prime conductor; and having given them a a full charge (which, with a good machine, may be executed in a few minutes, and may be estimated by an electrometer), a chain which communicates with the exterior of the jars must be wrapped round the thighs of the fowl; after which the operator, holding it by the wings turned back and made to touch behind, must raise it so high that the head may receive the first shock from the prime conductor. The animal dies instantly. Let the head be immediately cut off to make it bleed, when it may be plucked and dressed immediately. This quantity of electricity is supposed sufficient for a turkey of ten pounds weight, and perhaps for a lamb. Experience alone will inform us of the requisite proportions for animals of different forms and ages. Probably not less will be required to render a small bird which is very old tender than for a larger one which is young. It is easy to furnish the requisite quantity of electricity by employing a greater or less number of jars. As six jars, however, discharged at once are capable of giving a very violent shock, the operator must be very circumspect lest he should happen to make the experiment on his own flesh instead of that of the fowl."

Franklin's experiments upon the effect of the electric discharge upon the human subject he thus describes in a letter to a friend in Charleston, S. C., written in 1755:* "The knocking down of the six men was performed with two of my large jars not fully charged. I laid one end of my discharging rod upon the head of the first; he laid his hand on the head of the second; the second his hand on the head of the third; and so to the last, who held in his hand the chain that was connected with the outside of the jars. When they were thus placed, I applied the other end of my rod to the prime conductor and they all dropt together. When they got up they all declared they had not felt any stroke, and wondered how they came to fall; nor did any of them either hear the crack or see the light of it. You suppose it is a dangerous experiment; but I had once suffered the same myself, receiving by accident an equal stroke

* Letters and Papers on Philosophical Subjects. *New Experiments and Observations on Electricity*, p. 324.

through my head that struck me down without hurting me. And I had seen a young woman that was about to be electrified through the feet (for some indisposition) receive a greater charge through the head by inadvertently stooping forward to look at the placing of her feet, till her forehead (as she was very tall) came too near my prime conductor: She dropt, but instantly got up again complaining of nothing. A person so struck sinks down doubled or folded together as it were, the joints losing their strength and stiffness at once, so that he drops on the spot where he stood, instantly, and there is no previous staggering, nor does he ever fall lengthwise. Too great a charge might indeed kill a man, but I have not yet seen any hurt done by it. It would certainly, as you observe, be the easiest of all deaths."

If the condition of electrostatic science when the American Philosophical Society was founded was as primitive as we have above pointed out, that of the other departments of electricity was far more so. Galvani had not observed the twitching of the frog's legs as, suspended by a copper wire, they swung to and fro against the iron railing of his laboratory balcony. Volta had not made his important discovery that the contact of two metals developed electrification; and hence had not at this time constructed his celebrated pile. True, metals had been fused by the discharge of the electric battery, needles had been magnetized by it, and animals had been shocked and even killed by it, as in the experiments made by Franklin and others soon after 1743. But now various other modes of electrification were to be discovered and coördinated and the identity of the result, by whatsoever means obtained, was to be experimentally established.

Among the members of this Society whose names appear prominent as investigators in these new fields we should mention Robert Hare, Joseph Henry, Joseph Saxton, David Rittenhouse and Alexander Dallas Bache.

Robert Hare was elected a member of the American Philosophical Society in 1803. In 1821 he published an important paper "On Some New Modifications of Galvanic Apparatus." * In this paper he states that he had observed that, while the maximum effect of a single galvanic pair was reached as soon as the plates were immersed in the liquid, a series of troughs which had to be succes-

* *Amer. Jour. Science and Arts*, iii, 105, 1821.

sively immersed never reached their maxima together, the effect of the earlier ones being lost before that of the later ones came on. In order to remedy this difficulty, he prepared eighty concentric coils of copper and zinc plates and attached them to a system of levers so that they could be simultaneously immersed. The zinc sheets were nine inches by six in size, and the copper sheets fourteen inches by six, a quarter of an inch interval being left between them. Each pair, as rolled up, was two and a half inches in diameter, and eighty glass jars were arranged to receive the eighty coils of plates when they were lowered. A piece of charcoal a quarter of an inch thick and one and a half inches long was inserted between the ends of the lead pipes which served as conductors. On lowering the plates "no vestige of the charcoal could be seen. It was ignited so intensely that those portions of the pipes by which it had been embraced were destroyed."

He then had a trough constructed having a partition through the middle. In this trough he placed the eighty coils, forty of them being on each side of the partition. Although, when in action, this battery produced only a moderate sensation, and did not ignite charcoal as easily, a most intense ignition took place whenever a metallic point on one pole was brought in contact with a piece of charcoal on the other. And when a cylinder of platinum, nearly a quarter of an inch in diameter and tapering a little at the end, was placed in the circuit, it was at once fused and burned so as to sparkle to a considerable distance around and to fall in drops. When the two troughs were separated by an interval of four inches, so as to improve the insulation, charcoal was so vividly ignited that the eyes of the experimenter were affected for forty-eight hours, the charcoal assuming a pasty consistence.

In accordance with the theory which he had propounded in 1818,* Dr. Hare explained these differences in effect by the hypothesis that the fluid extricated by Volta's pile is a compound of caloric and electricity. According to this theory, "the galvanic fluid," he says, "owes its properties to caloric and electricity, the former predominating in proportion to the size of the pairs, the latter in proportion to the number, being in both cases excited by a powerful acid. Hence in batteries which combine both qualifications sufficiently, as in all those intervening between Children's large

* *Amer. Jour. Science and Arts*, i, 413, 1818.

pairs of two feet eight inches by six feet and the two thousand four-inch pairs of the Royal Institution, the phenomena indicate the presence of both fluids. In De Luc's column, where the size of the plates is insignificant and the energy of interposed agents feeble, we see electricity evolved without any appreciable quantity of caloric. In the calorimotor, where we have size only, the number being the lowest possible, we are scarcely able to detect the presence of electricity. When the fluid contains enough electricity to give a projectile power adequate to pass through a small space in the air, or through charcoal, which impedes or arrests the caloric and favors its propensity to radiate this principle, heat is evolved. This accounts for the evolution of intense heat under those circumstances which rarefy the air, so that the length of the jet from one pole to the other may be extended after its commencement. Hence, the portions of the circuit nearest to the intervening charcoal or heated space are alone injured; and even non-conducting bodies, as quartz, introduced into it are fused, and hence a very large wire may be melted by the fluid received through a small wire imperceptibly affected."

To these two forms of galvanic generators, which differed as materially in the effects which they produced as they did in their construction, Dr. Hare gave the names "calorimotor" and "deflagrator." The calorimotor was constructed first in 1818. He was led to this form of instrument by reflecting that, "as the number of pairs in Volta's pile had been extended, and their size and the number and energy of interposed agents lessened, the ratio of the electrical effects to those of heat had increased till, in De Luc's column, they had become completely predominant; and, on the other hand, when the pairs were made larger and fewer (as in Children's apparatus) the calorific influence had gained the ascendency; he was, therefore, led to go farther in this way and to examine whether one pair of plates of common size, or what might be equivalent thereto, would not exhibit heat more purely and demonstrate it to be, equally with the electric fluid, a primary product of Galvanic combinations."* This conception he put into practice by constructing a single galvanic pair, consisting of twenty copper plates, each about nineteen inches square, all soldered to the same metallic bar, so as to constitute, electrically, a single copper plate,

* *Amer. Jour. Science and Arts*, i, 416, July, 1818.

alternating, at intervals of half an inch, with twenty similar zinc plates, all united to another metallic bar. He found, on immersing these plates in the same portion of acid contained in a vessel without partitions, that, while a wire connecting the poles was intensely ignited, only a slight taste was produced on the tongue, not greater than that produced by a piece of silver and one of zinc an inch square. Hence he concluded that when the plates are arranged without alternation the effect is no greater than might be expected from one pair of plates. He then caused ten of the zinc plates on the one side to be connected with ten of copper on the other, the ten remaining plates of the same name on each side being connected with each other; the connection between these large plates, one of copper and the other of zinc, being effected by a wire. When these two alternating pairs were plunged in acid, in a common vessel without partitions, the wire became vividly ignited. Substantially, this arrangement was adopted in the construction of a large calorimotor ordered by Prof. Silliman for the laboratory of Yale College and made under Dr. Hare's direction. The plates were eighteen inches square; nine of zinc, on one side, alternated with ten of copper, and ten of zinc, on the other side, alternated with eleven of copper; the entire forty plates having in all ninety square feet of surface. The plates of the same name were connected by large bars of tin, the whole being supported on a balanced frame so as to be lowered readily into a cubical box without partitions. "This instrument," says Prof. Silliman, "gives no shock, produces no chemical decompositions, and does not move the gold-leaf electrometer, nor does it ignite charcoal points, however small, although in close contact, or strike through the smallest layer of air to pass even to the best conductor. But when any metallic substance with a bright surface is brought into perfect contact, by screwing it firmly into the jaws of the vices that terminate its poles, and the plates are then immersed in the acid, intense ignition follows and combustion also, if the metal is combustible in common air. Platinum wire is instantly ignited and melted, a large steel knitting needle is destroyed before the plates are half immersed, and, by a full immersion, iron nails of the size called ninepenny and tenpenny are ignited and burn vividly till the connection is destroyed by burning in two."* Further, it was observed that the calorimotor produced fine magnetic effects.

* *Elements of Chemistry*, Vol. ii, p. 670, New Haven, 1831.

The deflagrator of Dr. Hare was first described in 1821,* and as above mentioned consisted of eighty concentric coils of copper and zinc, each coil having its glass jar of acid; the coils being attached to a common beam which was raised and lowered by means of levers. Subsequently he adopted the form of flat, hollow, copper cases into which the zinc plates were made to slide, being secured in their places and prevented from actual contact with the copper by grooved pieces of wood which receive the edges of the zinc and rest against the inside of the copper cases; each zinc plate being connected to the next copper case by a metallic strip. These cases were supported in frames and well insulated from one another, these frames being movable and capable of being lowered into the troughs containing the acid, or being stationary, and the troughs raised in order to immerse the plates. This construction was the one adopted in the deflagrator made by Dr. Hare for the laboratory of Yale College. In his last form of instrument, called the Cruikshank deflagrator, the copper and zinc plates, soldered together in pairs at their edges, were fixed in a box supported on pivots; so that by rotating it through 90°, the acid surrounding the plates flowed into a second and similar box attached to the first and at right angles to it. By reversing the motion the acid flowed again upon the plates.† "Both in producing ignition and combustion," says Prof. Silliman, "the deflagrators far surpass any other form of galvanic instruments. Combustion is exceedingly vivid; the metallic leaves vanish in splendid coruscations; a platinum wire several feet in length fixed between the poles while the metals are in the air becomes red and white hot, and melts the instant they are immersed; the largest wire of this metal fixed in one pole and touched to charcoal in the other, melts like wax in a candle and is dissipated in brilliant scintillations; a watch-spring or a large steel knitting-needle fixed in the same manner and touched to the charcoal point burns completely away with a torrent of light and sparks; a stream of mercury flowing from a funnel is deflagrated with brilliant light, and an iron wire is fused and welded to another under water." ‡ It was with this instrument that Prof. Silliman, in 1821, observed for the first time the transfer of the carbon from the positive to the negative pole, this carbon rapidly collecting on the negative side into a

* *Amer. Jour. Science and Arts*, Vol, iii, p. 105, 1821.

† *Amer. Jour. Science and Arts*, Vol. vii, 347 (1824); Vol. xxxii, 285 (1837).

‡ *Elements of Chemistry*, Vol. ii, p. 672. 1831.

knob or projecting cone or cylinder, which frequently becomes half an inch or more long before it falls and gives place to another. On the positive pole a corresponding cavity is formed, out of which the vaporized matter rises and collects upon the negative pole. The carbon thus deposited "is in shining, rounded masses, aggregated often like a cauliflower. It has a semi-metallic appearance, is harder than the charcoal, heavier, much less combustible, and burns away slowly when ignited in the air."

In the light of the electrical science of those days, these constructions by Dr. Hare, the results obtained by their means and the theories which he offered in explanation of the phenomena, are all of very considerable interest. The principal effect of the calorimotor, obviously, was to produce a great flow of heat with very little electrical excitement. But experiment had pointed out that not only alternation of the plates but a repetition of the pairs to at least two was necessary to produce an intense calorific effect; the quantity being as the size and the intensity as the number of the series. True, Davy had shown in 1808 this necessity of repetition, and had stated that "the intensity increases with the number and the quantity with the extent of the series." * And Children the following year † had confirmed this view and elaborated it. "The absolute effect of a voltaic apparatus," he says, "seems to be in the compound ratio of the number and size of the plates, the intensity of the electricity being as the former, the quantity given out as the latter; consequently regard must be had in its construction to the purposes for which it is designed. For experiments on perfect conductors very large plates are to be preferred, a small number of wicks will probably be sufficient; but where the resistance of imperfect conductors is to be overcome the combination must be great but the size of the plates may be small; but if quantity and intensity be both required, then a large number of large plates will be necessary." It should be remembered, moreover, that the law of Ohm was not enunciated until 1827,‡ and that of Joule not until 1841.§ And, further, that we owe to these laws the simplification of the ideas upon the subject of the energy relations of electricity which existed before they were discovered. Ohm's law teaches us that the

* *Philosophical Transactions*, 1808, p. 3.

† *Ib.*, Vol. ix, p. 32 (1809).

‡ *Die galvanische Kette mathematisch bearbeitet*, Berlin, 1827.

§ *Phil. Mag.*, xix, p. 260 (1841).

current which flows through any circuit depends directly upon the electromotive forces contained in the circuit and inversely upon the resistances of the circuit. Evidently, therefore, when a considerable resistance is to be overcome, as when a long, fine wire is in circuit, the current necessary to fuse this wire, for example, can be secured only by increasing proportionately the electromotive force, *i. e.*, by increasing the number of pairs in series in the battery. While, when the external resistance is small, as is the case when a large metallic wire joins the terminals, very little electromotive force, and therefore only a few pairs, is required ; but by making the plates large the resistance of the battery is diminished, and so the current in the entire circuit is increased. In the deflagrator then, the result was attained by increasing the number of the plates in order to secure a high electromotive force. In the calorimotor the size was increased in order to decrease the total resistance and so to increase the current. Again, the law of Joule gives us the relation between the amount of current flowing through a circuit and the development of heat in it ; asserting that the heat thus developed is directly proportional to the resistance in the circuit and to the square of the current. Consequently the heating effects of Dr. Hare's calorimotor are due to the large current which it was the object of its construction to produce. While in the deflagrator, although the current is less, and therefore the total heating effect is less also, yet the current is urged by a greater pressure and hence exerts a greater disruptive effect. Another point should be noted in connection with these distinctions thus emphasized in Dr. Hare's generators. Electrical energy may be represented by the product of the current and the electromotive force. To transmit a given amount of this energy to a distance, either a strong current having a low electromotive force may be employed, or a weak current having a high electromotive force, provided the product be the same in both cases. But by the law of Joule, the energy dissipated as heat, being proportional to the square of the current, would entail a serious loss in the former case. Hence the economical transmission of electrical energy requires the use of generators developing a high electromotive force.

Joseph Henry became a member of the American Philosophical Society in 1835, although it was ten years earlier than this that he began his electrical researches at the Albany Academy. Oersted, in 1819,* had observed the tendency of a magnetic needle to place itself perpendicular to a wire conveying an electrical current. Ampère† had studied the mutual action of currents upon each other, and had thus created the science of electrodynamics. Schweigger had multiplied the number of convolutions of the wire about the needle, increasing proportionately in this way the effect.‡ Arago had succeeded in producing magnetism from an electrical current by winding the wire carrying this current in a loose helix and placing pieces of iron wire in the axis of this helix; thus creating the "electromagnet."§ Sturgeon had further developed this idea by coating the iron bar, which was bent into a horseshoe form, with a non-conducting substance, and winding the wire directly on the bar, thus increasing the closeness of the contact.|| Henry's first paper in electric science was a communication made to the Albany Institute, October 10, 1827, "On Some Modifications of the Electromagnetic Apparatus."¶ In this paper he suggested several improvements in the construction of the electromagnet, which greatly increased its efficiency. In the first place he adopted the multiple arrangement of turns proposed by Schweigger in his galvanometer; and in the second, instead of insulating the bar to be magnetized, he insulated the conducting wire itself, covering the whole surface of the iron with a series of coils in close contact. Sturgeon's electromagnet of 1825 consisted of a stout iron wire bent into a U form, having a copper wire wound loosely round it, forming eighteen turns. Henry's electromagnet of 1829 was made of a piece of round iron about one-quarter of an inch in diameter, bent into the form of a horseshoe, and tightly wound with thirty-five feet of wire covered with silk, forming about four hundred turns. Later in the same year, Henry still further increased the power of his electromagnet, by winding the wire upon the iron core, not in a single strand, but in several; the current flowing simultaneously through the different strands. Using a U-shaped bar of iron, half an inch in diameter and about ten inches long, wound with thirty feet of tolerably fine copper wire, he observed that with a cell containing two and

* *Schweigger, J.*, xxix, 273, 1820; *Gilb. Ann.*, lxvi, 295, 1820.

† *Ann. Chim. Phys.*, xv, 59, 170, 1820; xviii, 88, 313, 1821; xxvi, 390, 1824.

‡ *Allgem. Literaturzeitung*, No. 296, Nov., 1820; *Schweigg., J.*, xxxi, 12, 1826.

§ *Ann. Chim. Phys.*, xv, 93 (1820).

|| *Trans. Soc. Encour. Arts*, xliii, 38 (1825).

¶ *Trans. Albany Institute*, Vol. i, pp. 22, 23 (1827).

a half square inches of zinc surface, this magnet would sustain fourteen pounds. He then wound upon the core a second and similar wire, the ends of which were connected to the same cell; and now the magnet lifted twenty-eight pounds. With a single pair of plates 4 x 6 inches this magnet lifted thirty-nine pounds, or more than fifty times its own weight. This increase of power by multiplying the number of wires without increasing the length of each, as Henry points out, produces its effect in two ways: "first, by conducting a greater quantity of galvanism, and secondly, by giving it a more proper direction."* Thus was constructed what Henry called his "quantity" magnet.

Still larger electromagnets were constructed upon this plan in 1830 and 1831. The former magnet consisted of a bar of soft iron two inches square and twenty inches long, bent into the form of a horseshoe, and weighing twenty-one pounds. Around this was wound five hundred and forty feet of copper wire arranged in nine coils of sixty feet each; each strand being coiled in several layers, and occupying about two inches of the length of the core. The ends of these coils being left separate and numbered, the coils could be combined in any way desired so as to form one continuous coil, or a double coil of half the length, a triple coil one-third the length, etc. When a single pair of coils were put in series the electromagnet lifted sixty pounds; but when the coils were arranged in multiple, forming a double circuit, a lifting power of two hundred pounds was developed. The cell used with this magnet was composed of two concentric cylinders of copper, having a zinc cylinder between them; the exposed zinc surface being about 0.4 square foot, and the acid required about half a pint. With all the coils in parallel the magnet with this battery lifted six hundred and fifty pounds; and with a pair of plates exactly an inch square the magnet lifted eighty-five pounds.†

The 1831 magnet was made for the laboratory of Yale College.‡ The iron horseshoe was about a foot in length, and was made from a bar of octagonal iron three inches in diameter. It was wound with twenty-six strands of copper wire, each about twenty-eight feet

* *Am. Jour. Science and Arts*, xix, 402, Jan., 1831.

† *Am. Jour. Science and Arts*, xix, 404, 405, 1831. See also the excellent memorial address on "The Scientific Work of Joseph Henry," delivered before the Philosophical Society of Washington, Oct. 26, 1878, by Wm. B. Taylor, to which the author would here acknowledge his indebtedness. *Bull. Phil. Soc., Washington*, Vol. ii, p. 230.

‡ *Am. Jour. Science and Arts*, xx, 201, April, 1831.

long. With a single cell of the construction just described, and exposing about five feet of active zinc surface, this magnet lifted twenty-three hundred pounds. It was of this magnet that Sturgeon himself wrote thus: "By dividing about eight hundred feet of conducting wire into twenty-six strands, and forming it into as many separate coils around a bar of soft iron about sixty pounds in weight, and properly bent into a horseshoe form, Prof. Henry has been enabled to produce a magnetic force which completely eclipses every other in the whole annals of magnetism; and no parallel is to be found since the miraculous suspension of the celebrated Oriental impostor in his iron coffin."*

In his "quantity" magnet Henry sought to reduce the resistance to a minimum, and so to obtain a very considerable current even from a very small pair of plates. But he perceived that this was not the whole truth. And in January, 1831, he published a remarkable paper † in which he showed for the first time that a coil composed of several short circuits in parallel, while least effective with a battery of many pairs of plates, was most responsive, on the contrary, to a single voltaic cell; and, on the other hand, that a coil whose parts were all in series, which produced only trifling effects with a single pair, was highly effective with a battery of many pairs. Employing for example a small electromagnet having a core of quarter inch iron wound with about eight feet of copper wire, Henry found that with a single zinc plate, exposing about fifty-six square inches of surface, this magnet lifted four and one-half pounds. On interposing five hundred feet of copper wire between the magnet and the cell it lifted only two ounces; and with one thousand feet interposed only half an ounce. On using a trough battery of twenty-five pairs of plates, on the other hand, the zinc surface exposed being the same as before, the magnet lifted only seven ounces when directly connected. But when the one thousand feet of wire was interposed the magnet sustained eight ounces. In other words, the current from the battery produced a greater magnetic effect after traversing this length of wire than it did without it. He calls an electromagnet having its coil continuous in length an "intensity" magnet; and he says: "In describing the results of my experiments, the terms 'intensity' and 'quantity' magnets were introduced to avoid circumlocution, and

* *Phil. Mag. and Annals of Philosophy*, xi, 199, March, 1832.

† *Am. Jour. Science and Arts*, xix, 400, Jan., 1831.

were intended to be used merely in a technical sense. By the *intensity* magnet I designated a piece of soft iron so surrounded with wire that its magnetic power could be called into operation by an 'intensity' battery, and by a *quantity* magnet a piece of iron so surrounded by a number of separate coils that its magnetism could be fully developed by a 'quantity' battery."* Clearly, therefore, we owe to Henry the credit of having first worked out practically the functions of two entirely different kinds of electro-magnets; one having several separate coils of no great length, designated as a "quantity" magnet, the other provided with a continuous coil of very considerable length, designated as an "intensity" magnet. "The latter and feebler system (requiring for its action a battery of numerous elements) was shown to have the singular capability (never before suspected or imagined) of subtle excitation from a distant source. Here for the first time is experimentally established the important principle that there must be a proportion between the aggregate internal resistance of the battery and the whole external resistance of the conjunctive wire or conducting circuit; with the very important practical consequence that by combining with an 'intensity' magnet of a single extended fine coil an 'intensity' battery of many small pairs, its electro-motive force enables a very long conductor to be employed without diminution of the effect. This was a very important though unconscious experimental confirmation of the mathematical theory of Ohm, embodied in his formula expressing the relation between electric flow and electric resistance, which, though propounded two or three years previously, failed for a long time to attract any attention from the scientific world."†

The practical outcome of these experiments was a most important one. Although Ampère, at the suggestion of Laplace, had examined the question and had shown the possibility of making a telegraph by deflecting a needle through a long length of conducting wire, yet further experiments by Barlow proved that lengthening the conducting wire did actually produce a diminution of the effect. Even with only two hundred feet of wire he found such a sensible diminution as to convince him of the impracticability of the scheme. From Henry's experiment just described, however, "it appears that

* *Smithsonian Report* for 1857, p. 103.

† W. B. Taylor's address, Memorial of Joseph Henry, published by order of Congress, Washington, 1880, p. 227.

the current from a galvanic trough is capable of producing greater magnetic effect on soft iron after traversing more than one-fifth of a mile of intervening wire than when it passes only through the wire surrounding the magnet." In speculating on a result apparently so paradoxical, Henry suggests that the "current from a trough possesses more 'projectile' force (to use Prof. Hare's expression) and approximates somewhat in 'intensity' to the electricity from the common machine." "But be this as it may," he concludes, "the fact that the magnetic action of a current from a *trough* is at least not sensibly diminished by passing through a long wire is directly applicable to Mr. Barlow's project of forming an electromagnetic telegraph; and it is also of material consequence in the construction of the galvanic coil. From these experiments it is evident that in forming the coil we may either use one very long wire or several shorter ones, as the circumstances may require; in the first case, our galvanic combination must consist of a number of plates so as to give 'projectile' force; in the second, it must be formed of a single pair." *

In 1832, Henry described the production of electrical effects from the action of magnets.† Having wound upon the middle of the soft iron armature of his large electromagnet an insulated copper wire about thirty feet long, he observed that whenever the magnet was charged by the battery current a deflection of about 30° to the west took place on a galvanometer connected with the ends of this wire. This deflection was but momentary, however, the needle returning to zero, although the magnet remained excited. On opening the circuit, a momentary deflection to the east took place. "From the foregoing facts," he says, "it appears that a current of electricity is produced for an instant in a helix of copper wire surrounding a piece of soft iron whenever magnetism is induced in the iron, and a current in an opposite direction when the magnetic action ceases; also that an instantaneous current in one or the other direction accompanies every change in the magnetic intensity of the iron."

It was while engaged in these experiments that Henry observed the phenomena due to the induction of one portion of the wire upon another, now called "self-induction." He says: "When a small battery is moderately excited by diluted acid, and its poles

* *Amer. Jour. Science and Arts,* xix, 403, 404, Jan., 1831.

† *Amer. Jour. Science and Arts,* xxii, 403, July, 1832.

(which should be terminated by cups of mercury) are connected by a copper wire not more than a foot in length, no spark is perceived when the connection is either formed or broken; but if a wire thirty or forty feet long be used (instead of the short wire) though no spark will be perceptible when the connection is made, yet when it is broken by drawing one end of the wire from its cup of mercury, a vivid spark is produced." "The effect appears somewhat increased by coiling the wire into a helix; it seems also to depend in some measure on the length and thickness of the wire. I can account for these phenomena only by supposing the long wire to become charged with electricity which by its reaction on itself projects a spark when the connection is broken."*

In 1875, at the meeting of the National Academy in Philadelphia, I showed to Professor Henry the large electromagnet then recently acquired by the University of Pennsylvania. I asked him to place one of his hands upon one of the magnet-terminals, and then, holding the conductor in the other, to break the circuit. He did so, and, naturally, received a decided shock. He looked at me rather reproachfully, as I thought, for the advantage I had taken of him. "Pardon me, Professor Henry," I said, "but I desired to introduce to you one of your own children. He was a little fellow when you knew him and was quite unable to assert himself. But now he has grown to man's estate and is capable, as you see, of dealing a pretty vigorous blow." With a genial smile, he granted me complete absolution.

One of the most important of Henry's investigations, made after he removed to Princeton, was his research on successive induction, an account of which was published in the *Proceedings of the Amer. Philos. Soc.* for November, 1838. In this research he employed five annular spools of different sizes of fine wire (about one-fiftieth of an inch thick) varying from one-fifth of a mile to nearly a mile in length (which might be called intensity helices); and six flat spiral coils of copper ribbon, varying from three-quarters of an inch to one inch and a half in width and from sixty to ninety-three feet in length (which might be called "quantity" coils). "With the single larger ribbon coil in connection with the battery, and another ribbon coil placed over it, resting on an interposed glass plate, at every interruption of the primary circuit an induction spark was obtained at the rubbed ends of the second coil, though

* *Amer. Jour. Science and Arts*, xxii, 408, July, 1832.

the shock was feeble. With a double wire spool (one within the other) of 2650 yards, placed above the primary coil (having about the same weight as the copper ribbon), the magnetizing effects disappeared, the sparks were much smaller, 'but the shock was almost too intense to be received with impunity.'" * Evidently, the induced secondary in this case was a current of great "intensity" and of proportionately small "quantity." Hence these experiments showed that it is possible to induce an intensity current from one of quantity and a quantity current from one of intensity, a principle underlying our modern induction coils and transformers.

Further, Henry used the secondary induced current as an initial current, and so induced from it a tertiary current. "By connecting the secondary coil with another at some distance from the primary, so as not to be influenced by it directly, but forming, with the secondary, a single closed circuit, not only was the distant coil capable of producing, in an insulated wire helix placed over it, a distinct current of induction at the interruption of the primary, but sensible shocks were obtained from it." "By a similar but more extended arrangement, shocks were received from currents of a fourth and a fifth order; and, with a more powerful primary current and additional coils, a still greater number of successive inductions might be obtained." "It was found that, with the small battery, a shock could be given from the current of the third order to twenty-five persons joining hands; also shocks perceptible in the arms were obtained from a current of the fifth order." † As Henry, himself, remarks, "The induction of currents of different orders of sufficient intensity to give shocks could scarcely have been anticipated from our previous knowledge of the subject." By ingeniously introducing a small magnetizing helix into each circuit, Henry found that the direction of these successive currents was alternately reversed with reference to each other.

It was while endeavoring to repeat these successive inductions by means of ordinary electricity that Henry was led to one of his most important discoveries. His apparatus consisted of an open glass cylinder, about six inches in diameter, provided with two long narrow strips of tin foil pasted around it in corresponding heliacal courses, one of these strips being on the outside and the other on the inside, directly opposite to the first. The extremities of the inner

* *Memorial of Professor Henry*, p. 247.

† *Trans. Amer. Philos. Soc.*, Vol. vi (N. S.), p. 303, 1838.

strip were connected to a small magnetizing helix, while the ends of the outer strip were arranged so that the discharge of a half-gallon Leyden jar could be passed through the strip. The magnetization of a needle in the helix indicated an induced current through the inner tin-foil ribbon, and the direction of this magnetization showed the direction of this current. By means of a second and a third cylinder, provided with heliacal tin-foil ribbons, Henry was able to show the production of induced currents of the third and even of the fourth order.

While the results in general were quite similar to those obtained with the voltaic current, a puzzling difference was observed with reference to the direction of the currents of the different orders, as shown by the magnetized needles. "These currents," he says, "in the experiments with the glass cylinders, instead of exhibiting the alternations of the galvanic currents, were all in the same direction as the discharge from the jar; or, in other words, they were all plus." By suitably varying the experiments, the direction of the induced currents was found to depend notably on the distance between the conductors, the induction ceasing at a certain distance (depending upon the amount of the charge and the character of the conductors), and the direction of the induced current beyond this critical distance being contrary to that of the primary current. "With a battery of eight half-gallon jars," he says, "and parallel wires about ten feet long, the change in direction did not take place at a less distance than from twelve to fifteen inches, and, with a still larger battery and longer conductors, no change was found, although the induction was produced at the distance of several feet." Using Dr. Hare's battery of thirty-two one-gallon jars and a copper wire about one-tenth of an inch thick and eighty feet long, stretched across the lecture room and back on either side towards the battery, a second wire stretched parallel with the former for about thirty-five feet and extended to form an independent circuit (its ends connected with a small magnetizing helix) was tested at varying distances, beginning with a few inches until they were twelve feet apart; at which distance the induction in this parallel wire, though enfeebled, still indicated, by its magnetizing power, a direction corresponding with the primary current.*

Continuing his researches in this direction, Henry presented a paper to the American Philosophical Society, in June, 1842, giving

* *Trans. Amer. Philos. Soc.*, vi (N. S.), Art. ix, p. 303, 1838.

an account of these anomalies in electrical induction and the results of his investigation of them. While, with the larger needles subjected to the magnetizing helix, the polarity was always conformable to the direction of the discharge, he found that when very fine needles were employed an increase in the force of the electricity produced changes of polarity. In these researches not less than a thousand needles were magnetized in the testing helices. This perplexing phenomenon was finally cleared up by the important discovery that an electrical equilibrium was not instantaneously effected by the spark, but that it was attained only after several oscillations of the flow.

In a recent lecture before the Royal Institution of Great Britain, Dr. Oliver Lodge says, in speaking of the oscillatory character of a Leyden jar discharge: * "It was first clearly realized and distinctly stated by that excellent experimentalist, Joseph Henry, of Washington, a man not wholly unlike Faraday in his mode of work, though doubtless possessing to a less degree that astonishing insight into intricate and obscure phenomena; wanting also in Faraday's circumstantial advantages. This great man arrived at a conviction that the Leyden jar discharge was oscillatory by studying the singular phenomena attending the magnetization of steel needles by a Leyden jar discharge, first observed in 1824 by Savary. Fine needles when taken out of the magnetizing helices were found to be not always magnetized in the right direction, and the subject is referred to in German works as 'anomalous magnetization.' It is not the magnetization which is anomalous, but the currents which have no simple direction; and we find in a memoir published by Henry in 1842 the following words:

"'This anomaly, which has remained so long unexplained, and which at first sight appears at variance with all our theoretical ideas of the connection of electricity and magnetism, was, after considerable study, satisfactorily referred by the author to an action of the discharge of the Leyden jar which had never before been recognized. The discharge, whatever may be its nature, is not correctly represented (employing for simplicity the theory of Franklin) by the single transfer of an imponderable fluid from one side of the jar to the other; the phenomenon requires us to admit the existence of a principal discharge in one direction and then several reflex actions backwards and forwards, each more feeble than the preceding, until

* *Modern Views of Electricity*, p. 369, London and New York, 1889.

the equilibrium is obtained. All the facts are shown to be in accordance with this hypothesis, and a ready explanation is afforded by it of a number of phenomena which are to be found in the older works on electricity, but which have until this time remained unexplained.' " *

Dr. Lodge continues: "If this were an isolated passage it might be nothing more than a lucky guess. But it is not. The conclusion is one at which he arrives after a laborious repetition and serious study of the facts, and he keeps the idea constantly before him when once grasped and uses it in all the rest of his researches on the subject. The facts studied by Henry do, in my opinion, support his conclusion, and if I am right in this, it follows that he is the original discoverer of the oscillatory character of a spark, although he does not attempt to state its theory. That was first done, and completely done, in 1853, by Sir William Thomson; and the progress of experiment by Feddersen, Helmholtz, Schiller and others has done nothing but substantiate it." †

These investigations of Henry established the fact that "in every case of the electrostatic discharge the testing needles were really subjected to an oscillating alternation of currents and consequently to successive partial demagnetizations and remagnetizations." He at once made use of this singular reflux of current to explain the apparent change in the inductive action caused by distance. If "the primitive discharge wave be in excess of the magnetic capacity of the needle in a given position, the return wave might be just sufficient to completely reverse its polarity and the diminished succeeding wave insufficient to restore it to its former condition; while at a greater distance the primitive wave might be so far reduced as to just magnetize the needle fully, and the second wave, being still more enfeebled, would only partially demagnetize it, leaving still a portion of the original polarity; and so for the following diminished oscillations." ‡

"One more extract I must make from that same memoir by Henry," says Dr. Lodge, "and it is a most interesting one; it shows how near he was or might have been to obtaining some of the results of Hertz; though, if he had obtained them, neither he nor any other experimentalist could possibly have divined their real significance.

* *Proceedings Amer. Philos. Soc.*, Vol. ii, p. 193, June 17, 1842.

† *Modern Views of Electricity*, p. 370, London and New York, 1889.

‡ W. B. Taylor, *loc. cit.*, p. 255.

It is, after all, the genius of Maxwell and of a few other great theoretical physicists, whose names are on every one's lips, which endows the simple induction experiments of Hertz and others with such stupendous importance. Here is the quotation:

"'In extending the researches relative to this part of the investigations, a remarkable result was obtained in regard to the distance at which induction effects are produced by a very small quantity of electricity; a single spark from the prime conductor of a machine of about an inch long, thrown on to the end of a circuit of wire in an upper room, produced an induction sufficiently powerful to magnetize needles in a parallel circuit of iron placed in the cellar beneath at a perpendicular distance of thirty feet, with two floors and ceilings each fourteen inches thick intervening. The author is disposed to adopt the hypothesis of an electrical *plenum*' [in other words, of an ether], 'and from the foregoing experiment it would appear that a single spark is sufficient to disturb perceptibly the electricity of space throughout at least a cube of 400,000 feet of capacity; and when it is considered that the magnetism of the needle is the result of the difference of two actions, it may be further inferred that the diffusion of motion in this case is almost comparable with that of a spark from flint and steel in the case of light.' Comparable it is indeed," says Lodge, "for we now know it to be the self-same process."

A few months later Henry "succeeded in magnetizing needles by the secondary current in a wire more than three hundred feet distant from the wire through which the primary current was passing, excited by a single spark from an electrical machine." * The primary wire used for this purpose was the telegraph line which he had stretched seven years before across the campus of the college grounds in front of Nassau Hall; the secondary or induction wire being suspended in a parallel direction across the grounds in the rear of Nassau Hall, its ends terminating in buried metallic plates. The building itself intervened between the wires.

Moreover, Henry studied induced currents produced by atmospheric electricity. By a very simple arrangement he was enabled to magnetize needles strongly in his study, whenever a lightning flash took place within a radius of twenty miles and when the thunder was scarcely audible. "The inductions from atmospheric dis-

* *Proceedings Amer. Philos. Soc.*, Vol. ii, p. 229, Oct. 21, 1842. Vol. iv, p. 260, June 19, 1846.

charges were found to have the oscillatory character observed with the Leyden jar; and by interposing several magnetizing helices with few and with many convolutions, Henry was enabled to get from a needle in the former the polarity due to the direct current, and in the latter that due to the return current, thus catching the lightning, as it were, upon the rebound." In speaking, subsequently, of the phenomena attending electrical oscillation in discharge, extending as they do to a surprising distance on all sides, Henry remarks: "As these are the results of currents in alternate directions, they must produce in surrounding space a series of plus and minus motions analogous to, if not identical with, undulations;" * a reference to modern theories clearly prophetic. In 1845, he showed that the charge passed along the surface of the wire and not through its whole mass.

As a fitting sequel to the investigations of Hare and of Henry which have now been detailed, and especially to the experiments of the former on "quantity" and "intensity" batteries, taken in connection with those of the latter on "quantity" and "intensity" magnets, it is interesting to notice the experiments upon the electromagnetic telegraph which were subsequently made by two other members of the American Philosophical Society, John William Draper (elected in 1844) and Samuel Finley Breese Morse (elected in 1848). The story is told by Professor Draper himself, in an address delivered, in 1853, to the alumni of the University of the City of New York. He says: "Fourteen years ago, there stood upon the floor of the chemical laboratory of our University a pair of old-fashioned galvanic batteries. Like the cradle of a baby, they worked upon rockers, so that the acid might be turned on or off. A gray-haired gentleman had been using them for many years to see whether he could produce enough magnetism in a piece of iron, at a distance, to move a pencil and make marks upon paper. He had contrived a brass instrument that had keys something like a piano in miniature, only there was engraven on each a letter of the alphabet. When these were touched, the influence of the batteries was sent through a copper wire and a mark answering to a letter was made a long way off. . . . . But, long after the telegraph instruments were perfected, it was doubtful whether intelligence could be sent to any considerable distance. It is one thing to send an electric current

* *Proceedings Amer. Assoc. Adv. Science*, Albany meeting, 1851, p. 89.

a few yards and a totally different affair to send it a thousand miles. Experiments which had been made under the auspices of the Russian government, by Professor Jacobi, of the University of Dorpat, had led to the inference that the law of the conducting power of wires originally discovered in Germany was correct; and, in addition, a corroborative memoir had been read by Lenz before the Imperial Academy of Sciences at St. Petersburg. At this time, so little was known in England as regards this important point, that some of the most eminent natural philosophers connected with universities there embraced the opposite view. I may not be able to make the precise point in dispute clear; it was this: A current passing through a certain length of wire suffers a certain amount of loss. If it should go through a wire a thousand times as long, will the loss be a thousand times as great? The Russians said, yes; the English said, no. If the former was the case, it was universally concluded that the electric telegraph would not be practicable for any considerable distance. A series of experiments was made in the University of New York which established beyond all question the truth of the Russian view. But at that time the higher mathematics were cultivated in our laboratory as well as mere experimenting; and, on submitting the results to such a mathematical discussion, the paradoxical conclusion was brought out that it is a necessary consequence of that law that, after a certain length of wire has been used, the losses become imperceptible. Encouraged by this, a party of gentlemen went with the inventor of the telegraph to a rope-walk, near Bloomingdale, one summer morning and there tested the truth of these conclusions on lengths of wire varying from one to some hundreds of miles. The losses of the currents were measured by the quantity of the gas set free in the decomposition of water. The result was completely successful, and telegraphing for any distance became an established certainty."

Joseph Saxton was elected a member of the American Philosophical Society on October 20, 1837, shortly after his return from London to assume the office of constructor and curator of the standard weighing apparatus of the Philadelphia Mint; a position which had been tendered to him by the Director, Dr. R. M. Patterson. Before going abroad he had made several inventions of note, and, in association with Isaiah Lukens,* had constructed the clock

* Elected to the Amer. Philos. Soc., October 20, 1820.

which still occupies the belfry of Independence Hall. He reached London in 1831 and shortly afterwards became connected with the Adelaide Gallery of Practical Science, having charge of its extensive collection of philosophical apparatus. It was here that he met Telford, Brunel and other eminent English engineers. By them he was introduced to the meetings of the Royal Institution and was admitted into friendly relationship with its Fullerian professor of chemistry, Michael Faraday. The primary facts of magneto-electric and of dynamo-electric induction had already been discovered by Faraday in 1831. Saxton took a great interest in these discoveries and followed them up by constructing the first operative magneto-electric machine. In his appreciative biographical memoir of Mr. Saxton, Professor Henry thus speaks of his great scientific invention:

"It was a part of the general principle discovered by Mr. Faraday that, if an insulated or coated wire were wound with many coils around a cylinder of soft iron, which is suddenly magnetized by touching its ends with a magnet, the same effect would be produced as that described by thrusting in and drawing out a permanent magnet. A current in one direction would be excited in the coil when the core became magnetized, and a current would be produced in an opposite direction the moment the magnetism ceased. Mr. Saxton adopted for the inducing magnet to be employed in his machine a compound one, consisting of a number of steel bars bent into the form of a horseshoe, magnetized separately, and then screwed together so as to form one powerful combination. For the inducing part of the apparatus he bent a cylindrical rod of iron of about three-fourths of an inch in diameter twice at right angles so as to produce the form of a U, the parallel legs of which were at the distance of that of the centres of the two poles of the permanent magnet. Around each of these legs he wound thirty or forty yards of insulated copper wire. Now it is evident from the principle before stated that when the two ends of the legs of this U of soft iron are brought in contact with the poles of the permanent magnet, an instantaneous current will be produced in the natural electricity of the wires, each in a direction opposite to the other. Again, when the soft iron U is drawn suddenly away from the poles of the permanent magnet, a reverse current will take place in each of the coils. But a more intense effect will be produced if the legs of the soft iron horseshoe or U be made to rotate before the face or poles of the permanent magnet so as to slide off of one on to the other. In this case the effect will be double that of separating it from a single pole; since if, in passing from the first pole it loses its magnetism, in passing on to the second it may be considered as being demagnetized still further, since it is changed into the opposite magnetism. A similar result will be produced with the other leg of the horseshoe. To excite, therefore, the greatest possible amount of electrical induction, Mr. Saxton fastened the U to a revolving axis passing through its crown, to which a rapid rotation could be given by means of a driving wheel and pulley. In order, however, to obtain manifestations of the induced currents produced in the copper wire, the two ends of the coils were so soldered together as to give a single current in one direction through the entire length of the coils. One of the remaining ends was then permanently soldered to a circular disk fastened concentrically to the revolving axis by an insulating collar, with its plane perpendicular to it. This plate dipped into a cup of mercury. The other end of the wire was soldered directly to the revolving shaft or axis. In this arrangement the insulated disk formed one pole of the long wire and the revolving shaft the other; but as they were not connected no electrical excitement was observed when the bobbins were revolved. To make and break the connection at the proper moment, two wires were soldered diametrically opposite each other on a ferule which fitted tightly with friction on the revolving shaft. These wires standing out at right angles to the shaft were cut off at such a length that at each revolution the ends would plunge into the same cup of mercury with the revolving disk, and thus complete and break the circuit twice with each revolution of the bobbins. These wire points were then so adjusted by turning the ferule on the shaft as to cause them to enter and leave the mercury at the moment when the magnetism was increasing or diminishing most rapidly, and consequently when the current had the greatest intensity.

"With this instrument he was able to exhibit a brilliant electrical spark, to decompose water, to show the electrical light between charcoal points, and to give a rapid series of intense shocks. The instrument was exhibited to the public for the first time at the meeting of the British Association at Cambridge, in June, 1833, where it excited much interest. It was permanently placed in the Adelaide Gallery in August of the same year. The poet Coleridge, who was present at its exhibition in Cambridge, spoke with enthusiasm not only of the magnitude of the discovery of the inductive electrical effects of magnetism—one of the claims of Faraday to imperishable reputation—but also of the ingenious invention of Mr. Saxton by which the transient electrical currents might exhibit their effects in so brilliant and so powerful a manner." *

Notwithstanding the attention which this machine of Saxton's received in scientific circles, no description of it was published until 1836. In October of that year a philosophical instrument maker of London, named Clarke, published a description of a magneto electrical machine practically identical with that of Saxton, and differing only in the fact that the magnet was placed vertically, with the poles downward, instead of horizontally. Not only does he not mention Mr. Saxton by name, nor even allude to his machine, publicly exhibited three years before, but he says with great affectation of originality: "From the time Dr. Faraday first discovered magnetic electricity to the present my attention has been entirely devoted to that important branch of science, more especially to the construction of an efficacious magnetic electrical machine, which after much anxious thought, labor and expense, I now submit to your notice."† Naturally Saxton was prompt to take notice of this disingenuous statement. In the next number of the same journal he says, referring to Clarke's paper: "A reader unacquainted with the progress which magneto-electricity has made since this new path of science was opened by the beautiful and unexpected discoveries of Faraday, might be misled, from the paper I have alluded to, to believe that the electromagnetic machine there represented was the invention of the writer, and that the experiments there mentioned were for the first time made by its means. No conclusion, however, would be more erroneous. The machine which Mr. Clarke calls *his* invention differs from mine only in a slignt variation in the situation of its parts, and is in no respect superior to it. The experiments which he states in such a manner as to insinuate that they are capable of being made only by his machine, have every one been long since performed with my instrument, and Mr. Clarke has had every opportunity of knowing the truth of this statement.

* "Memoir of Joseph Saxton," by Joseph Henry, *Biographical Memoirs Nat. Acad. of Sciences*, Vol. i, pp. 287–317, Washington, 1877.

† *Philosophical Magazine*, III, ix, 262, October, 1836.

"Though my machine is tolerably well known to the public from its constant exhibition at the Adelaide-street Gallery since August, 1833," Saxton continues, "and my claims as its inventor have been acknowledged by Professors Faraday, Daniell and Wheatstone, in papers of theirs published in the *Philosophical Transactions*, yet as no description of it has yet been published I will thank you to insert the following in the ensuing number of the *Philosophical Magazine*."* Then follows an illustrated description of the Saxton machine of 1833.

In this article he says: "The first electromagnetic machine, that is, an instrument by which a continuous and rapid succession of sparks could be obtained from a magnet, was invented by M. Hypolite Pixii, of Paris, and was first made public at the meeting of the Academie des Sciences on September 3, 1832. . . . . It differs from mine principally in two respects: first in M. Pixii's instrument the magnet itself revolves and not the armature; and secondly, the interruptions instead of being produced by the revolution of points, were made by bringing one of the ends of the wire over a cup of mercury, and depending on the jerks given to the instrument by its rotation for making and breaking the contact with the mercury." With regard to the double armature in his machine, Saxton says that he was led to it by the following circumstances: "In November, 1833, Count di Predevalli brought from Paris one of M. Pixii's machines, and it was sent to the Adelaide-street Gallery in order that its effects might be compared with those of mine. Mine was found to excel in the brilliancy of the spark, while M. Pixii's machine was more effective in giving the shock and affecting the electrometer. M. Pixii's machine had a larger keeper and a much greater extent of copper wire. Shortly after Mr. Newman, of Regent street, made a smaller instrument on my construction, which gave the shock more powerfully than my large one did; this also had a greater length of coil, but the effect was at that time partly attributed to the better insulation of the wire. I then convinced myself by some experiments that the increased shock solely depended on the length of the wire. The cause of the difference of effect in the two cases admitted no longer of dispute after the publication of the experiments of Dr. Henry, of Philadelphia, of Mr. Jennings and of Dr. Faraday; as their investigations fully proved that the spark is best

* *Phil. Mag.*, III, ix, 360, November, 1836.

obtained from a magneto-electric coil when short, and the shock when it is long."

Many other ingenious instruments were constructed by Saxton while he was connected with the Adelaide Gallery. He made the apparatus with which Wheatstone's celebrated experiment of measuring the speed of electric transfer through a wire was performed, by which was established the fact that this transfer requires time for its accomplishment. He constructed for the Gallery a compound steel magnet which sustained the weight of five hundred and twenty-five pounds; and also a magnetic needle several feet in length, having a mirror on its end, by which he exhibited for the first time on a magnificent scale the daily and hourly variations of the magnetic force of the earth by the movements of a reflected beam of light. This use of the mirror, however, he had made use of as early as 1825, thus anticipating the similar application made by Ganss. One modification of the revolving mirror thus early used by Saxton consisted in fastening a small mirror to a rotating axis obliquely, so that when a beam of light was thrown upon the mirror, and sufficient speed given to it, a large circle of light would be projected on the ceiling. When, by a powerful train of wheel work, very rapid rotation was produced, any fluctuations taking place in the intensity of the light could at once be detected. He showed, for example, that when the light came from charcoal points forming the poles of a voltaic battery, the circle of light exhibited a mottled or dotted appearance, indicating a rapid alternation of intensity in the electrical discharge.

In a diary kept by him during his residence in London, he gives "a method of determining the position of the interior magnetic poles of the earth by projecting, in the form of a large circle, a section of the earth through the magnetic meridian. On the circumference of this drawing he next projected the dip of the needle in different latitudes from the equator to the pole, and by prolonging these projections until they meet in the interior of the earth, determining the positions of the centres of magnetic influence in the two hemispheres. By this process he arrived at the conclusion that the magnetic polarity of the earth is deeply seated in the interior, and that consequently the magnetism of the globe may be represented by a comparatively short magnet, the axis of which passes through the centre of the globe." Moreover, he made "a drawing of an arrangement of apparatus for obtaining an electrical spark from the magnetism of the earth. This consists in the rapid revolution of a large bar of soft iron on a horizontal axis at right angles to its length, in the plane of the meridian, the bar being surrounded with a very long wire insulated with a covering of silk, an arrangement being made to break the circuit at the instant of the bar receiving the greatest amount of magnetic induction. He succeeded, by this arrangement, in producing currents of electricity of considerable power, but for the want at the time of a sufficient length of insulated wire, he was unable to increase the intensity sufficiently to produce the spark." *

Although Saxton's preëminent ability as a mechanician had secured for him the tender of the office of director of the printing machinery of the Bank of England, he preferred to return to the United States and to accept the office of constructor and curator of the standard weighing apparatus of the Philadelphia Mint. During his connection with the Mint he constructed "the large standard balances still used in the annual inspection of the assays and the verification of the standard weights for all the Government assay and coining offices in the United States. The knife edges of these implements are of the hardest steel, turning upon plates of agate; and such sensibility has the apparatus that when loaded with fifty pounds it turns with one-tenth of a grain; or, in other words, with the three-millionth part of its load."

Already, in 1834, he had been awarded the John Scott medal of the Franklin Institute for a reflecting pyrometer, in which he had utilized the mirror method of observation to determine the temperature by means of the linear expansion of a metallic rod when under the influence of heat. In 1843, upon his appointment by Professor A. D. Bache to the office of Superintendent of Weights and Measures, he applied this mirror method to the construction of the standard bars used by the Coast Survey in such a way as to secure an unvariable length in the bar when subjected to different temperatures. This was done so successfully that the different measurements of a base line five miles in length did not differ by more than half an inch.

In 1858, Saxton presented to the American Association for the Advancement of Science, at its Baltimore meeting, a paper giving an account of the principal applications which he had made of the

* Henry's Biographical Memoir, *loc. cit.*, p. 303.

revolving mirror to minute measurements. In applying this principle to the adjustment of the measuring rods of the Coast Survey, as well as for certain other minute measurements, he had made use of a graduated scale instead of a beam of light, the reflected image of which, considerably magnified, was observed by means of a telescope. With this improvement, an elongation which does not exceed the one hundred thousandth part of an inch becomes a very distinct and measurable magnitude. The same apparatus was applied, at the request of General Meigs, to determine the expansion of different specimens of marble cut into prisms of the same length and cross section. The principle involved is evidently applicable in all cases where changes in length, in angle or in position are to be determined. Saxton himself applied it in the Magnetic Observatory of Girard College to indicate changes in the magnetic dip and also to magnify the motion of the axis of an aneroid barometer. For this latter purpose, the case of the instrument is removed and a mirror about one-half an inch square is attached to the first axis of motion. The aneroid is then fastened to a bracket on the wall, the axis carrying the mirror being placed horizontally. At a distance of about fifteen feet from the mirror a telescope is permanently adjusted, so that the image of a divided scale placed immediately below the object glass can be seen in the mirror. With this arrangement, the slightest change in the pressure of the air becomes apparent. The opening or closing of a door, or a gust of wind over the house, produces marked disturbances in the pressure of the atmospheric column, the extent of which can be readily measured.*

Besides the representative investigations of Franklin in Electrostatics, of Hare in Electrokinetics, of Henry in Electromagnetics, and of Saxton in Magneto-electrics, which have now been considered, members of the American Philosophical Society have made important researches in Magnetism, and especially in the magnetism of the earth.

David Rittenhouse became a member of the Philosophical Society on the 19th of January, 1768. On the 6th of February, 1781, he read a paper before the Society, entitled "An Account of Some Experiments on Magnetism,"† in which he set forth his theory of the magnetism of iron. In this paper he says: "I sup-

* Henry's Biographical Memoir of Saxton, *loc. cit.*, p. 312.

† *Trans. Amer. Philos. Soc.*, I, ii, 178, 1781.

pose then that magnetical particles of matter are a necessary constituent part of that metal which we call iron, though they are probably but a small proportion of the whole mass. These magnetical particles, I suppose, have each a north and a south pole, and that they retain their polarity however the metal may be fused or otherwise wrought. In a piece of iron which shows no signs of magnetism, these magnetical particles lie irregularly with their poles pointing in all possible directions; they therefore mutually destroy each other's effects. By giving magnetism to a piece of iron we do nothing more than arrange these particles, and when this is done it depends on the temper and situation of the iron whether that arrangement shall continue, that is whether the piece of metal shall remain for a long time magnetical or not. . . . . By applying a magnet to a piece of iron," he continues, "it becomes magnetical; for the magnet acting strongly on the above-mentioned particles, that action arranges them properly; overcoming the resistance of the surrounding parts of the iron, and this resistance afterwards serves to secure them in their proper situations and prevents their being deranged by any little accident." Moreover, "iron or soft steel receives magnetism more easily than hardened steel, but will not retain it. May not this be," he suggests, "because the magnetical particles are not so closely confined in soft as in hardened steel, and on that account more easily admit of arrangement or derangement?" In one of his experiments, Rittenhouse took a soft steel ramrod, having no sign of magnetism, and, holding it in the line of the dip, struck it on one end with a hammer. The lower end became a north pole, and when laid on a watch crystal "it traversed very well." "From all this," he reasons, "does it not seem very probable that during the concussion of the stroke and whilst the magnetical particles of the rod were most disengaged from the surrounding matter, the active power above mentioned seized them and arranged them properly, where being confined, the rod afterward remained magnetical." With reference to this "active power," he says in a footnote: "There is some power, whencesoever derived, diffused through every part of space which we have access to, which acts on these magnetical particles, impelling one of their poles in a certain direction with respect to the earth, and the other pole in the opposite direction. The direction in which this power acts I take to be the same with that of the dipping needle."

In his article on "Magnetism," published in the *Encyclopedia Britannica,* Professor Chrystal says: "The notion of molecular magnets seems to have been suggested by Kirwan; but it was not until a definite form was given to it by Weber that it acquired any importance." The views of Kirwan here referred to are contained in a paper entitled "Thoughts on Magnetism," published in the *Transactions of the Royal Irish Academy* for 1797. In this paper Kirwan states as follows: "A magnet therefore is a mass of iron or of iron ore, whose oxygenation does not exceed twenty per cent. or thereabouts, whose particles are arranged in a direction similar to that of the great internal central magnets of the globe. This I call the magnetic arrangement. . . . . Hence a magnet *attracts iron* when within the sphere of its action by forcing, in virtue of its attractive power, a certain proportion of its integrant particles into a disposition and arrangement similar to that of its own. . . . . The disposition of parts in a particular magnet, being similar to that which obtains in the great internal general magnet, extends in the direction of from north to south. Hence magnets, when at liberty to move with a certain degree of freedom, and iron when a sufficient number of its particles are arranged in that direction, and has sufficient liberty to conform to it, points to those poles. Hence this property is called polarity. . . . . The magnetic power is greater or lesser according to the number and homogeneity of the particles *similarly* and *magnetically* arranged. . . . . The power of a magnet (everything else being equal) depends on the *number of its surfaces magnetically arranged* and the *accuracy* of that arrangement. . . . . The arrangement is accurate when the synonymous surfaces are exactly parallel to each other and originally conformed to and parallel with those of the great general magnet. . . . . *Any motion* communicated to the integrant particles of iron placed in a proper situation helps them to assume the magnetic disposition already impressed upon them by the great general magnet."*

These quotations from Kirwan's paper appear to show that the views he held on the nature of magnetism were vague and indefinite; and therefore seem to justify Prof. Chrystal's conclusion that the molecular theory in the form proposed by Kirwan did not acquire any importance. Especially would this be so in view of the fact that in 1600 Gilbert, in his book "*De Magnete,*"

* *Trans. Royal Irish Acad.,* vi, 177, 1797.

showed that if a magnet be broken each piece becomes a complete magnet. The opinions of Rittenhouse, however, seem to be greatly more clear and precise. The idea of "magnetical particles" each having a north and a south pole, and each retaining its polarity, even when the metal is fused, is a perfectly definite one. When a piece of iron shows no magnetism, it is because the particles lie irregularly, and mutually neutralize one another's action; the process of magnetization consisting simply in arranging these particles so that their similar poles face similarly. If now we take into the account the fact that the paper of Rittenhouse antedates that of Kirwan by about sixteen years, it would seem clear that to our fellow-member belongs indisputably the credit of the origin of the molecular theory of magnetism.

Alexander Dallas Bache was elected a member of the American Philosophical Society, April 17, 1829; only a few months after he had taken up his residence in Philadelphia as Professor of Natural Philosophy and Chemistry in the University of Pennsylvania. His attention was early directed to the subject of Terrestrial Magnetism by the remarkable investigations in this direction made by Gauss and Weber. And, in 1830, he erected and equipped a little magnetic observatory in the garden attached to his residence, in which observations were made regularly for a period of four or five years. It was in this observatory that, aided by his wife and by his pupil, John F. Frazer, he determined with accuracy, for the first time in this country, the periods of the daily variations of the magnetic needle. Here, also, by another series of observations, he determined the connection of the fitful variations of the direction of the magnetic force with the appearance of the aurora borealis. His first memoir on the subject was presented to the American Philosophical Society in November, 1832, and contains the results of hourly observations on the declination.* These observations were made with a very long needle provided with a graduated arc at each end. Terrestrial magnetism soon became with him a favorite subject and one to which he continued to make valuable contributions at intervals during his whole life. Even in his journeys he carried with him portable instruments with which he determined the magnetic constants of the points he visited. "What he accomplished in later years for this favorite branch of science," says Dr. Gould,

* "On the Diurnal Variation of the Magnetic Needle," *Trans. Amer. Philos. Soc.* (New Series), Vol. v, p. 1.

"the world knows; and it is certainly not too much to say that, of what we know to-day of the distribution, intensity and periodic and secular changes of terrestrial magnetism, we are indebted quite as much to Bache as to any other one man."

In connection with his colleague, Courtenay, then Professor of Mathematics in the University of Pennsylvania, he undertook an elaborate investigation of the value of the dip and the horizontal intensity of the earth's magnetism at several places in the United States, the results of which were published in two extended memoirs printed in the *Transactions* of the Society.*

On his thirtieth birthday, July 19, 1836, Bache was elected President of Girard College, then about to be put into operation under the provisions of the will of Stephen Girard; and, receiving instructions to visit Europe in order to examine similar institutions there, he resigned his chair in the University and spent two years abroad. While in Europe he found opportunity to determine the magnetic dip and horizontal intensity at twenty-one stations, with the same apparatus and by the same methods which he had employed in America; the results of which determinations he communicated to the Society in a paper entitled, "Observations of the Magnetic Intensity at Twenty-one Stations in Europe." † These observations were made with the view of ascertaining the relative direction and strength of the magnetic force in Europe and America by the comparison of parallel series of observations in the two countries with the same instruments. They also served, in most instances, to settle with greater precision than had previously been attained the relative magnetic condition of the stations at which they were made.

It was while waiting for the College to go into operation that Prof. Bache entered into active coöperation with the great undertaking of the British Association, "to determine, by contemporaneous observations at widely separated points, the fluctuations of the magnetic and meteorological elements of the globe. This coöper-

* "Observations to Determine the Magnetic Dip at Baltimore, Philadelphia, New York, West Point, Providence, Springfield and Albany," *Trans. Amer. Philos. Soc.* (New Series), v, 209, 1834.

"On the Relative Horizontal Intensities of Terrestrial Magnetism at Several Places in the United States, with the Investigation of Corrections for Temperature and Comparisons of the Methods of Oscillation in Full and Rarefied Air," *Trans. Amer. Philos. Soc.* (New Series), v, 427, 1836.

† *Trans. Amer. Philos. Soc.* (New Series), vii, 75, 1840; *Proceedings Amer. Philos. Soc.*, i, 185.

ation, in which, no doubt, a feeling of national pride mingled itself with his ardor for the advancement of science, consisted primarily in the establishment of an observatory, to which the trustees of Girard College contributed a full set of instruments, combining all the latest improvements, and which was supported by the American Philosophical Society and by a number of liberal and intelligent individuals. The observations which were here continued at short intervals, both by day and night, for five years, form a rich mine of statistics from which, until within the last few years of his life, the professor drew a highly interesting series of results without exhausting the material." * Of this Girard College Magnetic Observatory, in which, by the untiring labors of Professor Bache himself and his efficient assistants, this great wealth of valuable scientific material was gathered, no vestige remains. Not only is there no trace of the building itself or any of its parts to be found within the walls of that institution, but there is even a considerable difference of opinion as to its exact location. No single spot in Philadelphia surpasses this in scientific interest. May we not hope that the trustees of Girard College will see to it that the exact site of this observatory is accurately determined and that at least a tablet be placed thereon to mark a spot so important as a magnetic centre? †

In November, 1843, Professor Bache was appointed Superintendent of the Coast Survey of the United States; and, a month later, Superintendent of Weights and Measures. "The volume of testimonials and recommendations," says Dr. Gould, "upon the strength of which this appointment was made, has been shown me; and their number and character has made a deep impression. I cannot believe that such a weight of recommendation was ever brought at any time in support of a candidate for office on purely intellectual grounds. I can think of no man in the country, eminent in physical science, or holding a prominent scientific position, whose name was not signed to some one of that voluminous mass of memorials asking the appointment of Professor Bache. All the sci-

* "Biographical Memoir of Alexander Dallas Bache," by Joseph Henry, *Biographical Memoirs Nat. Acad. Sciences*, Vol. i, p. 181 Read April 16, 1869.

† Mr. Charles H. Cramp, of this city, and Mr. George Davidson, of San Francisco, both members of the American Philosophical Society, were assistants to Prof. Bache in this observatory. Mr. Cramp recently gave to the writer an extremely interesting account of the building and of the instruments contained within it, as well as of the methods of observation which were pursued in the determinations.

entific societies and colleges, together with several of the learned associations of Europe, gave their influence and added their endorsement to the request."* It is gratifying to know that his appointment to this position was first suggested by the members of the American Philosophical Society.

Among the many directions in which the operations of the Coast Survey were now to be extended, Professor Bache very naturally included terrestrial magnetism; observations of the dip and the variation of the needle and of the intensity of the earth's magnetism being introduced as a part of the regular routine. He retained his own personal interest in these matters, and contributed from time to time scientific memoirs upon them to the learned bodies of which he was a member.

Of the memoirs thus communicated a few may here be mentioned. At the Albany meeting of the American Association, held in 1856, a paper was presented by Professor Bache, in conjunction with J. E. Hilgard, "On the General Distribution of Terrestrial Magnetism in the United States, from Observations Made in the United States Coast Survey and Others." At that time the number of magnetic stations established by the Survey amounted to one hundred and sixty, distributed, though somewhat irregularly, along the entire sea coast of the United States, on a great portion of which magnetic observations were now made for the first time. The object of the paper was to deduce from the Coast Survey observations, in connection with others of recent date, the general distribution of terrestrial magnetism in the United States, as far as the data available will warrant the conclusions. With regard to the method and instruments used, only a brief notice is given. "In observing the *declination*, the magnetic meridian has generally been obtained by means of collimator magnets, using Gauss and Weber's transportable magnetometer; while the astronomical meridian was derived from the triangle sides of the Coast Survey or obtained by direct observations. The *dip* has been observed with needles of from six to ten inches in length, made by Gambey and by Barrow. Two needles have generally been used, or, when only one was employed, it has been carefully tested and compared. The *horizontal intensity* has been determined in absolute measure by vibrations and deflections, according to the methods of Gauss and Lamont. The units of measure are those used in the British surveys.

*"Address in Commemoration of Alexander Dallas Bache," by Benjamin Apthorp Gould, *Proceedings Amer. Assoc. Adv. Science*, Chicago meeting, 1868, Vol. xvii, p 1.

From the agreement of repeated observations, it is inferred that the uncertainty of the observations at a particular spot does not exceed one or two minutes of arc in the declination and dip and one five-hundredth part of the horizontal force." The results obtained are given in a table, showing, in parallel columns, "the latitude and longitude of the stations, the declination, dip and horizontal intensity of the earth's magnetic force, the date of the observations and a reference to the particular locality, its geology and other attending circumstances." *

At the Springfield meeting in 1859, Professor Bache presented to the American Association a paper entitled "General Account of the Results of the Discussion of the Declinometer Observations made at Girard College, Philadelphia, between the Years 1840 to 1845, with Special reference to the Eleven-Year Period." "In coöperation," he says, "with the scheme adopted at the British colonial observatories, a series of magnetic and meteorological observations were made at the Girard College Observatory with instruments purchased under the direction of the trustees of the College, the observations being made under the patronage of the American Philosophical Society, and finally completed for the use of the Topographical Bureau of the War Department. These observations were made under my direction and superintendence. The series commenced in May, 1840, and, with short interruptions, terminated in June, 1845; thus furnishing a five years' series of magnetic observations taken bi-hourly up to October, 1843, and after that date hourly. . . . . It is proposed especially to investigate the law of the eleven-year period, or, as it is more frequently called, the decennial period, there being yet an uncertainty as to its precise length. It is supposed to have some direct or indirect connection with the solar spot period, which correspondence, according to late investigations by Prof. R. Wolf, is so close as to exhibit even analogous disturbances."† Mr. Schott's mathematical discussion of these observations gave results showing plainly the inequality constituting the ten or eleven-year period, the year 1843 being directly indicated as the year of the minimum range of the diurnal fluctuation.

Two papers dealing with the phenomena of Terrestrial Magnetism were presented by Professor Bache to the American Association at its meeting in Newport in 1860. The first of these was a "Gen-

* *Proc. Amer. Assoc. Adv. Science*, x, 187, 1856.

† *Ibid.*, xiii, 218, 1859.

eral Account of the Results of Part II of the Discussion of the Declinometer Observations, made at the Girard College, Philadelphia, between 1840 and 1845, with Special Reference to the Solar-diurnal Variation and its Annual Inequality." The results of this discussion are thus given: "The general character of the diurnal motion is nearly the same for the summer half year, for the winter half, and therefore for the whole year. The greatest eastern deflection is, at a mean, reached at a quarter before eight A.M., being a quarter of an hour earlier in the summer, and half an hour later in the winter. Near this hour the declination is a minimum. The greatest western deflection is reached, at a mean, at a quarter after one o'clock P.M., a few minutes earlier in both the summer and winter. At this hour the declination is a maximum. The diurnal curve presents but a single wave, slightly interrupted by a deviation occurring during the hours near midnight, or from ten P.M. to one A.M., when the magnet has a direct or westerly motion. Shortly after one A.M. the north end of the magnet moves easterly, completing the cycle and arriving at its eastern elongation shortly before eight A.M. This nocturnal deviation is well marked in winter, vanishes in summer, and is but slightly perceptible in the annual curve."*

The second paper is an "Abstract of a Discussion of the Influence of the Moon on the Declination of the Magnetic Needle, from the Observations made at the Girard College, Philadelphia, between the Years 1840 and 1845." In the previous discussions of the Philadelphia observations of magnetic declination, Professor Bache had shown how the influence of magnetic disturbances, of the eleven-year period, of the solar diurnal variation and its annual inequality, of the secular change and of the annual variation might be severally eliminated, leaving residuals from which the lunar influence is to be studied. "One of the first questions to determine is, how many of these residuals must be used to give a definite result? and another one is whether numbers deduced from different parts of the series would give harmonious results? To test both of these the observations were formed into three groups, one containing four thousand nine hundred in nineteen months of 1840 and 1841; another, six thousand seven hundred and fifteen results in twenty-one months of 1842 and 1843; and a third, ten thousand and twenty-nine

* *Proc. Amer. Assoc. Adv. Science*, xiv, 74, 1860.

results in eighteen months of 1844 and 1845; in all twenty-one thousand six hundred and forty-four results." The curves obtained by discussing these groups "all agree in their distinctive character, and show two east and two west deflections in a lunar day, the maxima W. and E. occurring about the upper and lower culminations, and the minima at the intermediate six hours. The total range hardly reaches 0.5′. These results agree generally with those obtained for Toronto and Prague. From eight thousand to ten thousand observations seem to be required to bring out the results satisfactorily, and the best results are derived from the use of both groups."*

These discussions of the magnetic and meteorological observations made at the Girard College Observatory, were published *in extenso* in the *Smithsonian Contributions to Knowledge*, and also in the *Reports of the Coast Survey*. Besides the three parts above mentioned, nine other parts were issued, the last in 1864; all covering the time from 1840 to 1845, and including only the observations made in that single observatory.

I have now accomplished the task which has been assigned to me by your Committee. I have endeavored to sketch briefly but clearly the progress which has been made in electrical science since this Society was founded, and to present the steps of this progress in the form of epochs, each typified by the work of one of the eminent men of science whose names have shed lustre upon the roll of its membership. The labors of these men have mightily contributed to advance the development of scientific thought throughout the world, and so to bring about that exceptional evolution of electrical facts and theories which is the distinguishing feature of the science of the nineteenth century. Space has not allowed me to recount all that has been done by the members of this Society, even in this single direction. Many of them are still actively pushing outward the boundaries of knowledge, and are laying the foundations of yet more remarkable achievements. The work of these men it will be the privilege of some future historian of the Society to chronicle. May the record of the contributions made by the American Philosophical Society to the progress of science, in the time to come, be as rich and as brilliant as is its record since it first came into existence in 1743.

* *Proc. Amer. Assoc. Adv. Science*, xiv, 83, 1860.

Appendix.

List of Papers on Electricity and Magnetism Published by the American Philosophical Society.

I. Transactions (Old Series).

II. Transactions (New Series).

III. Proceedings.

Mr. Wharton next addressed the Society as follows:

Gentlemen:—A few years ago it was not known that any other substance but iron possessed the power of acquiring permanent magnetism, though it was of course known that nickel and cobalt were magnetic metals. The fact that they themselves could be made into magnets was never known until I myself, with my own hands, hammered out the first magnetic needle that ever had been made of any other substance than steel, which I think was in the year 1874. I had after a short time several compasses constructed, furnished with needles made of nickel. One of them I sent to the Russian Government, one to the French Government, one to the British Government and one to our own, in order that they might be sent to sea and experimented with. The British Government and the American Government took no notice of it, but the Russian and French Governments investigated the subject very thoroughly and made reports on it. Lord Kelvin, then Sir William Thompson, investigated the properties of sheet nickel, I furnishing him a piece of sheet nickel with which he investigated the properties of nickel in that form as compared with iron in that form, for the production of galvanic currents. Several years later, in order to increase what is called the magnetic quality of nickel, which you no doubt know is much feebler than that of steel, I had a series of bars made of alloys of nickel and tungsten, as, it being known that tungsten increases the magnetic quality of steel, I thought it might act the same with nickel. With those bars I investigated and found that the hypothesis which I had formed was correct, and I had a series of those made with progressive increases of the alloy of tungsten, and the result of all that has been published and I will not detain you with it. Those series of bars unfortunately were lost, as I sent them to the Exhibition at Paris, and they were never returned. One of the ship's compasses which were magnetized, I think in the year 1874, I lately investigated and found that the magnetism remained apparently about as strong as it was in the beginning, showing that the magnetism of a magnetic needle composed of pure nickel is permanent.

President Fraley then made the following closing address:

The programme for the celebration of our 150th anniversary is now literally completed. I cannot say farewell to you, for what I have felt here in meeting so many new and so many old friends does not permit me to entertain the thought that I must part from them. All I can say is that we have been signally blessed in this celebration. We have not only had a perpetuation of good words and perpetuation of good cheer, but the beginning of friendships which will last certainly so long as we are permitted to tread the earth. I thank you all for what has been given to us upon this occasion, hoping, as Prof. Barker has expressed the hope, that the good work for the promotion of science will go on for a series and series and series of 150 years; that not only our own institution may take its part in the great work of promoting useful knowledge, but all the institutions that are represented here and all others who are not and have tendered their congratulations will equally continue at work, and that those who come, I will say 150 years hence, but I will shorten the period and say all those who may come here fifty years hence, will find the old hall standing on its foundation with accumulated treasures within its walls and precious memories encircling the hearts of all those who have been in the past members of the Society and who are now its present members, all those who have been correspondents of the Society in the past and are present correspondents, and that it will be followed by a perpetuity of existence and a perpetuity of correspondence that will endure forever.

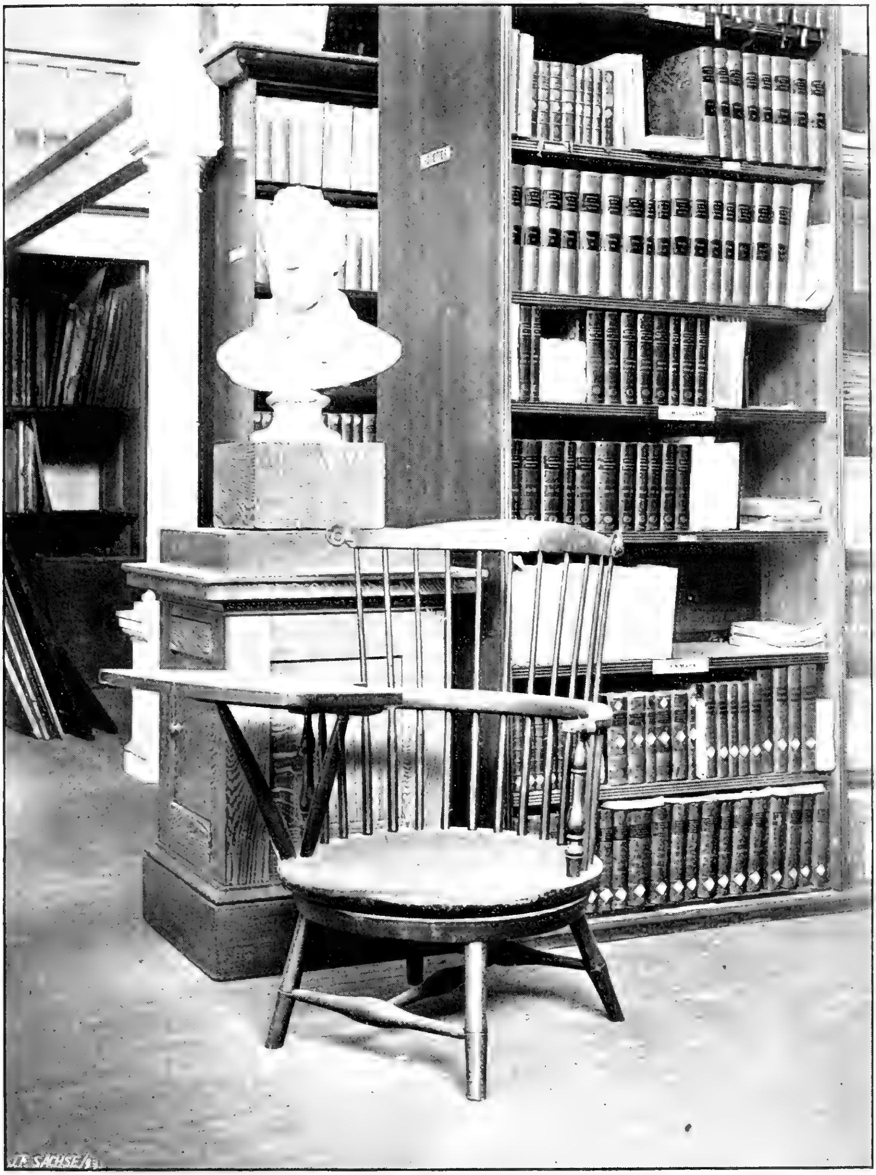
So I shall not say farewell, but I will announce that so far as I am concerned this body shall be continued in session until another fifty years roll around, and ask that you will make the advent of such a coming a welcome to every one.

Adjourned.

Friday, May 26—3 o'clock P.M. Through invitation of Mr. Charles H. Cramp, the Society and guests visited Cramp's ship yard and inspected the plant.

The Union League and the Art Club of Philadelphia opened their Houses for the use of the delegates and members during their stay in the city.

The rooms of the College of Physicians were opened daily for the use of the guests and members of the Society, from 10 A.M to 6 P.M.



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JEFFERSON'S CHAIR IN WHICH HE WROTE THE DECLARATION OF INDEPENDENCE.

APPENDIX.

PAPERS PRESENTED DURING THE ANNIVERSARY.

Tertiary Tipulidæ, with Special Reference to those of Florissant, Colorado.

By Samuel H. Scudder.

Plates 1–9.

I. Introduction.

The occasion of the present memoir is the wish to bring to public attention a portion of the remarkably preserved remains of insects at Florissant, Colorado, in a lake deposit adjudged to be of oligocene age. The locality is already famous for the extraordinary abundance and variety, as well as the excellent condition, of the insect remains therein entombed, and perhaps no group of insects shows this more strikingly than the family of "Crane-flies" or "Daddy Long-Legs."

Several hundred specimens have been collected there, and in a very considerable number of them, representing many species, as the accompanying plates * will testify, not only is the venation of the wings completely represented, with all their most delicate markings, but also the slender and fragile legs with their clothing of hairs and spurs, and to some degree, at least, the antennæ and palpi. Even the facets of the compound eye are often preserved as in life. Previous illustrations of fossil Tipulidæ have rarely represented more than the wings, and even these generally in a very insufficient manner; so that merely as illustrations of fossil remains, the present plates far surpass all that have gone before, and render the study of fossil Tipulidæ very different from our former meagre opportunities. If satisfactory illustrations could only be published

* By the cheerful permission of the Director of the U. S. Geological Survey, I have had placed at my disposal for the illustration of this memoir the drawings of these insects made under my direction, and belonging to the Survey.

of the numerous forms of Tipulidæ recognized by Loew in Prussian amber, we should now have a far better basis for some exact knowledge of the past.

Up to the present time the only known fossil Tipulidæ from America were the few which I have published from the Green River beds in Wyoming, and the White River beds in western Colorado. In preparing the present memoir these have been subjected to a fresh study by comparison with those at Florissant, though I have not attempted to extend our knowledge of the fauna of these deposits, but have merely described the Florissant species, and introduced those known from other localities in their proper systematic position. In doing this the number of the previously described types has been reduced by two, and there remain six species of four genera of Limnobinæ from White River, and two species of one genus of Tipulinæ from Green River. Other species are in my possession which will be published on a future occasion.

The new forms here described come, as stated, from Florissant only, and number twenty-nine species of ten genera of Limnobinæ, and twenty-two species of five genera of Tipulinæ. No such extensive addition to tertiary Tipulidæ has been made since Loew first indicated the riches (still unpublished, after the lapse of forty-three years) of the amber fauna of Europe. If we were to compare the now described and figured tertiary species of America with the actually described or figured tertiary species of Europe (seventeen species of seven genera of Limnobinæ, eleven species of three genera of Tipulinæ), we should find twice as many Limnobinæ, and more than twice as many Tipulinæ; or a Tipulid fauna considerably more than twice as rich as that of Europe.

In a memoir on the *Tertiary Rhynchophorous Coleoptera of North America*, now passing through the press (Monograph xxi, U. S. Geological Survey), I have called attention to the fact that not a single one of the one hundred and sixteen species of weevils found fossil at Florissant occurs in any of the three other prolific localities of fossil insects in Colorado and Wyoming; while each of these three (Roan Mountains, in western Colorado; White River, at the boundary between Colorado and Utah; and Green River, Wyoming—which together possess seventy-five species) shares from one third to two thirds its species with one or the other of its neighbors. From these facts, and from the field evidence, I have drawn the conclusion that the three principal insect localities in western Colorado and Wyoming are deposits in a single body of water, the ancient Gosiute Lake, as it was called by Clarence King; and in speaking of remains from these deposits as a whole, I have applied to them the term *Gosiute Fauna* in distinction from the Florissant or *Lacustrine Fauna* in central Colorado.

The result of the present studies upon the Tipulidæ also has been to show that no single species of the Lacustrine fauna occurs in the Gosiute fauna, though the paucity of remains in the latter does not give this fact the same weight as in the Rhynchophora; and it should also be mentioned that among the few genera found in two of the localities in the Gosiute fauna, the species of each locality are distinct from those of the other.

In his first extended communication on the amber Diptera, Loew called attention to the remarkable alliance of that fauna with the existing fauna of the eastern United States. He further expanded the subject in a most interesting essay, translated by Osten Sacken and published in *Silliman's Journal* for 1864. In this paper he reached the conclusion that "the amber Diptera stand in a much closer relation to the North American and to the European [*i. e.*, those now existing] than to those of any other fauna"; and he further asserts "with the utmost certainty that those among the living Diptera which most closely resemble the amber Diptera, abound in a most prevailing degree in North America and especially between the latitudes of about 32° to 40°."

Baron Osten Sacken, in numerous passages, has insisted upon the same resemblance. In the Tabular View of Tertiary Tipulidæ we have given further on, it will be seen that (omitting Tanymera as doubtful) thirteen genera are credited to the Baltic amber, of which ten are found in America, and one of them in North America only besides its occurrence in amber; this last is Idioplasta. On the other hand, only eight of the amber genera occur now in Europe, and all these genera have also American representatives. At the most, two genera, Trichoneura and Calobamon (and Tanymera also, if it is to be included), seem to be known so far only in amber, but they are all as yet imperfectly characterized. Only five of the amber genera have representatives elsewhere than in Europe or America, and one of these is cosmopolitan.

No such striking conclusions can be reached from the study of the tertiary Tipulidæ of North America, at least at present. A large proportion of the genera are extinct (genera which include about one third of the species), and of the remainder the larger proportion are genera found in north temperate regions of both worlds. Cladura only (with the allied extinct Cladoneura) shows distinctively American affinities, and none are more nearly allied to the genera of the European fauna, whether recent or extinct, than to those of the existing American fauna.

In making a comparison between our tertiary Tipulid fauna and that of North America north of Mexico on the one hand, and the more imperfectly known fauna of the southern part of North America * on the other, the tertiary fauna distinctly appears more nearly related to the former, for the latter contains the following only: Limnobini, 1 sp.; Rhamphidini, 3 sp.; Eriopterini, 3 sp.; Limnophilini, 6 sp.; and Anisomerini, 7 sp., a total of twenty Limnobinæ; and there are besides eighteen Tipulinæ. The relative proportion of Tipulinæ is therefore much greater; while among the Limnobinæ the tribe Anisomerini, not represented at all among the fossils (and having in the United States and Canada but six per cent. of the species, if the tribes represented in Mexico and Central America alone are counted) possesses no less than thirty-five per cent. of all Limnobinæ, while the Limnobini have but five per cent. It is only in the relative numbers of the Rhamphidini that any nearer approach is seen between the tertiary fauna of Colorado and the present Central American fauna.

Nor, if we examine the genera separately, can we come to any different result, for while the fossils show in several instances an identity with or close affinity to those found in the United States, the only genera among them which are also represented in the Central American fauna are the widespread and prolific types, Limnophila (sens. lat.) and Tipula; and not a single other genus found in the south shows any particular affinity to the extinct forms. We are forced to conclude, therefore, that the general affinities of the fossils are with the existing fauna of the general region in which they are found. The distribution, however, of the living genera in the United States is too little known to permit any definite and decisive conclusions on this latter point.

The relative representation in species of the different groups of Limnobinæ and of the total number of Limnobinæ and Tipulinæ in different regions in past and present times is shown in the follow-

* As given in Baron Osten Sacken's contribution to the *Biologia Centrali-Americana.*

ing table, where they are given first in numbers and next in percentages. Osten Sacken's *Catalogue of the Diptera of North America* (1878) is taken for the living American forms, excluding the species found only south of the United States; Schiner's *Fauna Austriaca* (1864) supplies the basis for the European forms, including the species merely enumerated as well as those described by him, and thus including all Europe; while the results of the present memoir, subsequently detailed, have been taken for the remaining columns.

Comparative View of Recent and Tertiary Tipulidæ.

Tribes.	In Numbers. (Figures represent number of species.)				In Percentages.			
	Recent N. A.	Tertiary N. A.	Tertiary Europe.	Recent Europe.	Recent N. A.	Tertiary N. A.	Tertiary Europe.	Recent Europe.
Limnobini	39	13	19	86	23	38	28	35
Rhamphidini	12	4	8	6	7	12	12	2
Eriopterini	41	7	11	57	25	21	16	23
Limnophilini	42	4	21	57	25	12	31	23
Anisomerini	8	0	3	8	5	0	4	3
Amalopini	15	0	4	22	9	0	6	9
Cylindrotomini	4	6	0	7	2	18	0	3
Ptychopterini	6	0	1	6	3	0	1	2
					99	101	98	100
Subfamilies.								
Limnobinæ	167	35	67	249	62	59	68	67
Tipulinæ	104	24	31	122	38	41	32	33
Totals	271	59	98	371	100	100	100	100

This table, and especially the side representing the percentages, shows some remarkable features. The relative proportion of the two subfamilies is shown to be somewhat different on the two continents, whether past or present time is considered, but it presents striking similarities when on either continent the tertiary and present times are compared, there being in Europe scarcely the slightest variation.

But when the several elements of the Limnobinæ are separately considered, a somewhat different state of things appears. Here, in a distinct though not in any striking way, the table shows that as far as the relative numbers of the subordinate groups of the tertiary fauna of North America are concerned, our tertiary Tipulidæ have a closer relationship to the fauna of tertiary Europe than to that of America to-day. One disturbing element, however, is introduced in the great prominence of the Cylindrotomini among the fossils, due to the large numbers of the genus Cyttaromyia, which must be looked upon as on the whole the most striking feature of the tertiary Tipulidæ of North America.

As a summary of general results obtained from the careful study of these remains, we venture to submit the following propositions:

1. The general facies of the Tipulid fauna of our western tertiaries is American, and agrees best with the fauna of about the same latitude in America, as far as we are at present acquainted with it.

2. All the species are extinct, and though the Gosiute Lake and the ancient lacustrine basin of Florissant were but little removed from each other, and the deposits of both are presumably of oligocene age, not a single instance is known of the occurrence of the same species in the two basins. The Tipulid fauna of the Gosiute Lake, however, is as yet very little known, and it should be added that the few described species are in no instance the same at Green River, Wyo., and White River, Colo., both localities in the same ancient lake basin.

3. No species are identical with any of the few described European tertiary Tipulidæ.

4. Restricting ourselves to the Florissant basin, from the paucity of material in the Gosiute fauna, it will be noticed that a remarkable proportion of genera (eight out of fifteen) are not yet* recognized among the living, these genera including about one third of the species.

5. With one (American) exception—Cladura—all the existing genera which are represented in the American tertiaries are genera common to the north temperate zone of Europe and America, and are generally either confined to these regions or the vast proportion of their species are so confined. A similar climate is indicated, but this latter conclusion should be received with hesitation, since

* It should be noted here that, in his enumeration of the amber Diptera, Loew recognized four genera as extinct, of which living representatives have since been found, without mentioning those which Osten Sacken regards as Limnophilæ.

our knowledge of the distribution of American genera is mostly confined to the Atlantic States. There are, however, no certain indications of a warmer climate, such as have been shown from the study of other groups.

6. There are no extinct groups higher than genera, but one or two of these, such as Cyttaromyia and Micrapsis, are of a somewhat striking character.

7. The relative importance of the two subfamilies of Tipulidæ, though differing on the two continents of Europe and America both in tertiary and in recent times, was much the same, on each continent, in tertiary times as now; while in the relative preponderance of the different tribes of Limnobinæ, our tertiary fauna shows a somewhat closer agreement with the European tertiary than with the existing American fauna. There are, however, no striking generic alliances pointing in the same direction.

The above general conclusions have been reached after as careful a study of the tertiary fauna of Europe as the literature would allow, it being unfortunately necessary to depend entirely upon published materials, most of them ancient, for any conclusions regarding the European fossils. Fortunately, the way has been lightened by occasional expressions of opinion from Baron Osten Sacken, who has personally examined not a few of them and published here and there valuable statements regarding them. Being compelled to subject all the literature of the subject to a careful scrutiny in order to obtain any proper glimpse of the known tertiary fauna of Europe, it has seemed best to publish in this connection a formal historical review of the European tertiary Tipulidæ, in order that the grounds of my general statements may be better understood.

Accordingly, in the next section of this memoir, I give such a review, following it with a summary of results in the form of an Alphabetical List of the Genera and Species; and again with a Tabular View of Tertiary Tipulidæ in general, systematically arranged; and add a note on Pretertiary Tipulidæ, before proceeding to a special and detailed systematic discussion of the American Tertiary Tipulidæ.

II. Historical Account of the European Tertiary Tipulidæ, with Comments.

The first fossil Tipulidæ described are those mentioned by Presl in 1822 (*Del. Prag.*), purporting to have come from amber. They are *Tipula antiqua*, *T. protogeæ*, and *T. curvicornis*. They are wholly irrecognizable from the descriptions, but their size (from one to two German lines in length) plainly shows that they are at least not Tipulinæ, and probably not even Tipulidæ. They must be left wholly out of consideration, both on this account and because it is believed that Presl's specimens were really preserved in the recent gum copal and not in amber.

UNGER in 1841 (*Verh. leop.-carol. Akad. Naturf.*, xix) described and figured the following species from Radoboj, afterwards reexamined by Heer.

Rhipidia extincta. The figures given by Unger and Heer do not entirely agree in the neuration of the wings; Unger's is the better and clearer. The head is lost, so that the antennal structure cannot be determined, and Loew has pointed out (*Zeitschr. ges. Naturw.*, xxxii, 190) the failures of the neuration, and believes Heer to have been misled in his determination by Meigen's inaccurate figure of the neuration of the modern *Rhipidia maculata*. Loew regards it as probably a true Limnobia.

Rhipidia major. The specimen has the tip of the wing broken, and with it are lost the parts necessary to decide to which of the subfamilies of Tipulidæ it should be referred. But as the wing must have had a length of about 22 mm., it is evident that it must belong to one of the Tipulinæ, and therefore it should be referred to Tipula in a large sense. Heer has already so referred it under the name *Tipula ungeri*, and Giebel has followed him in generic reference. On account of its abdominal markings, however, Heer compared it to the species of Tipula now placed in Pachyrhina.

HEER, in 1849, in his classical work on the fossil insects of Oeningen and Radoboj, makes the first important addition to the then known fossil Tipulidæ. His species are all mentioned below, and all of them stated to be from Radoboj, excepting *Limnobia formosa*, for which no locality is mentioned; it is probable that this was a mere oversight, and that it also comes from the same place. None of Heer's figures, it should be said, can be depended upon for the exact neuration, as some are manifestly incorrect, and in no case do different figures of the same wing (with different enlargements) agree. It is therefore impossible, even with the aid of the text, to place them confidently.

Tipula maculipennis. The neuration shown in Fig. 1^b differs from that in Fig. 1, the latter being undoubtedly the more correct, as the description also shows. The markings are said to be the same as in the living *T. hortensis* of Europe. In all probability it is a true Tipula, and appears to fall nearest to *T. limi* or perhaps *T. carolinæ* from Florissant.

Tipula æmula. The veins are differently shown for the same wing in Figs. 2 and 2[b], the latter undoubtedly the more correct, but both wrong. As Heer says, it is closely allied to the preceding species; it is probably a true Tipula, and may fall near *T. heilprini* from Florissant.

Tipula varia. This species, according to Heer, belongs near the modern *T. hortensis* and *T. hortulana* of Europe. It appears to be a true Tipula, but the figures all vary in the neuration, with a notable difference in those of the two specimens in the length of the petiole of the second posterior cell, if the enlarged figure, 3[b], is correct in this particular, as it undoubtedly is in the other points where it varies from Fig. 3[a]. It appears to come in the vicinity of *T. carolinæ.*

Tipula lineata. Here again the neuration of the enlarged figure, 4[b], differs, in the discal cell and elsewhere, from that of the figure of natural size, 4; the former is undoubtedly the more correct. It appears to be a true Tipula, and is said by Heer to stand next the European *T. obsoleta.* To judge from the length of the præfurca, it would seem to come nearest to *T. tartari* of any of the American tertiary species, but it is very different from it. Capellini credits this species to tertiary deposits at Gabbro, Italy.

Tipula oblecta. Here, too, the two figures differ, though but slightly, an omission in the smaller being supplied in the larger. There is no reason to suppose it is not a true Tipula, and it is regarded by Heer as near his *T. varia* from the same beds. It apparently belongs with the series having a relatively short præfurca and seems to come nearest to our *T. subterjacens.*

Tipula ungeri. This is the species mentioned above as originally described by Unger under the name *Rhipidia major.* Heer shows that it should be referred to Tipula, but there seems to have been no real occasion to change the specific name. Giebel held this view and described it as *Tipula major.*

Rhipidia extincta. See above under the same species described by Unger.

Rhipidia picta and *R. propinquans.* Loew's criticisms apply equally well to these two species, which there is every reason to place in the same genus as *R. extincta*. They may therefore be referred to Limnobia.

Limnobia formosa. Here Heer's two figures essentially agree and are very good. Heer compares it to two living European species, *L. quadrinotata* and *L. annulus*, both true Limnobiæ, and if the neuration is correctly given, it is plain from the length of the auxiliary that it is a Limnobia, and not a Dicranomyia. This is the species, presumably from Radoboj, the locality of which is not stated by Heer.

Limnobia cingulata. The two figures given by Heer disagree in important particulars, and that which is enlarged is plainly incorrect. Heer states that it agrees so closely with *L. nubeculosa* Meig. as hardly to be distinguished from it, and he specifies in particular the neuration. It is therefore probably a true Limnobia.

Limnobia tenuis. The neuration is only partially shown, and is said by Heer to be difficult to trace. Heer compares it to that of *L. lutea* Meig., a true Limnobia, and there is nothing in what is figured inconsistent with such a generic reference.

Limnobia vetusta. Two different figures of this are given by Heer, one of them useless, the other none too good, but showing the coarser parts of the neuration, from which it would appear to be a Limnobia. Heer compares it to *L. dumetorum* Linn., a true Limnobia. There is an additional figure of this species in Heer's *Fossile Hymenopteren*, Pl. iii, fig. 15c, overlooked in my *Index to Described Fossil Insects;* it is too small to be of any service, the neuration being only vaguely indicated.

Limnobia debilis. The venation given in the two figures by Heer does not agree, and the smaller figure is manifestly incorrect in this particular; besides Heer specifies that the larger figure is to be used for studying the venation. This shows that it is no Limnobia in the present sense. Heer, himself, says that the neuration agrees with that of *L. sylvatica* Meig., which Schiner refers to Gnophomyia, and as the neuration of the enlarged figure shows nothing discordant with Gnophomyia, it may best be referred here until reexamination of the type can be had.

The only other Tipulids to be credited to Heer are one given in his *Urwelt der Schweiz* (1865), coming from the miocene of Locle, Switzerland, and another from Aix, in his account of the Aix fossil insects (1856).

Limnobia jaccardi. This species from Locle is not described, but a clear figure of a complete wing is given. This shows some manifest inaccuracies, as in the origin of the fifth and sixth longitudinal veins, and a cross vein beyond the origin of the præfurca, uniting the first longitudinal vein and the costa and running *across* the auxiliary. A cross vein is also shown at about the middle of the second submarginal cell, which is probably misplaced. As there are plainly two submarginal cells, it is clearly not a Limnobia. If we interpret the cross vein beyond the origin of the præfurca as the subcostal cross vein (wrongly carried across to the costa), the parallel cross mark midway between it and the tip as the termination of the auxiliary (wrongly connected with the first longitudinal vein), and carry the misplaced cross vein in the second submarginal cell to the bend in the first longitudinal vein just beyond the base of the first submarginal cell, where a marginal cross vein would naturally occur, we have the essential characteristics of the neuration of Trichocera, and these manifest inaccuracies aside there is no other genus with which it agrees so well. Moreover, Loew indicates two fossil species of this genus from amber (without describing or naming them), so that the occurrence of the genus in Europe at the period when this insect flourished is certain.

Limnobia murchisoni from Aix. Heer's figure is plainly copied from that of Curtis, who figured but did not describe it (1829), but he describes from the original specimen, and compares it to the living *L. annulus* Meig., with which the neuration is said to correspond. The figure is good, but the auxiliary vein does not appear. There is nothing to show that it is not a true Limnobia, though it is possibly a Dicranomyia. Probably an examination of the fossil would determine. Heer's paper naming this species appeared in the same year (1856) as Giebel's volume applying to it the name *Limnobia curtisi.* As priority cannot be proved for either, it seems proper to prefer Heer's name, since he evidently studied the specimen itself.

In 1850, Loew, in his *Meseritz Programm*, gave the first important communication on amber Diptera, mentioning a large number of species (undescribed) under many new generic names; most of these are regarded by Osten Sacken, as appears by numerous references by him, to be identical with existing genera, and especially with Limnophila, a genus which he considers as not yet properly subject to division into more than subgenera. The genera given by Loew were in some cases named by him in a list appended to the introduction to Berendt's folio work on the amber fauna (1845), but one, Adetus, mentioned then by him does not appear later, and was evidently dropped by Loew; whether it was regarded as not separable from Tipula, next to which it stands in the list, or as equivalent to one of the numerous genera of Limnobinæ afterwards proposed, does not appear. These genera were not fully described by Loew in his *Meseritz Programm*, but merely separated from one another in a table prepared to show their relationships. They were as follows, the new ones prefixed by an asterisk; none of the species were named.

Tipula. Of this genus he names three species and records thirteen others.

Rhamphidia. Two species named and two others recorded.

* *Toxorhina.* Three species are named. The following year (*Linn. ent.*, v) they were partially described, especially the palpi which were also figured, and the genus described, but the characters of the genus were almost entirely based on a living species from the West Indies, which it has since been shown should be generically dissociated from them. Osten Sacken has since retained the name Toxorhina for the West Indian species, and referred the fossils at first to the existing genus Limnobiorhynchus, and (when it was found that this was based on incongruous material, the sexes of different genera already known) to the genus Elephantomyia, which also contains living representatives. Osten Sacken objects to Schiner's contention that the name Toxorhina should be primarily restricted to the fossil species, and mainly on the ground that though when first proposed only amber species were included in it, it was not characterized until the following year, and then on structures drawn from a living insect, which in part did not exist in the fossil. I regret to differ at all from Baron Osten Sacken—the foremost student of the group of Diptera—but it cannot be fairly claimed that Toxorhina was not characterized when first proposed, for not only does his mention of the genus include the statement that it has an extraordinarily long filiform rostrum, and exceptionally short four-jointed palpi, but the table on the preceding page, wherein the genera are differentiated (a table to which Osten Sacken appears to have paid no attention), practically defines the genus thus: Rostrum slender, longer than head and prothorax together. Palpi short, the last joint not so long as or scarcely longer than those which precede, taken together. This, though not all that could be

asked, is assuredly not to be ignored, and I have accordingly here retained the name Toxorhina for the fossil species, and Toxorhina fragilis of the West Indies—the bone of all this contention—should be known under some other generic name.

* *Macrochile.* One named species. The name, being found to be preoccupied, has been changed by Osten Sacken to Idioplasta. Living species are now known.

Cylindrotoma. Four named species. These have been studied by Osten Sacken, and regarded by him as belonging to Limnophila in a narrow sense, excepting *C. longicornis,* which he places in the subgenus Lasiomastix.

Trichocera. Two unnamed species.

Anisomera. One named species; it is regarded by Osten Sacken as an Eriocera.

Erioptera. Eight unnamed species.

* *Trichoneura.* One named and three unnamed species. According to Osten Sacken these belong to the division of Limnophila with four posterior cells.

* *Calobamon.* One unnamed species. Osten Sacken reproduces Loew's description of the genus, with additions of his own from examination of the type (*Berl. ent. Zeitschr.*, xxxi, 207). He gives no opinion of it other than to mention its "apparent relationship to the Limnophilina."

* *Haploneura.* Four unnamed species. Osten Sacken subsequently mentions one species by Loew's manuscript name, *H. hirtipennis,* which, he says, belongs to Ula. Probably the others also belong there.

* *Critoneura.* Two named species, regarded by Osten Sacken as belonging to Limnophila.

* *Tanymera.* Four unnamed species, one of which is afterwards specified by Osten Sacken by Loew's manuscript name, *T. gracilicornis,* which, he says, is a Limnophila; but he makes no statement regarding the others.

* *Tanysphyra.* One named species, called a Limnophila by Osten Sacken.

* *Styringomyia.* One named species, recognized by Osten Sacken as correctly placed. The genus has since been found living and also in copal.

* *Ataracta.* Eight unnamed species. Osten Sacken says this generic name is equivalent to Dicranomyia.

* *Allarithmia.* One named species, regarded by Osten Sacken as an Eriocera, of which, he says, he has recognized three species in Prussian amber, one other being the Anisomera mentioned above.

From this it would appear that the amber fauna does not contain a single extinct generic type, unless Calobamon be excepted, although several of the genera were first made known from amber.

In connection with the amber Diptera, it may be added that Burmeister, in his *Manual of Entomology* (1836), mentions several species of "Limnobia" found in amber, some small like *L. pulchella* (now referred to Idioptera, a subgenus of Limnophila), some larger. Of course, any nearer reference is impossible. So too several other authors—Defrance, Schlotheim, Sendel, etc.—have mentioned the occurrence in amber of species of "Tipula", but Loew's later and fuller statements are presumed to cover all these.

Guérin (*Rev. Zool.*, 1838, 170, pl. i, fig. 18) mentions "deux petits Tipulaires en état d'accouplement" in Sicilian amber. In my *Index to Described Fossil Insects*, p. 667, I have wrongly quoted this as "Tipula," as no genus is specified, and it is evident from the figure that the insect is rather one of the Mycetophilidæ.

Aymard, in 1854, catalogues two named but undescribed species of a genus he calls Dichaneurum, without further indication of its characters than that it belongs to the family Tipulidæ, as found fossil at Le Puy, France. The reference is of course valueless without further details.

Giebel, in his *Fauna der Vorwelt* (1856), describes anew, so far as possible, all the then known fossil Tipulidæ, and adds descriptions of two new forms from amber found in the collection of the Leipzig Museum. Concerning Giebel's *Tipula major* and *Limnobia curtisi*, see above under Heer's species *Tipula ungeri* and *Limnobia murchisoni*. The new species are the following:

Limnobia furcata. Giebel states that in regard to its neuration this species belongs to the group containing *L. fulvescens, ferruginea, bicolor*, etc., *i. e.*, to that now classed as Limnophila. The description agrees entirely with Limnophila. Giebel may easily have overlooked the tibial spurs of which he makes no mention. There are no means of determining whether it be not one of the numerous Limnophilini mentioned by Loew.

Limnobia deleta. The single specimen has the wings damaged "so that a closer comparison with living species is not possible." The antennæ are described as fifteen-jointed and twice as long as the body, with equal cylindrical joints; the halteres are nearly as long as the abdomen; the wings have the first longitudinal vein (schulterader) rather distant from the auxiliary (randader), with which it is connected by the subcostal cross vein before the middle of the wing. From this brief description it is impossible to tell where it belongs, but the fifteen-jointed antennæ point to the Limnobini.

In 1859 and 1870, HEYDEN described in the *Palæontographica* the following species, all from Rott in Rhenish Prussia.

Ctenophora decheni. Both the form of the abdomen and the character of the antennæ show it to be a male. Heyden says the neuration shows little variation from that of living species of Ctenophora. But his delineation of the same is like no Ctenophora and manifestly incorrect, affording no clew to the affinities which a correct sketch might offer. The stout legs show that it cannot be a Tipula, and the apparently pectinate antennæ suggest a possible alliance to South American forms like Ctedonia and Ozodicera. The specimens should be restudied, but in the meantime be retained in Ctenophora.

Erioptera danæ. The wings are not preserved, or only along the costal margin. By the short middle femora, the spurless tibiæ, and the small size, it was referred by Heyden to Erioptera. It would probably not be possible to place it more definitely. The male appendages also agree fairly.

Limnobia sturi. The two figures of the same wing do not agree, but the differences are slight, and the description shows the enlarged figure to be the more correct, as indeed the left wing (not enlarged) shows. It is plain from the neuration that the insect is not a Limnobia in its present sense, but a Gonomyia, and not very far removed from *G. profundi* from Florissant.

NOVÁK, in 1877, published an account of the fossil insects of Krottensee, Bohemia, in the *Sitzungsberichte* of the Vienna academy. Among them were the following Tipulidæ:

Tipula angustata. This species closely resembles *T. sepulchri* from Florissant, but the latter is nearly twice as large. This Krottensee species is the smallest fossil Tipula known.

Tipula expectans. This species has a very long præfurca. It appears to be a Tipula so far as can be told from the wing alone. From its long præfurca it seems to be most nearly allied to the spotted *T. tartari* of Florissant, but it differs in the length of the petiole of the second posterior cell, and in the narrowness of the wing.

Ptychoptera deleta. The figure of this species is excellent, showing the species to be certainly nearer to Ptychoptera than to any known genus, though the number of posterior cells cannot be determined from the imperfection of the specimen. It certainly must belong to the Ptychopterini, but shows some peculiarities worthy of special notice. Thus in Ptychoptera (at least in the American species—and Osten Sacken says that the two European species seen by him do not materially differ from it) the first longitudinal vein appears to end in the costa, and to be connected with the uppermost branch of the second by a marginal cross vein, while in the fossil it ends in the second longitudinal vein at the point where the marginal cross vein would occur did it exist. And there is further a costal cross vein uniting the auxiliary vein to the costa in the middle of the wing. Novák's description as well as figure attest these points and indicate a peculiar genus.

Omboni, in 1886, in a brief account of some Italian fossil insects (*Atti r. ist. Veneto*, (6), iv) describes and figures the following from the miocene of Chiavon.

Tipula zignoi. The figure of this fossil is utterly worthless, gives no sort of clew to its relationship, and would seem to show that the fossil itself is irrecognizable. Omboni indeed says it would be "difficult, not to say impossible," definitely to refer it, and adds that it has no trace of wings, and is probably a Chironomus, a Tipula, or a Limnobia. Its size alone quite precludes reference to Tipula, and it may well be left to oblivion.

Foerster, in an elaborate account of the fossil insects found in the middle oligocene of Brunstatt (*Abh. Specialk. Elsass-Lothr.*, iii, 1891) mentions, without naming, the following two species of Tipulidæ.

Tipula sp. 1. This species evidently belongs to our new genus Tipulidea, the length of the præfurca just equaling, or certainly not surpassing, the greatest breadth of the first basal cell. It differs, however, from any of the American species, but seems most nearly allied to *T. picta*.

Tipula sp. 2. This, too, belongs to Tipulidea, and resembles the preceding species more nearly than it does any of the American forms. Both European species have a smaller second posterior cell than any of ours, and the length and slenderness of the fourth posterior cell is much greater.

Finally, to specify a few minor instances of little present value, SERRES (*Géogn. terr. tert.*, 1829) states that a fossil fly of the genus Nephrotoma, allied to the European *N. dorsalis*, occurs in the beds at Aix, Provence, and credits to the same beds a species of Trichocera.—HOPE mentions a Tipula from Aix (*Trans. Entom. Soc. Lond.*, iv, 253, 1847) which he compares with *T. rivosa*. I do not know what that species may be. HEER has also named a species from the same place, *Tipula infernalis*, but it is undescribed.—WOODWARD, in a list of insect remains from the Isle of Wight (*Quart. Journ. Geol. Soc. Lond.*, xxxv, 344, 1879) gives among others "Tipulidæ, 6" specimens.—SCHÖBERLIN (*Soc. Entom.*, iii, 69, 1888) mentions the occurrence of a species of Tipula at Oeningen, Baden, which he compares to *T. ochracea*, a true Tipula.—BELL, in the *Entomologist* (xxi, 1888) in an article on glacial insects, mentions a "Dicæra, allied to Tipula," as found in a "crannoge" in Wigtonshire, England, presumably in the refuse of lake-dwellings. Apparently he must have meant something akin to Dictenidea or Ctenophora, but closer reference is impossible; it is perhaps hardly fair to class it at all among fossil insects, and it is accordingly not alluded to in the tabular lists in this paper.—Lastly, KLEBS, in his *Catalogue of the Stantien and Becker bernstein-museum* (1889), on p. 65, lists a specimen (No. 478) "in the vicinity of Tipula, a new species with striking antennæ."

These data are all summarized in the following list, in which the species which are known purely by name, without description or figure, are prefixed by an asterisk.

III. ALPHABETICAL LIST OF EUROPEAN TERTIARY TIPULIDÆ, WITH THEIR PROBABLE SYSTEMATIC POSITION.

* Adetus 1 sp. Loew, amber. Indeterminable.
* Allarithmia palpata Loew, amber. *Eriocera.*
* Anisomera succini Loew, amber. *Eriocera.*
* Ataracta 8 sp. Loew, amber. *Dicranomyia.*
* Calobamon 1 sp. Loew, amber. *Calobamon.*
* Critoneura longipes Loew, amber. *Limnophila.*

* Critoneura pentagonalis Loew, amber. *Limnophila.*
Ctenophora decheni Heyden, Rott. *Ctenophora.*
* " 1 sp. Foerster, Brunstatt (afterwards described as Tipula, q. v.)
* Cylindrotoma brevicornis Loew, amber. *Limnophila.*
* " longicornis " " "
* " longipes " " "
* " succini " " "
* Dichaneurum infossum Aymard, Le Puy. Indeterminable.
* " primævum " " "
Elephantomyia brevipalpa Osten Sacken, amber. *Toxorhina.*
" longirostris " " "
" pulchella " " "
* Eriocera palpata Osten Sacken, amber. *Eriocera.*
* " succini " " "
* " 1 sp. " " "
Erioptera danæ Heyden, Rott. *Erioptera.*
* Erioptera 8 sp. Loew, amber. "
* Geranomyia 1 sp. Osten Sacken, Aix. *Geranomyia.*
* Haploneura hirtipennis Loew, amber. *Ula.*
* " 3 sp. " " "
* Idioplasta spectrum Osten Sacken, amber. *Idioplasta.*
Limnobia cingulata Heer, Radoboj. *Limnobia.*
" curtisi Giebel, Aix (= L. murchisoni). *Limnobia.*
" debilis Heer, Radoboj. *Gnophomyia.*
" deleta Giebel, amber. *Limnobia.*
" extincta Loew, Radoboj. "
" formosa Heer, Radoboj? "
" furcata Giebel, amber. *Limnophila.*
" jaccardi Heer, Locle. *Trichocera.*
" murchisoni Heer, Aix. *Limnobia.*
" picta Loew, Radoboj. "
" propinqua Loew, Radoboj. "
" sturi Heyden, Rott. *Gonomyia.*
" tenuis Heer, Radoboj. *Limnobia.*
" vetusta " " "
* " sev. sp. Burmeister, amber. "
Limnobiorhynchus brevipalpus Osten Sacken, amber. *Toxorhina.*
" longirostris " " "
" pulchellus " " "
* Limnophila brevicornis Osten Sacken, amber. *Limnophila.*
* " gracilicornis " " "
* " gracilis " " "
* " longicornis " " "
* " longipes (1) " " "
* " " (2) " " "
* " pentagonalis " " "

* Limnophila succini Osten Sacken, amber. *Limnophila.*
* " vulgaris " " "
* Macrochile spectrum Loew, amber. *Idioplasta.*
* Nephrotoma 1 sp. Serres, Aix. *Nephrotoma ?*
Ptychoptera deleta Novák, Krottensee. *Ptychoptera ?*
* Rhamphidia minuta Loew, amber. *Rhamphidia.*
* " pulchra " " "
* " 2 sp. " " "
Rhipidia extincta Unger, Radoboj. *Limnobia.*
" major " " *Tipula.*
" picta Heer, " *Limnobia.*
" propinqua Heer, " "
* Styringomyia gracilis Loew, amber. *Styringomyia.*
* Tanymera gracilicornis Loew, amber. *Limnophila.*
* " 3 sp. Loew, amber. *Tanymera ?*
* Tanysphyra gracilis Loew, amber. *Limnophila.*
* Tipula sp. vic. T. ochracea Schöberlin, Oeningen. *Tipula.*
* " " " T. pratensis Burmeister, amber. "
* " " " T. rivosa Hope, Aix. "
" " 1 Foerster, Brunstatt. *Tipulidea.*
" " 2 " " "
" æmula Heer, Radoboj. *Tipula.*
" angustata Novák, Krottensee. *Tipula.*
" antiqua Presl, amber (?). Indeterminable.
* " brevirostris Loew, amber. *Tipula.*
" curvirostris Presl, amber (?). Indeterminable.
* " eucera Loew, amber. *Tipula.*
" expectans Novák, Krottensee. *Tipula.*
* " goliath Loew, amber. "
* " infernalis Heer, Aix. "
" lineata " Radoboj. "
" maculipennis Heer, Radoboj. "
" major Giebel, " "
" obtecta Heer, " "
" protogæa Presl, amber (?). Indeterminable.
" ungeri Heer, Radoboj (= T. major). *Tipula.*
" varia " " "
" zignoi Omboni, Chiavon. Irrecognizable.
Toxorhina brevipalpa Loew, amber. *Toxorhina.*
" longirostris " " "
" pulchella " " "
* Trichocera 1 sp. Serres, Aix. *Trichocera ?*
* " 2 sp. Loew, amber. "
* Trichoneura vulgaris Loew, amber. *Limnophila.*
* " 3 sp. " " *Trichoneura ?*

IV. Tabular View of Tertiary Tipulidæ, Systematically Arranged.

(*Species known by name only are prefixed with an asterisk.*)

List of Species.	North American.	European.
Limnobini.		
* Dicranomyia 8 sp. (Loew),	....	Prussian amber.
" longipes Scudd.	Florissant, Colo.	
" stagnorum "	" "	
" inferna "	" "	
" fragilis "	" "	
" stigmosa "	White River, Colo.	
" primitiva "	" "	
" fontainei "	Florissant, Colo.	
" rostrata "	White River, Colo.	
Spiladomyia simplex "	" "	
* Geranomyia 1 sp. (Osten Sacken)	....	Aix, Provence.
* Limnobia sev. sp. (Burmeister)	....	Prussian amber.
" cingulata Heer	....	Radoboj, Croatia.
" deleta Giebel	....	Prussian amber.
" extincta (Unger) Loew	....	Radoboj, Croatia.
" formosa Heer	....	" " (?)
" murchisoni Heer	....	Aix, Provence.
" picta (Heer) Loew	....	Radoboj, Croatia.
" propinqua (Heer) Heyden.	....	Rott on the Rhine.
" tenuis Heer	....	Radoboj, Croatia.
" vetusta Heer	....	" "
Limnocema marcescens Scudd.	Florissant, Colo.	
" lutescens "	" "	
" styx "	" "	
" mortoni "	" "	
Rhamphidini.		
Rhamphidia saxetana Scudd.	" "	
" fæcaria "	" "	
" loewi "	" "	
* " minuta Loew	....	Prussian amber.
* " pulchra "	....	" "
* " 2 other species (Loew)	....	" "
* Styringomyia 1 sp. (Loew)	....	" "
Toxorhina brevipalpa Loew	....	" "
" longirostris "	....	" "
" pulchella "	....	" "
Antocha principialis Scudd.	Florissant, Colo.	
Eriopterini.		
* Erioptera 8 sp. (Loew)	....	Prussian amber.
Erioptera danæ Heyden	....	Rott on the Rhine.

List of Species.	North American.	European.
Eriopterini (*continued*).		
Gnophomyia debilis (Heer) Scudd..	....	Radoboj, Croatia.
Gonomyia profundi "	Florissant, Colo.	
" labefactata "	" "	
" primogenitalis "	" "	
" frigida "	" "	
" sturi (Heyden) Scudd....	....	Rott on the Rhine.
Cladoneura willistoni Scudd........	Florissant, Colo.	
Cladura maculata "	" "	
" integra "	" "	
Limnophilini.		
Limnophila rogersii Scudd.....	" "	
" vasta "	" "	
" strigosa "	" "	
" ruinarum "	" "	
* " brevicornis (Loew) Osten Sacken....................	....	Prussian amber.
Limnophila furcata (Gieb.) Scudd.	....	" "
* " gracilicornis (Loew) Osten Sacken................	....	" "
* Limnophila gracilis (Loew) Osten Sacken......................	....	" "
* Limnophila (Lasiomastix) longicornis (Loew) Osten Sacken.......	....	" "
* Limnophila longipes (1) (Loew) Osten Sacken.................	....	" "
* Limnophila longipes (2) (Loew) Osten Sacken	....	" "
* Limnophila pentagonalis (Loew) Osten Sacken	....	" "
* Limnophila succini (Loew) Osten Sacken......................	....	" "
* Limnophila vulgaris (Loew) Osten Sacken......................	....	" "
* Trichocera 1 sp. (Serres).........	....	Aix, Provence.
* " ? 2 sp. (Loew).........	....	Prussian amber.
" jaccardi (Heer) Scudd.	....	Locle, Switzerland.
* Tanymera? 3 sp. (Loew)........	....	Prussian amber.
* Trichoneura ? 3 sp. "	....	" "
* Calobamon 1 sp. "	....	" "
Anisomerini.		
* Eriocera palpata (Loew) Osten Sacken.....................	....	" "

List of Species.	North American.	European.
Anisomerini (*continued*).		
* Eriocera succini (Loew) Osten Sacken	....	Prussian amber.
* Eriocera 1 other sp. (Osten Sacken)	....	" "
Amalopini.		
* Ula hirtipennis (Loew) Osten Sacken	....	" "
* " ? 3 other sp. " "	....	" "
Cylindrotomini.		
Cyttaromyia fenestrata Scudd......	White River, Colo.	
" princetoniana Scudd..	Florissant, "	
" oligocena " ..	" "	
" cancellata " ..	" "	
" clathrata " ..	" "	
Oryctogma sackenii " ..	" "	
Ptychopterini.		
* Idioplasta spectrum (Loew) Osten Sacken	....	Prussian amber.
Ptychoptera deleta Novák..........	....	Krottensee, Bohemia
Pronophlebia rediviva Scudd......	White River, Colo.	
Tipulinæ.		
Manapsis anomala Scudd..........	Florissant, Colo.	
Rhadinobrochus extinctus Scudd....	" "	
Tipula magnifica "	" "	
" rigens "	" "	
" florissanta "	" "	
" clauda "	" "	
" sepulchri "	Green River, Wyo.	
" angustata Novák............	....	Krottensee, Bohemia
" revivificata Scudd...........	Florissant, Colo.	
" evanitura "	" "	
" maclurei "	" "	
" heilprini "	" "	
" æmula Heer...............	....	Radoboj, Croatia.
" tartari Scudd...............	Florissant, Colo.	
" expectans Novák...........	....	Krottensee, Bohemia
" lineata Heer...............	....	Radoboj, Croatia.
" carolinæ Scudd.............	Florissant, Colo.	
" varia Heer.................	....	Radoboj, Croatia.
" maculipennis Heer.........	....	" "
" limi Scudd.................	Florissant, Colo.	
" internecata Scudd...........	" "	
" subterjacens "	" "	

List of Species.	North American.	European.
Tipulinæ (*continued*).		
Tipula obtecta Heer.............	....	Radoboj, Croatia.
" lethæa Scudd.............	Florissant, Colo.	
" lapillescens Scudd..........	" "	
" spoliata "	Green River, Wyo.	
* " brevirostris Loew..........	....	Prussian amber.
* " eucera "	....	" "
* " goliath "	....	" "
* " infernalis Heer...........	....	Aix, Provence.
" ? major (Unger) Giebel......	....	Radoboj, Croatia.
* " sp. vic. T. pratensis (Burm.)	....	Prussian amber.
* " " " T. rivosa (Hope)....	....	Aix, Provence.
* " " " T. ochracea (Schöberlin)......................	....	Oeningen, Baden.
* Tipula 9 other sp. (Loew)........	....	Prussian amber.
Tipulidea consumpta Scudd........	Florissant, Colo.	
" bilineata "	" "	
" picta "	" "	
" reliquiæ "	" "	
" ("sp. 1" Foerster) Scudd.	....	Brunstatt, Alsatia.
" ("sp. 2" ") "	....	" "
* Nephrotoma ? sp. (Serres)........	....	Aix, Provence.
Ctenophora decheni Heyden.......	....	Rott on the Rhine.
Micrapsis paludis Scudd..........	Florissant, Colo.	

V. Note on Pretertiary Tipulidæ.

The allusions in literature to pretertiary Tipulidæ are all from the mesozoic, and all somewhat unsatisfactory, most of them vague and entirely uncertain. All but two are from Great Britain, and these may be first considered.

The earliest reference is in a paper by Buckman (*Proc. Geol. Soc. Lond.*, iv, 212, 1843), in which he merely refers to a wing found in the upper Lias at Dumbleton, as "supposed to belong to Tipula."

A couple of years later, Murchison, in the second edition of the *Geology of Cheltenham*, figures (Pl. viii, fig. 3) the wing of an insect, of which nothing is said in the text, except in the explanation of the plate, which reads, "Wing (perhaps) of Tipula." On p. 82 it is stated that the insects figured on this plate are "principally" from the lower Lias, which is the only indication of its horizon or locality.

The wing may easily be one of the Tipulinæ, but is too poorly engraved to be certain, and it looks just as much like one of the Neuroptera common in the British Lias. Only examination of the specimen can possibly determine it.

In the same year Brodie, in his *Fossil Insects*, gives in one of the lists of fossils from Purbeck strata: "Tipulidæ; there are several unfigured specimens which belong to this family"; further details are lacking. "Tipulidæ" is given in a similar list in his *Distr. Correl. Foss. Ins.*, p. 15 (1873), while on p. 17 of the same is listed a "Tipula" from the lower Lias of Strensham.

In 1854, Westwood (*Quart. Journ. Geol. Soc. Lond.*, x) makes three references to Tipulidæ. One, which is figured on Pl. xv, fig. 1, is merely an abdomen marked "Tipulideous." It is also mentioned on p. 386, and briefly described later by Giebel (*Ins. d. Vorw.*, 242) as a Tipula. By accident it has been twice inserted in my *Index to Described Fossil Insects* as Nos. 1625 and 1666.

A second from the same place is briefly mentioned (pp. 387, 390) as the "wing of a Tipulideous insect," and is figured on the same plate (fig. 2), in the explanation to which it is named *Corethrium pertinax*. This is described by Giebel under the same name. The name will indicate the wide range then given by Westwood to the term Tipulidæ. I have reproduced this figure in Zittel's *Handbuch der Palæontologie* (fig. 1082), placing it under the Chironomidæ, but it now seems to me that it may equally, if not more probably, be referred to the Limnobinæ. The original would repay study.

A third form is figured by Westwood (Pl. xviii, fig. 20) and briefly mentioned as the "wing of a Tipulideous insect" (p. 390) from the Purbecks of Durdlestone Bay. This, however, is certainly not one of the Tipulidæ, but more probably one of the Rhyphidæ or possibly Bibionidæ; a careful study of the original should be sufficient to decide in this case.

The only other English reference I find is the statement by Theobald (*Brit. Flies*, p. 4, 1891) that he has found in the Wealden a specimen belonging to the Tipulidæ, but in a very imperfect condition.

Outside of England there have been only two references to mesozoic Tipulidæ. The first is that of Weyenbergh, who figured (*Arch. Mus. Teyl.*, ii, pl. xxxiv, fig. 6) an exceedingly obscure fossil from the Jura of Solenhofen under the name of *Tipularia ? teyleri*. The author himself says that no trace of neuration can be seen in the wings. It is quite impossible to place it, except by merest conjecture.

The last instance is to be found in the paper by Brauer, Redtenbacher, and Ganglbaur (*Mém. Acad. St. Petersb.*, (7), xxxvi, 1889) on the Jurassic insects of eastern Siberia; these authors mention among the "Dubiosa," a dipterous pupa "somewhat resembling that of Ptychoptera."

From these unsatisfactory data we may conclude that Tipulinæ and perhaps Limnobinæ have probably been found as far back as the Jura, but that further details regarding specimens will need to be published before the evidence is satisfactory.

VI. Family Tipulidæ.

The two subfamilies of Tipulidæ may be separated by means of the structure of the wings (often the only characteristic part remaining in fair preservation among the fossils) in the following manner:

Auxiliary vein usually ending in the costa and connected by a cross vein with the first longitudinal vein; the latter ends in the costa without aiding in the formation of a trapezoidal cell; last posterior cell in broad contact with the discal cell. . . . . *Limnobinæ.*

Auxiliary vein ending in the first longitudinal vein by abruptly curving down to it, but otherwise free from it; first longitudinal vein, by an apical incurvation and the emission at its base of an oblique costal cross vein, enclosing a trapezoidal cell at the distal extremity of the stigma; last posterior cell touching the discal cell at only one corner . . . . *Tipulinæ.*

In the enumeration of the specimens at the end of the following specific descriptions the numbers of the obverse and reverse of the same specimen are always connected by "and" without any intervening comma, and this typographical method is employed only in expressing this relation.

VII. The Subfamily Limnobinæ.

For the sake merely of simplicity, I use this term to include all the Tipulidæ brevipalpi of authors. There seems to be a greater diversity of structure among them than among the Tipulinæ proper, and they have been divided by Osten Sacken into eight groups, which may be regarded as tribes, the relative importance of which in recent and ancient times has been pointed out in a preceding table, from which it will appear that every one of them has been recognized among the fossils.

The Limnobini take precedence as they do among modern types, while the Rhamphidini (in Europe in amber only), the Eriopterini, and Limnophilini follow in numbers, the remaining groups being of least importance and three of them altogether lacking in American deposits; while the Cylindrotomini, the only remaining tribe appearing in America, is lacking in the European tertiaries. The Anisomerini are represented in Europe by three species of Eriocera in amber, the Amalopini by four species of Ula in amber, and the Ptychopterini by a single species of Idioplasta in the same and by a Ptychoptera at Krottensee. It thus appears that with the exception of the Ptychopterini all the tribes represented in the European rock deposits occur also in America, while America is also well represented in the tribes Rhamphidini and Cylindrotomini. The American genus Pronophlebia cannot yet be placed.

Especially difficult of determination among the Limnobini has been the position or the absence of the subcostal and marginal cross veins, which play so important a part in the arrangement and distinction of the genera. It is by no means impossible that in some instances I may have erred in my interpretation of marks upon the stones, but I have endeavored to give all points a rigid scrutiny. It is certainly here that errors are most likely to have been made.

Nearly one hundred additional specimens from Florissant, more or less imperfect, but certainly belonging to this subfamily, await study; and I may add that there is a specimen in the collection of the U. S. Geological Survey (No. 1470) which represents an interesting new genus falling near Atarba with distinct tibial spurs, but which I refrain from characterizing here, as I can give now no illustration of it.

As the number of genera in no one of the tribes exceeds three, I have thought it best to include all the genera of the subfamily in one table, as follows:

Table of the Genera of American Fossil Limnobinæ.

A¹. Only a single submarginal cell.
  b¹. The normal first posterior cell, lying (in forms having but one submarginal cell) between the second and third longitudinal veins, closed, forming at base a supernumerary discal cell. . . . . *Cyttaromyia.*
  b². First posterior cell open throughout.
    c¹. Five posterior cells. . . . . *Oryctogma.*
    c². Four posterior cells.
      d¹. The first longitudinal vein ends in the second longitudinal vein.
        e¹. Discal cell closed; submarginal much longer than first posterior cell. . . . . *Dicranomyia.*
        e². Discal cell open; submarginal scarcely longer than first posterior cell. . . . . *Spiladomyia.*
      d². The first longitudinal vein ends in the costa.
        e¹. A marginal cross vein.
          f¹. Marginal cell excessively long, much exceeding in length the breadth of the wing. . . . . *Limnocema.*
          f². Marginal cell normal, not so long as breadth of cell (applicable to fossil species only). . . . . *Antocha.*
        e². No marginal cross vein. . . . . *Rhamphidia.*

A². Two submarginal cells.
  b¹. Third longitudinal vein arising at normal distance from the second.
    c¹. First submarginal cell not, or hardly more than, half as long as the second . . . . *Gonomyia.*
    c². First submarginal cell much more than half as long as the second.
      d¹. Tibiæ without spurs at the tip.
        e¹. Auxiliary vein ending at a distance beyond the origin of the second longitudinal vein considerably more than equal to the breadth of the wing; third posterior cell petiolate. . . . . *Cladoneura.*
        e². Auxiliary vein (in the fossil species) ending at a distance beyond the origin of the second longitudinal vein less than, sometimes only about half, the breadth of the wing; second posterior cell petiolate. . . . . . *Cladura.*
      d². Tibiæ with spurs at the tip. *Limnophila.*
  b². Third longitudinal vein arising from the second at a very short distance beyond the base of the latter. . . . . *Pronophlebia.*

Tribe CYLINDROTOMINI.

This tribe is placed first in the series instead of near the end really because the arrangement of the table just given requires the early appearance of the two genera recognized in the American rocks. Its place in the arrangement given by Osten Sacken is rather at the other end of the series in nearer proximity to the Tipulinæ; but it may be noticed that in some of the features in the neuration of the wing, as in the arrangement in the vicinity of the stigma, in which it approaches the Tipulinæ, it also shows most resemblance to the Limnobini.

Although Loew referred some amber species to Cylindrotoma, Osten Sacken, who has since examined them, says they are all Limnophilæ, so that the species described below, six species of two genera, both extinct, are the only ones known in a fossil state.

Cyttaromyia Scudder.

Cyttaromyia Scudd., *Bull. U. S. Geol. Geogr. Surv. Terr.*, iii, 751 (1877); *Tert. Ins. N. A.*, 574–575 (1891).

This genus was founded, in 1877, upon a specimen showing the apical half of a single wing, somewhat distorted by folding, and rather obscurely preserved, found by Denton among the first known tertiary insects of North America, on the lower White River of Colorado and Utah. A number of specimens and several species of the same genus have since been obtained by me from the same spot, while exploring for the U. S. Geological Survey, but no further specimens of the same species. The beds at Florissant have also yielded several species of the genus and permit a more accurate and complete account of the generic characteristics. These specimens show that my original description was faulty in its interpretation of the structural elements of the wing: the cells lying beyond the "secondary discal cell" were wrongly regarded as submarginal cells, for they belong to the "posterior" series, and all the errors of statement followed from this wrong interpretation; but the neuration is none the less remarkable, and, so far as I have been able to discover, unique.

The wings are very long and slender, four or more times as long as broad. The auxiliary vein ends in the costa, without any sudden curve, at the beginning of the stigma. The first longitudinal vein, by very gradually curving downwards, ends in the second, which curves upward to meet it, forming a long and slender marginal cell; there is neither subcostal nor marginal cross vein. The second longitudinal vein arises near the middle of the wing, varying in the species, is generally considerably arcuate at the base, the præfurca considerably shorter than the rest of the vein, which terminates above the apex of the wing. The third longitudinal vein arises from the second a little before the tip of the auxiliary vein and is met by the short cross vein at a distance from its origin equal to the length of the short cross vein. The space between the third longitudinal vein and the upper branch of the fourth longitudinal vein, normally—and so far as I am aware invariably—open in all Limnobinæ, is here closed about half way to the tip of the wing (varying in different species) by a cross vein, from which springs an intercalary vein, *thus doubling the upper posterior cell at the apex and forming of its basal portion a supernumerary discal cell*, essentially a counterpart of the normal discal cell and overlying it; it would seem to be formed by a mesial forking of the third longitudinal vein, and the base of the fork then connected by a cross vein to the uppermost branch of the fourth longitudinal vein. Both discal cells are usually very elongate (least so in the species upon which the genus was founded), the upper, or supernumerary, usually the longer and narrower, though they are subequal in length. There are five posterior cells and the great cross vein strikes the fourth longitudinal vein at the discal cell close to the base of the latter. The fifth longitudinal vein is very gently arcuate beyond this cross vein, while the sixth and seventh are straight throughout, the latter, however, arcuate at the extreme tip and almost reaching the middle of the wing. The legs are long and slender and the tibiæ without spurs at the tip.

This genus was well developed in the American oligocene, especially in the White River basin, where it seems to include the larger number of species of Limnobinæ. I leave their description, however, to another occasion and characterize at this time only the species found at Florissant, none of which appear to be identical with those from the White River basin. The genus does not appear to be found among the European fossil Limnobinæ heretofore published.

This genus, it seems to me with little doubt, must fall into the Cylindrotomini, although the tibiæ lack spurs. I am forced to this conclusion by the close resemblance of the neuration to that of Cylindrotoma and Liogma, notwithstanding the striking differences. Especially the formation of the marginal cell is essentially the same, while the absence of the anterior cross veins and the general behavior of the auxiliary vein sustain this view. It seems to me very doubtful if the presence or absence of tibial spurs can be of so great significance in the Limnobinæ as seems to be accorded it in the classification of Baron Osten Sacken. But, on the other hand, it is due to classing this genus among the Cylindrotomini that this tribe is made to show such an anomalous preponderance in the American tertiaries.

The species mentioned below may be grouped as in the following table:

Table of the Species of Cyttaromyia.

Normal discal cell hardly more than twice as long as broad.........*fenestrata.*
Normal discal cell nearly or quite three times as long as broad.
  Discal cell shorter, or no longer, than third posterior cell.
    Marginal cell but little longer than breadth of wing.....*princetoniana.*
    Marginal cell nearly one third longer than breadth of wing...*oligocena.*
  Discal cell longer than third posterior cell.
    Proximal portion of marginal cell (measured from the point of origin of third longitudinal vein) nearly one third longer than the distal portion; præfurca almost as long as the remainder of second longitudinal vein..................................*cancellata.*
    Proximal portion of marginal cell only one seventh longer than the distal portion; præfurca only about half as long as the remainder of second longitudinal vein............................*clathrata.*

Cyttaromyia fenestrata.

Cyttaromyia fenestrata Scudd., *Bull. U. S. Geol. Geogr. Surv. Terr.*, iii, 751–752 (1877); *Tert. Ins. N. A.*, 575–576, pl. 5, fig. 78 (1891).

White River, Utah.

Cyttaromyia princetoniana.

Pl. 1, fig. 1.

Wings four times as long as broad, the marginal cell but very little longer than the breadth of the wing, the proximal much longer than the distal portion. Auxiliary vein terminating midway between the origin of the third and the tip of the first longitudinal vein. Second longitudinal vein arising well beyond the middle of the wing, the præfurca about two thirds as long as the rest of the vein. Supernumerary discal cell considerably broadening apically and shorter than the first posterior cell. Discal cell equal, slightly less than three times as long as broad, its distal extremity lying considerably within that of the supernumerary discal cell, shorter than the third posterior cell. Fifth posterior cell of equal width with the discal cell. Stigma normal.

This species is of about the size of the preceding.

Length of wings, 8.75 mm.; fore femora, 5.5? mm.; fore tibiæ, 6.5 mm.; mid femora, 4.75 mm.; mid tibiæ, 5.75 mm.; hind femora, 5.5 mm.; hind tibiæ, 6.5 mm.

Florissant, Colorado. Five specimens, Nos. 345, 7381, 7591, 13051; and from the Princeton collection No. 1.770.

Cyttaromyia oligocena.

Pl. 1, fig. 2.

Wings scarcely more than four times as long as broad, the marginal cell more than one fourth longer than the breadth of the wing, the proximal nearly one half longer than the distal portion. Auxiliary vein terminating beyond a point midway between the origin of the third and the tip of the first longitudinal vein. Second longitudinal vein arising at the middle of the wing, the præfurca about one fourth shorter than the remainder of the vein. Supernumerary discal cell broadening a little apically and as long as the first posterior cell. Discal cell equal, three times as long as broad, its distal extremity lying considerably within that of the supernumerary discal cell, a little shorter than the third posterior cell. Fifth posterior broader than the discal cell. Stigma normal.

This is the largest species of the genus.

Length of wings, 9.65 mm.; fore femora, 5.25? mm.; fore tibiæ, 5.75 mm.; mid femora, 5.5? mm.; mid tibiæ, 6.25 mm.; hind femora, 6.25 mm.

Florissant, Colorado. One specimen, No. 13259.

Cyttaromyia cancellata.

Pl. 1, fig. 7.

Wings slightly less than four times as long as broad, the marginal cell nearly one third longer than the width of the wing, its proximal fully a third longer than the distal portion. Auxiliary vein terminating somewhat short of a point midway between the origin of the third and the tip of the first longitudinal vein. Second longitudinal vein arising slightly before the middle of the wing, the præfurca almost as long as the remainder of the vein. Supernumerary discal cell very slender, gently broadening apically, longer than the first posterior cell. Discal cell equal, fully three times as long as broad, slightly longer than the third posterior cell, its distal extremity on a line with that of the supernumerary discal cell. Fifth posterior no broader than the discal cell. Stigma very faint.

Length of wings, 9 mm.

Florissant, Colorado. One specimen, No. 86.

Cyttaromyia clathrata.

Pl. 1, fig. 8.

Wings more than four times as long as broad, the marginal cell more than one fourth longer than the breadth of the wing, its proximal not more than one fifth longer than its distal portion. Auxiliary vein terminating midway or at slightly less than midway from the origin of the third to the tip of the first longitudinal vein. Second longitudinal vein arising at or scarcely before the middle of the wing, pretty strongly arcuate at base, the præfurca only a little more than half as long as the remainder of the vein. Supernumerary discal cell long and slender, very slightly enlarging apically, considerably longer than the first posterior cell. Discal cell enlarging apically, almost four times as long as broad, about as long as the third posterior cell, its distal extremity lying considerably within that of the supernumerary discal cell. Fifth posterior broader than the discal cell. Stigma faint.

This is the smallest species of the genus.

Length of wings, 7.25 mm.; fore femora, 5 mm.; fore tibiæ, 6 mm.; mid tibiæ, 5.75 mm.; hind femora, 5.25 mm.; hind tibiæ, 6.6 mm.

Florissant, Colorado. Three specimens, Nos. 3520, 8649 of my collection, No. 1510 U. S. Geological Survey.

ORYCTOGMA (ὀρυκτὸς, ὄγμος) gen. nov.

I separate here a single species which seems to belong to the Cylindrotomini and to be most nearly allied to Cylindrotoma and Liogma, but which differs from them as from other living Cylindrotomini in that the first longitudinal vein not only ends distinctly in the second, as in Cyttaromyia, Dicranomyia, and others, but is also connected apically with the costa by a cross vein as distinct as its own deflected apex, the apical portion of the vein appearing rather to fork and send one shoot in each direction. The disposition of the venation at the ends of the basal cells is much as in Cylindrotoma, and not as in Liogma and Triogma, the short cross vein being present and as long as the peduncle of the third longitudinal vein. The discal cell is brief, and the upper of the three veins emitted from its extremity is deeply forked, so that there are five posterior cells. The tibiæ are distinctly spurred, the spurs short.

These characters hardly permit it to be classed with existing genera, though its relationship to the Cylindrotomini is intimate. I am the more assured of the correctness of this view because of the existence in the collection made at Florissant for the U. S. Geological Survey of another allied genus, hitherto unknown, which has a single submarginal cell and spurred tibiæ, and in which the first longitudinal vein ends in precisely the same manner, though the auxiliary vein certainly ends in the costa immediately previous to it. Unfortunately most of the remainder of the neuration is obscured in the single specimen seen (No. 1470).

Oryctogma sackenii.

Pl. 1, fig. 6.

Wings ample, three and a half times longer than broad. The auxiliary vein appears to end free somewhat before the base of the third longitudinal vein. The stigma is distinct, somewhat broad and triangular. The second longitudinal vein arises in a faintly clouded spot at some distance beyond the middle of the wing without basal arcuation, the præfurca being straight and but little shorter than the apical portion of the vein. The marginal cell is only as long as the breadth of the wing and rather broad in the middle. The discal cell is distinctly shorter than the third posterior cell, considerably broader apically than at base. The second posterior cell has a short peduncle; the fifth posterior cell is about twice as long as broad, narrowing a little apically. The fifth longitudinal vein is somewhat bent at the great cross vein; the seventh longitudinal vein is straight like the sixth and ends at or before the middle of the wing. A faint cloud attends the cross veins at the end of the basal cells.

Length of wings, 13 mm.; fore femora, 5.5 mm.; tibiæ, 8 mm.; tarsi, 12.5 mm.; mid femora, 7 mm.; tibiæ, 8.5 mm.; tarsi, 11+ mm.; hind femora, 7 mm.; tibiæ, 7.5 mm.; tarsi, 12 mm.

Florissant, Colorado. One specimen, No. 206.

Named for Baron C. R. von Osten Sacken, without whose studies on recent Tipulidæ, the investigation of the fossil American forms would be attended with far greater difficulty.

Tribe LIMNOBINI.

This is one of the dominant tribes of Limnobinæ, whether now or in past times. Five genera and more than thirty fossil species are known, the only extinct genera being two—Spiladomyia with one, and Limnocema with four species, all found in North American rocks. Dicranomyia is shared about equally between the Colorado tertiaries and the Baltic amber, while Geranomyia and Limnobia are known only from Aix and other European deposits, the latter genus in considerable numbers.

DICRANOMYIA Stephens.

Dicranomyia Stephens, *Catal. Brit. ins.*, 243 (1829).

This genus, according to Osten Sacken, probably occurs in all parts of the world, although it may be principally at home in the more temperate latitudes. It appears to have been well developed in our tertiaries, and occurs in equal abundance in the European. The eight fossil European species, still unpublished, all come from amber, and were referred by Loew to a new genus, Ataracta, which Osten Sacken says is "apparently synonymous with Dicranomyia." In this country, besides the three species already described by me from the lower White River of Colorado and Utah (and to which two of the species described by me as Tipulæ must probably be joined) the U. S. Geological Survey has two others from the same locality, and five are described below from Florissant. The described species may be separated by the following table:

Table of the Species of Dicranomyia.

Marginal cell shorter than the breadth of the wing.
  Distal portion of marginal cell almost as long as the proximal.
    Larger species, with wings about 7 mm. long............... *longipes.*
    Smaller species, with wings but little more than 5 mm. long. *stagnorum.*
  Distal portion of marginal cell much shorter than the proximal.

Subcostal cross vein lying just before the origin of the second longitudinal vein................................*inferna.*
Subcostal cross vein lying at the tip of the auxiliary vein, beyond the origin of the second longitudinal vein.*
Auxiliary vein ending at a distance beyond the origin of the second longitudinal vein equal to the width of the marginal cell.
Great cross vein running in exact continuity with the basal portion of the anterior branch of the fourth longitudinal vein..*fragilis.*
Great cross vein striking the discal cell beyond the origin of the anterior branch of the fourth longitudinal vein. *stigmosa.*
Auxiliary vein ending barely beyond the origin of the second longitudinal vein............................*primitiva.*
Marginal cell as long as the breadth of the wing.
Smaller species, the wings less than 6 mm. long.............*fontainei.*
Larger species, the wings more than 7 mm. long...............*rostrata.*

Dicranomyia longipes.

Pl. 1, figs. 4, 5.

This is one of the largest species of those found at Florissant. The auxiliary vein ends barely beyond the origin of the præfurca, but the position of the subcostal cross vein cannot be determined. The præfurca arises considerably beyond the middle of the wing, though nearer to it than in the other species having, like this, a marginal cell shorter than the breadth of the wing; the distal portion of this cell is of about the same length as the proximal, and it terminates by the abrupt descent of the first longitudinal vein upon the second. The discal cell is closed, and is much narrower apically than at base by the length of the third posterior cell. The legs are very long and slender.

Length of wings (in largest specimen), 7 mm.; fore femora, 5.5 mm.; fore tibiæ, 6.25 mm.; fore tarsi, 6? mm.; mid and hind femora, 7.25 mm.

Florissant, Colorado. Two specimens, Nos. 214, 5582.

Dicranomyia stagnorum.

Pl. 2, figs. 4, 8.

In this species, the most abundant in specimens known, the auxiliary vein terminates barely beyond the origin of the præfurca,

* This is not quite certain as regards *D. stigmosa*, but appears to be the case.

and the subcostal cross vein lies as much before that origin as a little more than half the width of the marginal cell. The præfurca arises at about three fifths the distance from the base of the wing to the tip; the marginal cell is distinctly shorter than the breadth of the wing, its distal portion almost as long as the proximal. The first longitudinal vein descends obliquely but with some abruptness upon the second. The discal cell is closed, broadest apically, the second and third posterior cells of equal length, and the great cross vein strikes the lower inner angle of the discal cell. The legs are long and very slender, and the tarsi show the peculiar arcuation of the apical joint characteristic of Dicranomyia; the tibiæ have no spurs.

One specimen (No. 3683) has the discal cell open and continuous with the third posterior cell; in others the cross vein closing the cell is weak.

Length of wings, 5–6.5 mm., aver. 5.5 mm.; fore femora, 4.75 mm.; tibiæ, 5.6 mm.; tarsi, 6.5 mm.; mid femora, 5.2 mm.; tibiæ, 5.25 mm.; tarsi, 5.75 mm.; hind femora, 5.5 mm.; tibiæ, 6.25 mm.; tarsi, 5.5 mm. The leg measurements are from the smallest specimen.

Florissant, Colorado. Thirty-one specimens, Nos. 60, 73, 223, 581, 710, 774, 779, 808, 982, 1486, 2687, 2927, 3683, 6273 and 6416, 8439, 8472, 8751, 8865, 8904, 9127, 9626, 9665, 10268, 12230, 12612, 12760, 13043, 13684 of my collection; Nos. 1.727, 1.791 of the Princeton collection; No. 1512 U. S. Geological Survey.

Dicranomyia inferna.

Pl. 1, fig. 3.

Here the auxiliary vein terminates a very short distance beyond, and the subcostal cross vein lies at an equal distance before the origin of the præfurca, which arises beyond the basal two fifths of the wing. The marginal cell is short, considerably shorter than the breadth of the wing, and the distal portion considerably shorter than the proximal. The first longitudinal vein descends with considerable abruptness upon the second, which curves gently upward to meet it. The discal cell, which is closed, is slightly the broadest apically, and the second and third posterior cells are of equal length. The legs are long and slender, but in no case very fully preserved; they are relatively a little shorter than in the two preceding species, the hind femora being shorter than the wings.

Length of wings, 6.75 mm.; fore femora, 4.75 mm.; tibiæ, 5.5 mm.; hind femora, 5.75 mm.; tibiæ, 6.25 mm.

Florissant, Colorado. Three specimens, Nos. 3751, 8050 and 8151, 13715. The last is accompanied and partly overlain by a specimen of *D. fontainei*.

Dicranomyia fragilis.

Pl. 2, fig. 3.

This appears to be the most abundant species of Dicranomyia at Florissant after *D. stagnorum*. The auxiliary vein terminates at a little distance beyond the origin of the præfurca, equal to about the width of the marginal cell, and has the subcostal cross vein at its tip. The præfurca arises at no great distance beyond the middle of the wing, but the marginal cell is nevertheless much shorter than the breadth of the wing, and its distal much shorter than its proximal portion. The first longitudinal vein descends obliquely though rather rapidly to the second longitudinal, giving a pointed extremity to the marginal cell. The discal cell is closed and a little broader apically than at base, the second and third posterior cells short and subequal. The great cross vein strikes the inner lower angle of the discal cell. A delicate fringe of moderately long microscopic hairs can sometimes be seen around the entire wing, subrecumbent and stouter on the costa than elsewhere, nearly erect on the lower margin. Legs slender, the femora gradually thickened at apex, the tibiæ apically spined, and the apical joint of tarsi characteristically arcuate.

Length of wings, 6–6.5 mm.; of legs in smallest specimens: fore femora, 4.5 mm.; tibiæ, 5.75 mm.; tarsi, 6 mm.; mid femora, 6.3 mm.; tibiæ, 6.4 mm.; tarsi, ?; hind femora, 6.4 mm.; tibiæ, 6.75 mm.; tarsi, 4.75 mm.

Florissant, Colorado. Eleven specimens, Nos. 1388, 1997, 4701, 5463, 6708, 7207, 8553, 8716, 11831, 12127, 13258.

Dicranomyia stigmosa.

Dicranomyia stigmosa Scudd., *Bull. U. S. Geol. Geogr. Surv. Terr.*, iii, 746–748 (1877); *Tert. Ins. N. A.*, 568–570, pl. 5, figs. 16, 17, 25–27, 42, 43, 68, 69 (1891).

? *Tipula tecta* Scudd., *Bull. U. S. Geol. Geogr. Surv. Terr.*, iii, 752–753 (1877); *Tert. Ins. N. A.*, 577, pl. 5, figs. 46, 47 (1891).

In the description given of this species I have inadvertently spoken of the marginal as the subcostal cross vein. The specimen described by me as *Tipula tecta* certainly belongs to the Limnobinæ, and is most probably referable to this species.

Lower White River, at the boundary between Colorado and Utah.

Dicranomyia primitiva.

Dicranomyia primitiva Scudd., *Bull. U. S. Geol. Geogr. Surv. Terr.*, iii, 748 (1877); *Tert. Ins. N. A.*, 570–571, pl. 5, figs. 20, 21, 65–67 (1891).

The auxiliary vein in the only well-preserved specimen of this species is excessively faint, but appears to terminate barely beyond the origin of the præfurca and the subcostal cross vein to be at its tip. I have accordingly placed it in the table next *D. fragilis* and *D. stigmosa*.

Lower White River, at the boundary line between Utah and Colorado.

Dicranomyia fontainei.

Pl. 2, fig. 1.

This is one of the smallest of the Florissant species, and differs from all the others in having the marginal cell as long as the breadth of the wing. The auxiliary vein is also much longer than in the others, extending far beyond the origin of the præfurca and apparently, though this is obscure, with the subcostal cross vein at its tip. Further, the first longitudinal vein falls upon the second at a slighter angle, giving the marginal cell an unusually pointed tip. The præfurca arises not very far beyond the middle of the wing, and the distal portion of the marginal cell is not much more than half as long as the proximal. The discal cell is closed, though the cross vein separating it from the third posterior cell is very faint, as is also the great cross vein, which appears to strike the inner lower angle of the discal cell. The second and third posterior cells are subequal, the second slightly the longer. The legs are poorly preserved on the two specimens known, but the hind femora appear to be somewhat shorter than the wings.

Length of wings, 5.5–5.75 mm.; hind femora, 5 mm.

Named for Prof. W. M. Fontaine of the U. S. Geological Survey.

Florissant, Colorado. Two specimens, Nos. 173, 13715, the latter partly overlying a specimen of *D. inferna*.

Dicranomyia rostrata.

Dicranomyia rostrata Scudd., *Bull. U. S. Geol. Geogr. Surv. Terr.*, iii, 749 (1877); *Tert. Ins. N. A.*, 571–572, pl. 5, figs. 40, 41, 63, 64 (1891).

Tipula decrepita Scudd., *Bull. U. S. Geol. Geogr. Surv. Terr.*, iii, 752 (1877); *Tert. Ins. N. A.*, 576–577, pl. 5, figs. 56, 57 (1891).

Renewed examination of the material formerly studied shows these two supposed distinct species to be in all probability identical.

Lower White River, at the boundary between Utah and Colorado.

SPILADOMYIA Scudder.

Spiladomyia Scudd., *Bull. U. S. Geol. Geogr. Surv. Terr.*, iii, 749 (1877).

In this genus the discal cell is open and continuous with the second posterior cell, while the first posterior cell is scarcely longer than the submarginal. In other respects it is closely allied to Dicranomyia. In a second species belonging to the U. S. Geological Survey (No. 1069) the auxiliary vein continues to the stigma and as it otherwise agrees tolerably well with the described species where the auxiliary vein is very obscure, the generic characterization given should probably be modified to that extent. In both species, the second longitudinal vein appears to rise towards the first at their apical junction, giving the terminal portion the appearance of being a continuation of the first rather than of the second longitudinal vein. I leave the description of the new species to another occasion.

Spiladomyia simplex.

Spiladomyia simplex Scudd., *Bull. U. S. Geol. Geogr. Surv. Terr.*, iii, 750 (1877); *Tert. Ins. N. A.*, 573, pl. 5, figs. 37, 38 (1891).

Lower White River, next the boundary between Colorado and Utah.

LIMNOCEMA (*λίμνη, κεῖμαι*) gen. nov.

This name is proposed for a group of species which seem to be more nearly allied to Limnobia and Trochobola than to any other living genus, but which are peculiar for the presence of a marginal cross vein near the extreme apex of the wing, well beyond the position of the stigma, which is here marked only by a faint cloud; and for the great length of the posterior cells, as in Dicranoptycha, for example. The wings are a little less than four times as long as broad. The auxiliary vein is very long, terminating at or beyond the origin of the third longitudinal vein, and is connected at some distance before its tip with the first longitudinal vein by the subcostal cross vein. The second longitudinal vein arises well before the middle of the wing, the præfurca but little declivent, so that the marginal cell is slender throughout and exceedingly long, since the marginal cross vein is situated at but little before the tip of the first longitudinal vein and scarcely at all affects the curvature either of that or of the second longitudinal vein. The single submarginal is considerably longer than the first posterior cell, and all the posterior cells, four in number, are long, the discal cell being closed and generally less than twice as long as broad. The great cross vein strikes the discal cell slightly beyond the base of the latter. The legs are slender, the tips of the tibiæ unarmed. The abdomen appears to have been longitudinally striped.

Four species occur, each of them at Florissant only; they may be separated by the following table:

Table of the Species of Limnocema.

Second longitudinal vein arising within the basal third of the wing. . *marcescens.*
Second longitudinal vein arising beyond the basal third of the wing.
 Subcostal cross vein lying a long distance from the tip of the auxiliary vein.
  Præfurca arising before the middle of the wing; submarginal much longer than the first posterior cell. . . . . *lutescens.*
  Præfurca arising at or beyond the middle of the wing; submarginal scarcely longer than the first posterior cell. . . . . *styx.*
 Subcostal cross vein lying a short distance from the tip of the auxiliary vein. *mortoni.*

Limnocema marcescens.

Pl. 2, fig. 7.

This is the largest species of the genus, and remarkable for the excessive length of the marginal cell, which is more than half as long as the wing. The auxiliary vein ends just at the origin of the third longitudinal vein, but the subcostal cross vein cannot be made out. The second longitudinal vein arises distinctly within the basal third of the wing, and the marginal cross vein is so near its tip that the proximal and distal portions of the marginal cell are about equal. The discal cell is relatively small and narrower apically than at base, and the second and third posterior cells are slender and twice as long as the discal cell. The wings are uniformly and very slightly fuliginous, but no trace of stigma can be detected. The hind (or middle ?) femora are much shorter than the wings.

Length of wings, 10.75 mm.; hind (or mid ?) femora, 8 mm.; tibiæ, 9 mm.

Florissant, Colorado. One specimen, No. 13069.

Limnocema lutescens.

Pl. 2, fig. 2.

The auxiliary vein in this species ends a little way beyond the origin of the third longitudinal vein, and the subcostal cross vein is at a considerable distance before it, about half way to the origin of the præfurca, and at about the middle of the wing. The second longitudinal vein arises at some distance before the middle of the wing, and the marginal cross vein is at some distance before the tip of the second longitudinal vein, so that the distal is but slightly longer than the proximal portion of the marginal cell. In neither of the known specimens are the parts about the discal cell well preserved, but the posterior cells can be seen to be very long, and the submarginal to be much longer than the first posterior cell. One of the specimens shows a slight infumation in the position of the stigma.

This species bears a close general resemblance to the larger *Rhamphidia saxetana* from the same beds, which lacks any marginal cross vein.

Length of wings, 8.2–9.5 mm.; fore femora of larger specimen, 5.75 mm.; tibiæ, 6.75 mm.; mid femora of smaller specimen, 5.5 mm.; tibiæ 5.75 mm.

Florissant, Colorado. Two specimens, Nos. 603, 11817.

Limnocema styx.

Pl. 2, fig. 6.

This species is very near the last, and the single specimen is imperfect by the loss of the tip of the wing. It differs from the preceding mainly in these points: The subcostal cross vein, though situated, as there, about midway between the tip of the auxiliary vein and the base of the præfurca, is very far beyond the middle of the wing, for the præfurca arises not far from and probably itself beyond the middle of the wing. The position of the marginal cross vein, being beyond the break, cannot be determined, and it is therefore possible that this species does not belong in this genus at all. The submarginal is but very little longer than the first posterior cell. The discal cell must be of excessive length if it is not open, as it cannot be seen on the fragment, which is supposed to include just about one half of the apical cellular area, that is, the region beyond the basal cells. The wing is perfectly clear except that faint signs of a stigma can be seen just beyond the tip of the auxiliary vein.

Length of fragment of wing, 8 mm.; presumed length of wing, 9.5 mm.; hind femora, 6 mm.; tibiæ, 6 25 mm.

Florissant, Colorado. One specimen, No. 11389.

Limnocema mortoni.

Pl. 2, fig. 5.

A single specimen with its reverse represents the smallest of the species of this genus. The outspread wings show a faint broadly diffused infumation in the region of the stigma, but are otherwise, and excepting the dark veins, hyaline. The auxiliary vein ends at a noticeable distance beyond the origin of the third longitudinal vein, and the subcostal cross vein lies directly over the latter, and so at considerably less than half way from the tip of the auxiliary vein to the origin of the præfurca. The latter arises somewhat before the middle of the wing, and the marginal cross vein is close before the tip of the first longitudinal vein, so that the marginal cell is very long, and its distal a little longer than its proximal portion. The submarginal is much longer than the first posterior cell,—indeed by as much as the length of the discal cell, which is here only about half as long again as broad, and considerably less than half as long as the slender posterior cells beyond it. A single femur is all that is preserved of the legs—a fore femur, to judge by its position, and in that case exceptionally long, being but little shorter than the wings.

Length of wings, 7.9 mm.; fore? femora, 6.25 mm.

Named in memory of Dr. S. G. Morton, the distinguished Philadelphia naturalist of a past generation.

Florissant, Colorado. One specimen, Nos. 8038 and 8215.

Tribe RHAMPHIDINI.

I have chosen to call this tribe by a name derived from one of its principal genera, rather than to use the compound term *Limnobina anomala* introduced by Osten Sacken. The Rhamphidina of this writer is a more restricted group within this.

Four genera and a dozen species of this tribe are known in a fossil state, all the genera but one, Antocha, being found in amber. None of the genera are extinct, though two of them were first known from amber inclusions, and in consequence have been the subject of many comments by Loew and Osten Sacken, who find in them striking examples of the resemblance between the amber fauna and the existing fauna of America. None of this tribe have been recognized in the European rock deposits, but Florissant furnishes two genera and four species.

RHAMPHIDIA Meigen.

Rhamphidia Meig., *Syst. Beschr. eur. zweifl. Ins.*, vi, 281 (1830).

In this genus are here placed several species which agree in their neuration quite as well with Toxorhina, but appear to lack the elongated rostrum of the latter genus. The neuration, however, shows so many minor points of departure from the described characteristics of each of these genera, that the characters of Rhamphidia must be made more elastic for their reception. Among themselves they differ also in similar particulars, and until the fossil species indicated from amber are better known, enabling us to compare all the Rhamphidini living and fossil, it will probably be best to include these under Rhamphidia, to which they appear to be most nearly allied. There is no trace in them of apical spurs to the tibiæ. Attention should especially be directed in studying the fossil species to the length of the auxiliary vein, the point of origin of the præfurca, and the position of the great cross vein.

This genus contains but few species, most of which are found in Europe, the others in eastern North America, Porto Rico, and Brazil (one each). Four undescribed species are recorded by Loew as occurring in Baltic amber. The three species found at Florissant may be thus separated:

Table of the Species of Rhamphidia.

Auxiliary vein ending opposite the origin of the third longitudinal vein. .*saxetana.*
Auxiliary vein ending about midway between the origin of the second and third longitudinal veins.

Third longitudinal vein arising about the middle of the wing; great cross vein striking the fourth longitudinal vein before the discal cell. . . . *fæcaria.*
Third longitudinal vein arising well beyond the middle of the wing; great cross vein striking the fourth longitudinal vein at the base of the discal cell . . . . *loewi.*

Rhamphidia saxetana.

Pl. 3, fig. 4.

An exceptionally large species. The auxiliary vein ends opposite the origin of the third longitudinal vein, but the position of the subcostal cross vein cannot be made out. The præfurca arises at the middle of the wing, is arcuate at its base and then subparallel to the first longitudinal vein, and not half so long as the remainder of the vein. The first longitudinal vein is carried much farther toward the apex of the wing than in the other species, farther beyond the long auxiliary vein than the breadth of the wing. The submarginal is not very much longer than the first posterior cell. The discal cell is rather short, and the posterior cells beyond it more than twice as long as it. The great cross vein strikes the discal cell close to the base of the latter. The costal margin of the wing is very thick and deeply colored; the wing itself is hyaline, with scarcely even a fuliginous tint at the stigma. The legs are slender, the femora gradually thickening toward the tip.

Length of wings, 12 mm.: fore femora, 8.25 mm.; tibiæ, 9.75 mm.; tarsi, 9 mm.; mid femora, 9.5 mm.; tibiæ, 9.25 mm.; hind femora, 9.5 mm.

One cannot but be struck by the close general resemblance of this species to the much smaller *Limnocema lutescens* from the same beds, a species with a marginal cross vein.

Florissant, Colorado. One specimen, No. 10490.

Rhamphidia fæcaria.

Pl. 3, fig. 5.

The auxiliary vein ends midway between the origin of the second and third longitudinal veins, the subcostal cross vein at its very tip. The præfurca arises at the middle of the wing, is gently arcuate and slightly declivent and distinctly more than half as long as the remainder of the vein. The first longitudinal vein ends as far from the origin of the third as that is from the origin of the second longitudinal vein, and at a less distance beyond the tip of the auxiliary vein than the breadth of the wing. The submarginal is much longer than the first posterior cell. The discal cell is moderately small, equal, about half as long again as broad and distinctly but not greatly shorter than the posterior cells beyond it. The great cross vein strikes the fourth longitudinal vein at a slight distance before the discal cell. The seventh longitudinal vein is rather short. A slight infumation marks broadly the position of the stigma, the veins are all exceptionally heavy and fusco-luteous, the wing barely infumated. Three legs are preserved on the single specimen known and are presumed to be the hind pair and one middle leg.

Length of wings, 7.5 mm.; mid femora, 5.2 ? mm.; tibiæ, 5.5 mm.; hind femora, 5.2 ? mm.; tibiæ, 5.75 mm.; tarsi, 5 mm.

Florissant, Colorado. One specimen, No. 9399.

Rhamphidia loewi.

Pl. 3; fig. 2.

The auxiliary vein ends at a little less than half way from the origin of the second to that of the third longitudinal vein, the subcostal cross vein at its tip. The præfurca arises considerably beyond the middle of the wing, is nearly straight and declivent, and is less than half as long as the remainder of the vein. The first longitudinal vein is as in the preceding species. The submarginal is much longer than the first posterior cell. The discal cell is rather elongate, equal, twice as broad as long and fully as long as the posterior cells beyond it. The great cross vein strikes the discal cell near to but distinctly removed from the base of the latter. The seventh longitudinal vein is normal. The wing is hyaline, with a very faint infumation at the stigma, the veins luteous and delicate. The legs are detached and partly obscured (though in a natural position) so that the measurements are mostly in doubt.

Length of wings, 7.25 mm.; fore femora, 5.5 ? mm.; tibiæ, 6.5 mm.; mid femora, 6 ? mm.; tibiæ, 6.5 ? mm.; hind femora, 6.4 ? mm.

Named in memory of Dr. H. Loew, the distinguished investigator of the amber Diptera.

Florissant, Colorado. One specimen, No. 1369.

Antocha Osten Sacken.

Antocha Osten Sacken, *Proc. Acad. Nat. Sc. Philad.*, 1859, 219.

To this genus I refer a single species which differs markedly from the only recent species known—occurring in eastern North America and in Europe—in the character of the præfurca, which is arcuate at base and only half as long as the rest of the vein, so that the marginal cell is relatively brief. It differs further in minor points, such as the normal removal of the discal cell from the apex of the wing, the normal base of the first posterior cell, etc., but these are of much less importance. If the entire neuration could be determined with accuracy I am disposed to believe it would have to be separated from Antocha; but the position of the marginal cross vein just before the tip of the first longitudinal vein, the gradual approach of the first longitudinal vein to the costal margin, and the apparent merging of the auxiliary in the first longitudinal vein (though this is an obscure point) are so many features in common with Antocha that it seems best to place it here at present. The shape of the anal angle of the wing cannot be determined. The tips of the tibiæ are unarmed.

"It is not at all improbable," wrote Osten Sacken more than thirty years ago (*l. c.*, 200), "that my genera Antocha and Dicranoptycha will be found fossil in the Prussian amber." The present illustration is almost a fulfilment of this partial prophecy.

Antocha principialis.

Pl. 3, fig. 1.

Represented by a single specimen with rather obscure neuration over most of one wing and the whole of the other. The auxiliary vein appears to unite with the first longitudinal vein about the middle of the wing. The latter runs very gradually into the margin, without curving upward toward it, at a point about as far beyond the origin of the third, as that is beyond the origin of the second longitudinal vein. The præfurca arises a little beyond the middle of the wing, is at first strongly arcuate, then subparallel to the margin, toward which it turns slightly at the marginal cross vein, which is opposite the base of the discal cell, a little within the tip of the first longitudinal vein, at the inner margin of the faint stigma. The submarginal is much longer than the first posterior cell, but by no means so much so as in the living species. The discal cell is long and rather slender, widening apically and as long as the third posterior cell. The great cross vein strikes the fourth longitudinal vein at some distance short of the discal cell. The legs are very slender and the fore tarsi of excessive length.

Length of wings, 6.5 mm.; fore femora, 5.25 mm.; tibiæ, 5.5 mm.; tarsi, 10.5 mm.; mid femora, 5.75 mm.; tibiæ, 6 mm.; tarsi, 6.25 mm.; hind femora, 6 mm.

Florissant, Colorado. One specimen, No. 215.

Tribe ERIOPTERINI.

Of this tribe five genera and eighteen species, including those described below, are known in a fossil state. Only three species of as many genera—Erioptera, Gnophomyia, and Gonomyia—have been described from the European rocks, but eight species of Erioptera are said by Loew to occur in amber. Gonomyia has four species in America, and Cladura has two, while a single other species has been referred to a distinct genus, Cladoneura, closely allied to the last.

Gonomyia Megerle.

Gonomyia Meg., in Meig., *Syst. Beschr. eur. zweifl. Ins.*, i, 147 (1818).

This is a north temperate genus, the known existing species being confined to Europe, which has eleven species, and eastern North America, which has five. It has before this been found fossil, the species described by Heyden in the Aquitanian of Rott in Rhenish Prussia under the name of *Limnobia sturi*, being certainly a Gonomyia. But in this country it is found fossil more abundantly, for to this genus belong four nearly allied species from Florissant with very characteristic neuration. Except that the auxiliary vein is relatively long and the marginal cell slender, they do not appear to differ in any common characteristics from modern forms. The species may be separated thus:

Table of the Species of Gonomyia.

Præfurca with little or no basal arcuation, nearly straight throughout.

Base of first submarginal cell lying scarcely beyond the tip of the first longitudinal vein.

Small species. Tip of auxiliary vein lying much less than half way from the origin of the second to the origin of the third longitudinal vein.. *profundi.*

Large species. Tip of auxiliary vein lying much more than half way from the origin of the second to the origin of the third longitudinal vein.. *labefactata.*

Base of first submarginal cell lying distinctly beyond the tip of the first longitudinal vein.................................. *primogenitalis.*

Præfurca with strong arcuation at base............................ *frigida.*

Gonomyia profundi.

Pl. 3, fig. 3.

The wings are hyaline. The auxiliary vein ends barely before the middle of the wing and a little distance beyond the origin of the præfurca, the subcostal cross vein appearing to lie midway between the two. The first longitudinal vein ends in the costa opposite the middle of the discal cell. The præfurca is long, nearly straight, arises at the end of the basal two fifths of the wing, and is considerably more than half as long as the rest of the vein. The oblique upper branch of the second longitudinal vein arises opposite the tip of the first longitudinal vein, making the first submarginal cell more than half as long as the second; the latter is considerably longer than the first posterior cell, and the second and third posterior cells twice as long as the discal cell, which is closed. All the veins running longitudinally are gently and uniformly arcuate.

This is the smallest of the fossil species of the genus.

Length of wings, 5 mm.; fore femora, 2.75 mm.; tibiæ, 2.75 mm.; mid femora, 3 mm.; tibiæ, 3 mm.; hind femora, 3 ? mm.; tibiæ, 3 mm.; tarsi, 3.25 mm.

Florissant, Colorado. One specimen, No. 7461.

Gonomyia labefactata.

Pl. 4, fig. 4.

The wings are hyaline, without trace of color except the luteous veins, which appear to be a little thickened in certain parts, especially the fifth longitudinal vein; there is no trace of a stigma. The auxiliary vein terminates at a remarkable distance beyond the origin of the præfurca, reaching nearly to the base of the third longitudinal vein, and well beyond the middle of the wing, the subcostal cross vein shortly anterior to its tip. The first longitudinal vein reaches as far as opposite the distal end of the discal cell. The præfurca arises at about the end of the basal two fifths of the wing, is straight, not very long, but little more than half as long as the remainder of the vein. The oblique upper branch of the second longitudinal vein arises directly opposite the tip of the first longitudinal vein, so that the first submarginal cell is just as long as its petiole. The second submarginal is but little longer than the first posterior cell. The discal cell is pretty large and nearly as long as the posterior cells beyond it. The great cross vein strikes it just before its middle.

This is the largest of the fossil Gonomyiæ.

Length of wings, 8.25 mm.

Florissant, Colorado. One specimen, No. 147.

Gonomyia primogenitalis.

Pl. 4, fig. 10.

In this species the wings are hyaline, without spots or stigma, but with fusco-luteous veins. The auxiliary vein ends in the middle of the wing, the subcostal cross vein shortly before its tip and nearly midway to the base of the præfurca, which, though no longer than usual, arises at an exceptionally early point, not far beyond the basal third of the wing; it is straight, with no basal arcuation whatever, and only half as long as the rest of the vein; indeed the whole cellular area of the wing, that is, the region beyond the basal cells, is much longer in proportion to the rest of the wing than in any of the other species. The first longitudinal vein ends about opposite the distal end of the discal cell, and the oblique upper branch of the second longitudinal vein arises distinctly beyond its tip, though the first marginal cell is longer than its petiole. The submarginal is not greatly longer than the first posterior cell; the discal cell is rather small and only about half as long as the posterior cells beyond it, the great cross vein striking it at the end of its basal third. The fifth longitudinal vein is scarcely bent at the cross vein. The femora are considerably thickened apically.

The figure on the plate represents only the wing of one of the specimens, drawn by the camera lucida.

Length of wing, 6.5–7.5 mm.; legs in the smaller specimens: fore femora, 2.6 mm.; tibiæ, 3.25 mm.; tarsi, 2.75 mm.; mid femora, 2.25 mm.; tibiæ, 2.5 mm.; tarsi, 2.4 mm.; hind femora, 3.2 mm.; tibiæ, 3.1 mm.; tarsi, 2.25 ? mm.

Florissant, Colorado. Three specimens, Nos. 8161, 8846 and 8871 of my collection; No. 1.748 of the Princeton collection.

Gonomyia frigida.

Pl. 4, fig. 9.

Wings hyaline without spots or stigma, the veins fuscous. Auxiliary vein terminating a little beyond the middle of the wing, and not far from midway between the origin of the second and third longitudinal veins, the subcostal cross vein shortly before its tip and midway between it and the base of the præfurca. First longitudinal vein ending about opposite the distal extremity of the discal cell. Præfurca arising somewhat before the middle of the wing, strongly arcuate at base, thereafter subparallel to the first longitudinal vein, the strongly oblique upper branch of the second arising opposite the tip of the first longitudinal vein, the first submarginal cell about as long as its petiole. Second submarginal considerably longer than the first posterior cell. Discal cell small, equal, considerably shorter than the posterior cells beyond it, the great cross vein striking it close to its base. The femora are gradually though very slightly thickened and darkened apically.

Length of wings, 5.5–5.75 mm.; fore femora, 2.8 mm.; tibiæ, 3 mm.; tarsi, 3 mm.; mid femora, 3 mm.; tibiæ, 2.75 mm.; tarsi, 2.75 mm.; hind femora, 3.5 mm.; tibiæ, 3 mm.; tarsi, 3.25 mm.

Florissant, Colorado. Three specimens, Nos. 3434, 6034, 8656.

CLADONEURA (κλάδος, νευρά) gen. nov.

Among the species which in my preliminary survey of these fossils I had grouped under Cladura, is one which agrees with modern forms of that genus in one particular, namely, the distance between the base of the præfurca and the tip of the auxiliary vein, which more than equals the breadth of the wing; while in the fossil species of Cladura described below the distance is less, sometimes much less, than the breadth. It further agrees better with the modern than with the fossil species of Cladura in that the tip of the auxiliary vein extends a little beyond the base of the first submarginal cell; and in that the petiole of this cell about equals the distance between the subcostal and marginal cross veins,—points more or less related. But it differs from the modern forms of Cladura in so many and, as it appears to me, so much more important points than do the fossil species here referred to Cladura, that it seems more rational to separate it generically from both.

The points of its distinction from Cladura are the following: The præfurca arises at a far earlier point in the wing, at the end of the basal third of the same, and though immediately arcuate has but a slight basal curve and is thereafter straight, running very near to and but slightly divergent from the first longitudinal vein; in this respect the fossil species of Cladura agree more nearly with it than with the recent species. The subcostal cross vein is at the tip of the auxiliary vein, so that its distance from the base of the præfurca is a fourth more than the breadth of the wing. The marginal cross vein is in consequence much nearer the subcostal cross vein than the tip of the first longitudinal vein, and the petiole of the first submarginal cell is a little longer than the interval between the two cross veins. Moreover, the branch of the second longitudinal vein through which the first submarginal cell originates is straight throughout and not, as in the modern species of Cladura, strongly arcuate basally; in this particular again the fossil species of Cladura agree rather with Cladoneura. The third and not the second posterior cell is petiolate. The anterior branch of the fourth longitudinal vein arises at a small angle (and not at nearly or quite a right angle) from the main stem, so that the proximal end of the discal cell is pointed and not broad. Finally, the great cross vein lies much nearer the margin of the wing, striking the discal cell opposite the origin of the posterior branch of the fourth longitudinal vein. In addition, the legs, which are very imperfectly known in the single specimen preserved, appear to be much shorter than in the fossil species of Cladura, the hind femora being but about half as long as the wings, while in the latter they are fully two thirds as long. The wings are but little more than three times as long as broad, with rather full posterior margin.

A single species is known.

Cladoneura willistoni.

Pl. 4, fig. 2.

Wings a little more than three times as long as broad, immaculate, without stigma, very feebly infumate. The auxiliary vein ends scarcely before the middle of the apical half of the wing and just beyond the extreme base of the first submarginal cell, the subcostal cross vein next its tip. The præfurca arises at the end of the basal third of the wing and is scarcely shorter than the rest of the vein. The marginal cross vein is as far beyond the base of the first submarginal cell as that from the origin of the third longitudinal vein; the latter is hardly in the least bent at its base where united to the branch of the fourth longitudinal vein. The second submarginal and first posterior cells are of almost equal length and longer than the breadth of the wing. The discal cell is subtriangular, enlarging toward its rectangular apex from its pointed base. Petiole of third posterior cell shorter than the cell. Fifth longitudinal vein distinctly and considerably bent at the great cross vein, the fifth posterior cell less than twice as long as its median breadth. The legs are imperfectly preserved, but are relatively very short.

Length of wings, 9 mm.; breadth, 2.75 mm.

Named for Prof. S. W. Williston, of the University of Kansas, a diligent student of American Diptera.

Florissant, Colorado. Two specimens, Nos. 9312, 12688.

Cladura Osten Sacken.

Cladura Osten Sacken, *Proc. Acad. Nat. Sc. Philad.*, 1859, 229.

Cladura is a North American genus and has indeed been found only along the eastern shore from Canada to the District of Columbia. Loew described a European species, but Osten Sacken says it cannot be placed here. Two living species only are known. Up to this time it has not been found fossil, but I now place here a couple of species from Florissant, differing considerably from each other, in that one, a stout species, has spotted wings, very short and broad for a Cladura; while the other, a slender form, has clear wings of the usual proportions, nearly four times as long as broad. They agree, however, tolerably well in their neuration, but differ from modern species of Cladura in that the distance between the base of the præfurca and the tip of the auxiliary vein is less than, in the stout form hardly more than one half, the breadth of the wing; in that the tip of the auxiliary vein lies distinctly before the base of the first submarginal cell; that the petiole of this cell is only about half as long as the distance between the subcostal and marginal cross veins; and in the slight basal arcuation and subsequent straightness of the præfurca—in which particular they approach Cladoneura, just described. The stouter of the two further differs from modern species of Cladura in the form of the wings, as above remarked, and in the somewhat greater distance of the great cross vein from the base of the discal cell. These differences seem to be no more than we should expect between living and tertiary forms in the same genus, and indicate the direction development has taken within relatively recent times.

Table of the Fossil Species of Cladura.

Wings less than three times as long as broad, spotted; great cross vein striking middle of lower margin of discal cell. . . . . *maculata.*
Wings more than three times as long as broad, immaculate; great cross vein striking lower margin of discal cell near the base . . . . *integra.*

Cladura maculata.

Pl. 4, fig. 1.

Wings slightly less than three times as long as broad, spotted with brownish fuscous along the front margin, but otherwise hyaline; the largest of these spots is at the stigma, where it is more luteous and includes the marginal cross vein; the others are situated next the humeral cross vein, midway between it and the base of the præfurca, at that base, at the subcostal cross vein, at the origin of the third longitudinal vein, and at the tips of the veins bordering the first submarginal cell. The auxiliary vein ends at the distal extremity of the middle fifth of the wing, earlier than the origin of the third longitudinal vein, and has the subcostal cross vein a very little way before its tip. The præfurca arises at the proximal end of the middle fifth of the wing, is arcuate at extreme base, thereafter straight and a little divergent from the first longitudinal vein, and is a little shorter than the rest of the vein. The marginal cross vein lies at a less distance beyond the base of the first submarginal cell than the length of the petiole of that cell. The third longitudinal vein is abruptly bent a little beyond its base where the cross vein strikes it, and the second submarginal and first posterior cells are subequal in length and fully as long as the breadth of the wing. The petiole of the second posterior cell is shorter than the cell. The discal cell is about twice as long as broad, subequal and a little shorter than the posterior cells beyond it. The great cross vein strikes the middle of the discal cell, and the fifth posterior cell is hardly twice as long as broad. There is a distinct supplementary cross vein in the middle of the second basal cell, lying outside a point opposite the base of the præfurca. The legs are relatively stout, the femora apically blackened.

Length of wings, 6.5 mm.; breadth, 2.25 mm.; length of fore femora, 3.5 mm.; tibiæ, 4.75 mm.; tarsi, 4.6 mm.; mid femora, 3.75 mm.; tibiæ, 4.75 mm.; hind femora, 4.6 mm.; tibiæ, 5 mm.

Florissant, Colorado. One specimen, Nos. 7954 and 10399.

Cladura integra.

Pl. 4, fig. 8.

Wings almost four times as long as broad, hyaline and immaculate except for the faintest possible infumation on the stigma. The auxiliary vein ends but little before the middle of the apical half of the wing, between the origin of the third longitudinal vein and the base of the first submarginal cell; the subcostal cross vein lies but a short distance from the tip of the auxiliary vein. The præfurca arises at about the middle of the wing, is arcuate at base, beyond straight, divergent and rather distant from the first longitudinal vein, and is distinctly shorter than the rest of the vein. The marginal cross vein lies as far beyond the base of the first submarginal cell as the length of its petiole. The third longitudinal vein is not bent at the base, the cross vein uniting it to the branch of the fourth longitudinal vein meeting it at the very base; consequently the second submarginal and first posterior cells are equal in length, and they are much longer than the breadth of the wing. The petiole of the second posterior cell is very much shorter than the cell, the discal cell is less than twice as long as broad, equal and hardly more than half as long as the posterior cells beyond it. The great cross vein strikes the discal cell near its base and the fifth posterior cell is several times longer than broad and equal, the fifth longitudinal vein being hardly bent. Legs very slender. The sides of the abdomen are distinctly darker than the dorsum.

Length of wings, 10.5 mm.; breadth, 2.6 mm.; length of fore femora, 5.5 mm.; tibiæ, 6.75 mm.; tarsi, 6.25 mm.; hind femora, 6 mm.; tibiæ, 7.5 mm.; tarsi, 6 mm.

Florissant, Colorado. One specimen, No. 1590.

Tribe LIMNOPHILINI.

This is the most important tribe among the Limnobinæ whether living or fossil. Five genera and twenty-five species have been recognized among the fossils, though only a very few of the European species are described or figured. Three or more species each of Limnophila, Trichocera, Tanymera, and Trichoneura—the last two extinct genera—have been recorded from the European tertiaries, besides one of the extinct genus Calobamon; these are all from amber except a single species each from Aix and Locle, belonging to Trichocera. From America only four species of Limnophila are known.

LIMNOPHILA Macquart.

Limnophila Macq., *Hist. Nat. Dipt.*, i, 95 (1834).

Limnophila is a prolific north temperate genus with numerous species both in North America and in Europe, in each of which about thirty species are known. In North America it occurs across the continent and from Alaska to Mexico, and it is also found in South America.

In his first studies upon this group, Osten Sacken suggested the use of several subgeneric names, which he proposed in a tentative manner, to be used until a complete revision of the genus could be made. In later writings he has still further subordinated these, which are in part founded upon minor points in the neuration of the wings. The examination of the few fossils of this group from Florissant seems to emphasize his later judgment, since we find several species with a cross vein in the first submarginal cell (one of the characteristics of his subgenus Dicranophragma), but which do not well agree in other features of Dicranophragma, while one of them has a supplementary cross vein in the costal area, as in Epiphragma—a group which he later regards as of generic value. It has seemed best, therefore, pending a complete revision of the Limnophilæ of the world, to use for these fossil species only the broader generic name Limnophila. It is a striking fact that of the four species known (each, unfortunately, by only a single example) three should have only four posterior cells, and three should have a supplementary cross vein in the first submarginal cell, both these features being rare in modern Limnophilæ.

Numerous fossil species of this group have been found in Europe, but only in Prussian amber, where the variety of forms is so great that Loew placed them in no less than four of his proposed new genera, and did not recognize among them at all the typical Limnophilæ. These genera were Trichoneura, Critoneura, Tanymera, and Tanysphyra, with eleven species; and besides these Osten Sacken refers his species of Cylindrotoma, four in number, to this group. The species described below, which are the first found in rock deposits, may be separated as follows:

Table of the Species of Limnophila.

First submarginal cell with a supernumerary cross vein.
- A supplementary cross vein in the costal area, next the base of the præfurca. *rogersii.*
- No cross vein in costal area.
  - Larger species, possessing only four posterior cells .... *vasta.*
  - Smaller species, with five posterior cells..................... *strigosa.*

First submarginal cell with no supernumerary cross vein.......... *ruinarum.*

Limnophila rogersii.

Pl. 4, fig. 3.

Wings hyaline with fuscous veins and no sign of a stigma. Auxiliary vein ending opposite the base of the first submarginal cell, the subcostal cross vein at its tip; a supernumerary cross vein in the costal area, opposite the base of the præfurca. First longitudinal cross vein ending about midway between the tip of the auxiliary vein and the apex of the wing. Præfurca arising about the middle of the wing, rather strongly arcuate at base, straight beyond, two thirds as long as the rest of the vein. Marginal cross vein just beyond the tip of the auxiliary vein and opposite the base of the first submarginal cell, which has a supernumerary cross vein a little beyond its middle. Apparently only four posterior cells, but by the folding and overlapping of the wings in the only example known, this point is not entirely clear; the same disturbance prevents any statement regarding the discal cell. Legs very slender and long, the tibiæ apically spurred.

Length of wings, 6.5 mm.; fore femora, 3.5 mm.; tibiæ, 4.5 mm.; tarsi, 3.75 mm.; mid femora, 4 mm.; tibiæ, 5 mm.; tarsi, 5.25 mm.; hind femora, 4.8 mm.; tibiæ, 5.25 mm.

Named in memory of Prof. H. D. Rogers, formerly state geologist of Pennsylvania.

Florissant, Colorado. One specimen, No. 13732.

Limnophila vasta.

Pl. 4, fig. 7.

Wings very faintly infumated, with a faint and small fuscous stigma. Auxiliary vein ending opposite the base of the first submarginal cell. First longitudinal vein continuing far toward the apex of the wing, being apically deflected with the margin. Præfurca arising at a little distance before the middle of the wing, considerably arcuate at base, beyond straight and gently divergent from the first longitudinal vein, as long as the end of the vein beyond the marginal cross vein, which is a little beyond the tip of the auxiliary vein and oblique. First submarginal cell with a supernumerary cross vein in the middle of its apical half. Four posterior cells. Discal cell short relative to the posterior cells beyond it, which are very long. The specimen is a male, and the antennæ are very long as in the subgenus Idioptera, but whether there is a supernumerary cross vein in the second basal cell cannot be determined. The legs are not preserved. It is the largest of the fossil species.

Length of wings, 11.75 mm.

Florissant, Colorado. One specimen, No. 7021.

Limnophila strigosa.

Pl. 4, fig. 5.

Wings uniformly and very faintly infumated, with no sign of a stigma. Auxiliary vein long, extending slightly beyond the base of the præfurca and the apex of the wing, the subcostal cross vein at its tip. First longitudinal vein extending far toward the tip of the wing, but scarcely declivent apically. Præfurca arising a little before the middle of the wing, gently arcuate throughout, two thirds as long as the first submarginal cell. Marginal cross vein as far beyond the base of the first submarginal cell as that from the origin of the third longitudinal vein, oblique. First submarginal cell with a supernumerary cross vein near its apex. Five posterior cells, the second petiolate, apparently longer than its petiole. The discal cell and parts below obscured by the folding of the wing in the only specimen known. Legs slender, not very long, the tibiæ distinctly spurred at apex.

Length of wings, 6.25 mm.; hind tibiæ, 2.75 mm.

Florissant, Colorado. One specimen, No. 8178.

Limnophila ruinarum.

Pl. 4, fig. 6.

Wings very faintly and uniformly infumated, with no stigma. The front margin of both wings is imperfect, not permitting the auxiliary vein to be fully traced; but it is probably rather short, as the first longitudinal vein ends about opposite the middle of the first submarginal cell. The præfurca is very long, arising before the end of the basal third of the wing, is gently arcuate at base, straight thereafter, and nearly as long as the rest of the vein, which is exceptionally arcuate. Marginal cross vein oblique, further from the base of the first submarginal cell than it is from the origin of the third longitudinal vein; this cell without any supplementary cross vein. Four posterior cells. The discal cell pointed at base, and though by this made longer, it is not much more than half as long as the second posterior cell. The great cross vein strikes the middle of the discal cell, and the fifth longitudinal vein is slightly bent where met by it. No supplementary cross vein in the second basal cell. Legs not very slender and relatively shorter than in the other fossil species, the tibiæ with apical spurs. Abdomen dark above, light below.

Length of wings, 8.25 mm.; hind femora, 4.25 mm.; tibiæ, 5.5 mm.

Florissant, Colorado. One specimen, No. 9575.

PRONOPHLEBIA Scudder.

Pronophlebia Scudd., *Bull. U. S. Geol. Geogr. Surv. Terr.*, iii, 750 (1877); *Tert. Ins. N. A.*, 573–574 (1891).

This genus was established upon a single imperfect specimen, in which the third appeared to rise from the second longitudinal vein almost immediately after the separation of the latter from the first longitudinal vein, and so was very different from its origin in any other group of Limnobinæ. Renewed examination of the specimen does not enable me to contradict this interpretation of the fossil, although it appears very improbable. I accordingly leave it until more perfect material shall enable some one to correct or verify it and fill out the remainder of the neuration. It is, therefore, placed at the end of the series, as it is quite impossible to tell in what tribe it should fall.

Pronophlebia rediviva.

Pronophlebia rediviva Scudd., *Bull. U. S. Geol. Geogr. Surv. Terr.*, iii, 750–751 (1877); *Tert. Ins. N. A.*, 574, pl. 5, fig. 39 (1891).

White River, near the boundary of Colorado and Utah.

VIII. The Subfamily Tipulinæ.

The fossil representatives of this subfamily are, relatively to the Limnobinæ, just about as numerous in the European deposits as in the present fauna of Europe or of America, being in each case about half as numerous as they; but in the American rocks, and still more in the European rock deposits (*i. e.*, exclusive of amber), they hold a much more important place. In tertiary Europe nine species of Tipula, one of Ctenophora, and two of Tipulidea (an extinct genus) have been described, and the presence of about fifteen other species of Tipula indicated, besides a Nephrotoma; while in North America, seventeen species of Tipula (including those in the present essay) have been described, and four species of Tipulidea, an extinct genus, besides single species of three other extinct genera. The tertiary fauna appears therefore to be somewhat more diversified in this subfamily in America than in Europe.

I have used here the terms employed by Osten Sacken for the neuration of the wings, but the neuration of these fossils seems to render it probable that what he calls (*Monogr. Dipt. N. A.*, iv, 290) the anterior branch of the apical fork of the second longitudinal vein is really the termination of the first vein itself, which is connected by a cross vein to the second, where it approaches it. This last would then be a "marginal" cross vein, and the fact that no other marginal cross vein ever exists in the Tipulinæ lends greater probability to this view, which would bring the structure into better accordance with that of many Limnobinæ.

The American genera of fossil Tipulinæ may be separated by the following table:

Table of the Genera of American Fossil Tipulinæ.

a^1. Last posterior cell in contact with the discal cell; the latter of moderate size.
- b^1. Anterior branch of fourth longitudinal vein unforked, or very feebly forked .... *Manapsis.*
- b^2. Anterior branch of fourth longitudinal vein strongly forked.
  - c^1. Posterior branch of fourth longitudinal vein doubly forked, so that there are six posterior cells .... *Rhadinobrochus.*
  - c^2. Posterior branch of fourth longitudinal vein simply forked, so that there are five posterior cells.
    - d^1. Præfurca nearly as long as, as long as, or longer than, the width of the first and second basal cells together, opposite the origin of the præfurca .... *Tipula.*
    - d^2. Præfurca not, or scarcely, longer than the greatest width of the first basal cell .... *Tipulidea.*

a^2. Last posterior cell not in contact with the discal cell; the latter minute. *Micrapsis.*

MANAPSIS (μανὸς, ἀψίς) gen. nov.

This name is here given to a genus of crane-flies closely allied to Tipula, in which the second posterior cell does not exist, or if it does, exists only as an exceedingly small and slender cell formed by the apical and very slight forking of the upper branch of the fourth longitudinal vein. In the single specimen known it forks thus upon one wing and not at all upon the other; the latter would appear to be the normal condition to judge from the weak character of the fork upon the other wing. So far as I can discover, no such condition is known to exist elsewhere among the Tipulinæ, and I accordingly suggest the separation of this form as a distinct genus. In all other respects the neuration agrees with that of Tipula and Ctenophora, and the legs appear to be much as in Tipula. The markings of the abdomen seem to be peculiar, for they consist of a very broad pale mediodorsal stripe on an otherwise dark abdomen.

A single species is known.

Manapsis anomala.

Pl. 5, fig. 1.

Wings almost four times as long as broad, uniformly infumated, with a distinct very dark stigma. Auxiliary vein terminating at the middle of the inner marginal cell; poststigmatal cross vein rather brief, slightly oblique; trapezoidal cell brief. Præfurca a little longer than the width of the first and second basal cells together at its base. Lowest posterior cell much wider at base than at margin ; discal cell of medium size, about twice as long as broad. Sixth longitudinal vein moderately approximated to the fifth; seventh longitudinal vein distinctly less than half as long as the wing. Abdomen very dark, with a broad pallid mediodorsal stripe. Legs slender, the tibiæ distinctly slenderer than the femora, which are three fifths as long as the wings.

Length of wings, 14.75 mm. ; of mid femora, 9 mm.

Florissant, Colorado. One ♀ specimen, No. 8200.

RHADINOBROCHUS (ῥαδινὸς, βρόχος) gen. nov.

It is with some hesitation that I propose the above name, as the single object upon which it is based is so imperfect. But the portion that is well preserved is so anomalous, while preserving in most of its features the exact neuration of Tipula, that it can hardly be properly treated excepting under a distinct generic name. These peculiarities consist of two features : the extraordinary slenderness of the discal cell, and the presence of a supplementary posterior cell by the longitudinal division with slightly unequal but symmetrical halves of the third posterior cell by an additional nervule, running from the discal cell to the margin.

A single species is known.

Rhadinobrochus extinctus.

Pl. 5, fig. 4.

Wings nearly four times as long as broad, uncolored except for the rather faint stigma at the extremity of the inner marginal cell. Auxiliary vein terminating at the middle of this cell ; poststigmatal cross vein slightly oblique, moderately long ; trapezoidal cell not much elongated. Præfurca of normal length. Petiole of second posterior cell about half as long as the discal cell ; third posterior cell broken into two, as described under the genus ; last posterior cell not much wider at base than at margin. Discal cell broadest basally, tapering throughout, of the usual length in species of Tipula, but four times as long as its basal breadth, not in close contact with the last posterior cell. Sixth longitudinal vein moderately near the fifth. Legs slender, the femora fully three fifths the length of the wings. Abdomen with a dark dorsal stripe on a pale ground.

Length of wings, 13.5 mm.; hind femora, 8.5 mm.

Florissant, Colorado. One ♂ specimen, No. 8847.

Tipula Linné.

Tipula Linn., *Syst. Nat.*, ed. i (1735).

This is a cosmopolitan genus with an enormous number of species, found in every quarter of the world, but most numerous in north temperate countries. Sixty-seven species have been credited to North America from Greenland to Mexico, and no less than eighty-eight to Europe. Fossil remains of this genus have also frequently been credited to different deposits in Europe, as at Sieblos, Oeningen, and Brunstatt in Germany, Aix in France, Gabbro and Chiavon in Italy, and the Krottensee in Bohemia, besides numerous examples at Radoboj in Austria and in Prussian amber. From the former of these last two deposits half a dozen species are described and figured, while in amber Loew has recognized from eleven to sixteen species, none of them yet described. In a very few instances the fossil species referred to Tipula can be shown to belong elsewhere, but most of them can be assumed to be true Tipulæ. In America we have already found seventeen species, most of them at Florissant, the remainder in the Gosiute fauna at Green River, Wyoming.

The greater number, both of individuals and species, of the Florissant Tipulinæ belong to the genus Tipula in the strictest sense. I have been unable to discover any constant and pervading differences to distinguish them from existing forms, but have separated on one side and the other certain species which show marked individual characteristics, sometimes in unexpected and rather surprising features; and have besides divided the genus in the following table into two groups by the length of the præfurca, the extreme brevity of which in certain species closely allied to Tipula has induced me to separate them as a distinct genus, Tipulidea. The species with relatively short præfurca, which I leave in Tipula, seem to agree in this particular with the existing Mexican species, *T. edwardsii*, figured by Bellardi.

Two fossil species formerly described by me as Tipulæ (under the names *Tipula decrepita* and *Tipula tecta*) are certainly not Tipulinæ and most probably belong to Dicranomyia (*q. v.*). Excluding therefore these two, the species of Tipula found fossil in America may be separated by the following table:

Table of the Species of Tipula.

A¹. Præfurca relatively long, as long as, generally longer than, the breadth of the first and second basal cells together next its base; or, half as long as the intersected apical area of the wing beyond the basal cells.

- b¹. Wings immaculate except at stigma.
  - c¹. Markings of the abdomen linear and light.
    - d¹. Wings exceeding 28 mm. in length .... *magnifica.*
    - d². Wings less than 26 mm. in length.
      - e¹. Wings 21 mm. or more in length .... *rigens.*
      - e². Wings between 16 and 21 mm. in length ..... *florissanta.*
      - e³. Wings less than 16 mm. in length.
        - f¹. Discal cell fully twice as long as broad....... *clauda.*
        - f². Discal cell less than twice as long as broad. *sepulchri.*
  - c². Markings of the abdomen oblique and heavy.
    - d¹. Larger species, the wing length exceeding 20 mm. *revivificata.*
    - d². Smaller species, the wing length less than 17 mm... *evanitura.*
- b². Wings maculate or discolored along the veins.
  - c¹. Abdomen with transverse markings.................. *maclurei.*
  - c². Abdomen with longitudinal markings.
    - d¹. Larger forms, the wings exceeding 19 mm. in length.
      - e¹. Præfurca of ordinary length, not much exceeding the breadth of the first and second basal cells together, next its base; wings relatively slender, nearly or quite four times as long as broad. .... *heilprini.*
      - e². Præfurca exceptionally long, exceeding the breadth next its base of the combined first and second basal and anal cells; wings relatively broad, not exceeding three and a half times their breadth................. *tartari.*
    - d². Smaller forms, the wings not reaching a length of 19 mm.
      - e¹. Wings not more than four times as long as broad.
        - f¹. Discal cell relatively short and broad, less than twice as long as broad; petiole of second posterior cell relatively long, much more than half as long as the cell. *carolinæ.*
        - f². Discal cell relatively long and narrow, at least twice as long as broad; petiole of second posterior cell relatively short, not more, generally much less, than half as long as the discal cell................ *limi.*
      - e². Wings more than four times as long as broad. *internecata.*

A². Præfurca relatively short, distinctly shorter than the breadth of the first and second basal cells together, next its base; or, much less than half the length of the intersected apical area of the wing beyond the basal cells.

b¹. Species of larger size, with wings at least 17 mm. long, the auxiliary vein stopping far short of the middle of the inner marginal cell........................ *subterjacens.*

b². Species of smaller size, with wings less than 17 mm. long, the auxiliary vein reaching the middle of the inner marginal cell.

c¹. Præfurca contained about two and a half times in the length of the intersected apical area of the wing beyond the basal cells.

d¹. Larger forms; the margin of some of the veins discolored. *lethæa.*

d². Smaller forms; some of the principal veins discolored (in some obscure specimens, this discoloration may be wholly or partially obliterated)............... *lapillescens.*

c². Præfurca only one third the length of the intersected apical area of the wing beyond the basal cells............. *spoliata.*

Tipula magnifica.

Pl. 5, fig. 3.

Wings slightly more than four times as long as broad, uncolored except for the faint stigma. Auxiliary vein terminating at some distance before the middle of the inner marginal cell; poststigmatal cross vein (uniting the first and second longitudinal veins) oblique and moderately long; trapezoidal cell elongate. Præfurca of normal length. Second posterior cell more than twice as long as its petiole. Middle branch of the fourth longitudinal vein gently arcuate, making the third posterior cell apically narrower than the fourth. Discal cell not very large, less than twice as long as broad. Sixth longitudinal vein distant from the fifth. Legs moderately slender, the femora distinctly stouter than the tibiæ and very slightly more than half as long as the wings, the tibiæ a very little longer than the femora, and the middle tarsi nearly two fifths longer than the tibiæ. Abdomen light colored, with slender median and broad lateral darker stripes.

This is by far the largest fossil Tipulid known, but is not so large as some modern species.

Length of wings, 29.5–30 mm.; fore femora, 15.5 mm.; tibiæ, 18.5 mm.; mid femora, 15.5 mm.; tibiæ, 18 mm.; tarsi, 24.5 mm.; hind femora, 16.5? mm.; tibiæ, 19.75 mm.

Florissant, Colorado. Three ♀ specimens, Nos. 5481, 12107, 16310 and 16311.

Tipula rigens.

Pl. 5, fig. 5; pl. 6, figs. 1, 3.

Wings four or slightly less than four times as long as broad, uncolored, except for the rounded stigma which is situated above the proximal half or more of the discal cell and is denser on its distal than its proximal side. Auxiliary vein terminating at the middle of the inner marginal cell; poststigmatal cross vein slightly oblique and moderately long (it is given too short in pl. 5, fig. 5); trapezoidal cell brief. Præfurca of normal length. Petiole of second posterior cell varying from about half as long as the discal cell to nearly its length. Fifth posterior cell much broader at base than at margin. Discal cell of moderate size, nearly twice as long as broad. Sixth longitudinal vein moderately distant from the fifth; seventh longitudinal vein much shorter than half the length of the wing. Femora moderately stout, distinctly stouter than the slender tibiæ, half or almost half as long as the wings, the tibiæ a little longer than the femora, and the tarsi of the fore pair one third, of the mid pair nearly one half longer than the tibiæ. Abdomen light colored and, when not obscured, with median and marginal narrow dark stripes, and occasionally with a feebler intermediate stripe on either side.

Length of wings, 21–25 mm.; fore femora, 11 mm.; tibiæ, 13.5 mm.; tarsi, 18.5 mm.; mid femora, 11 mm.; tibiæ, 12 mm.; tarsi, 18.5 mm.; hind femora, 11.5 mm. The measurements of the legs are all from one ♂, having a wing length of about 22 mm.

Florissant, Colorado. Fifteen specimens, all but one (with the possible exception of a second) females; Nos. 1638, 8061, 8088, 8477, 10427, 11332, 11669, 11677, 11805, 12105 and 12106, 12561, 13714, 16314 of my collection; No. 14699 collected by Miss C. H. Blatchford; No. 1.793 of the Princeton collection.

Tipula florissanta.

Pl. 5, fig. 2; pl. 6, figs. 4, 5; pl. 7, fig. 1.

Wings almost exactly four times as long as broad, uncolored except for the rounded obovate stigma situated over the proximal two thirds of the discal cell. Auxiliary vein terminating at the middle of the inner marginal cell ; poststigmatal cross vein slightly oblique and rather short, trapezoidal cell moderately elongate. Præfurca of normal length. Petiole of second posterior cell short, rarely exceeding, seldom equaling half the length of the discal cell, in one instance (No. 1697) barely one third its length; fifth posterior cell much broader at base than at margin. Discal cell fairly large, elongate, arcuate, more than twice as long as broad; it varies in one specimen which seems to belong here (No. 8944), in being straighter and exceptionally slender, being fully three times as long as broad. Sixth longitudinal vein moderately near the fifth, but slightly variable, usually nearer than in *T. rigens*, but occasionally as distant; seventh longitudinal vein nearly or very nearly half as long as the wing. Legs slender, the femora not greatly stouter than the tibiæ and considerably more than half as long as the wings, the tibiæ distinctly longer than the femora, except the middle pair, which is subequal to them; the tarsi subequal and fully half as long again as the tibiæ. Abdomen pale beneath, above light colored with a rather narrow dark median stripe and a pair of similar but generally more conspicuous lateral stripes, nearer the lateral margins than the middle line, unless the abdomen is inflated, as when heavy with eggs, when they may recede farther from the margin, as seen from above.

Length of wings, 16–20.5 mm.; of legs in one specimen, No. 13685, in which all the legs are perfectly preserved and the wing measures 17 mm. long, as follows: fore femora, 10 mm.; tibiæ, 12 mm.; tarsi, 18.5 mm.; mid femora, 11.5 mm.; tibiæ, 11 mm.; tarsi, 18.5 mm.; hind femora, 11 mm.; tibiæ, 13.5 mm.; tarsi, 19.5 mm.

Florissant, Colorado. Fifty-one specimens, of which ten are ♂, the remainder ♀ or indeterminate; Nos. 92, 775, 883 and 1692, 1617, 1697 and 7732, 2161, 2780, 3267, 3685, 4435, 4618, 5545, 5595, 6060, 7220, 7721, 8185, 8210, 8390, 8538 and 11676, 8821, 8858, 8944, 9040, 9261, 9857, 10386, 10634, 11137, 11334, 11338, 11339, 11667, 11812, 11845, 12142, 12715, 13273, 13280 and 13296, 13281, 13685, 13694, 13724, 13985, 14004, 14995, 16312 from my collection; also Nos. 1481, 1502 U. S. Geological Survey; No. 16420 collected by R. Thaxter; and 1.750 from the Princeton collection.

Tipula clauda.

Pl. 6, fig. 2; pl. 7, figs. 2–4.

Wings about four times as long as broad, generally a trifle less than more, uncolored except for the generally distinct and rather small stigma. Auxiliary vein terminating at the middle or scarcely beyond the middle of the inner marginal cell; poststigmatal cross vein transverse or scarcely oblique, rather short; trapezoidal cell rather elongate. Præfurca of normal length. Petiole of second posterior cell generally rather short, rarely exceeding half the length of the discal cell, but sometimes slightly longer than that; fifth posterior cell somewhat, sometimes considerably, broader at base than at margin. Discal cell not very large, elongate, fully twice as long as broad. Fourth longitudinal vein usually running slightly nearer the first than the fifth longitudinal vein, the sixth longitudinal vein moderately approximated to the fifth; seventh longitudinal vein as in *T. florissanta.* Legs slender, the tibiæ considerably slenderer than the femora, the hind femora slightly longer than the others and nearly two thirds as long as the wings, the tibiæ and especially the fore pair distinctly longer than the femora, and the tarsi more than half as long again as the tibiæ. Abdomen light colored, with a dark median longitudinal stripe, sometimes obscure and generally rather broad, and pretty uniformly distinct and equally broad dark lateral stripes—all occasionally obscured in preservation.

Length of wings, 12–15.5 mm.; of legs in one specimen (No. 3820) where the wing measures 15 mm. in length, as follows: fore femora, 9 mm.; tibiæ, 11.2 mm.; tarsi, 17.7 mm.; mid femora, 9 mm.; tibiæ, 10 mm.; hind femora, 9.7 mm.; tibiæ, 11 mm.; tarsi, 17 mm.

Florissant, Colorado. Thirty-four specimens, of which 7 are ♂, the rest ♀ or uncertain; Nos. 88, 100, 649, 989, 1038, 1205 and 3396, 1356, 3003, 3307, 3368 and 11671, 3570 and 5329, 3820 and 4974, 4634, 4664, 6910, 8057, 8195, 8478, 8873, 8899, 10659, 10683, 11336, 11337, 12623, 13066, 13118, 13229, 13260, 13266, 14118, 14169 of my collection; Nos. 1.753, 1.756 of the Princeton collection.

Tipula sepulchri.

Tipula sepulchri Scudd., *Tert. Ins. N. A.*, 578, pl. 10, fig. 1 (1891).

This species differs from the preceding, *T. clauda*, principally in the brevity of the discal cell.

Green River, Wyoming.

Tipula revivificata.

Wings fully four times as long as broad (the exact width cannot be measured), uncolored except for the greatly enlarged stigma and a slight infuscation on the middle of the fourth longitudinal vein. Auxiliary vein terminating slightly before the middle of the inner marginal cell; poststigmatal cross vein scarcely oblique, rather short; trapezoidal cell rather brief. Præfurca of normal length. Second posterior cell obscure but apparently as in *T. magnifica*. Discal cell rather small, apparently about twice as long as broad; remainder of neuration obscure. Legs slender, the femora but slightly stouter than the tibiæ and a little more than half as long as the wings. Abdomen dark, with oblique light markings midway between the middle and the lateral margins, becoming longitudinal on the first two segments, the middle dark markings on the third to the seventh abdominal segments being subtriangular elongate patches, having a rude and rounded **T** shape, the cross bar of the **T** short and rounded.

Length of wings, 21 mm.; mid femora, 11 mm.; hind femora, 12.5 mm.

Florissant, Colorado. One ♀ specimen, No. 9119.

Tipula evanitura.

Wings with the same proportions as in *T. clauda*, and as there without markings except the distinct and rather small obovate stigma. Auxiliary vein terminating at the middle of the inner marginal cell; poststigmatal cross vein transverse and rather short; trapezoidal cell rather more than usually elongate. Præfurca of normal length. Petiole of second posterior cell brief, hardly more than a fourth as long as the discal cell; fifth posterior cell subequal throughout. Discal cell moderately large, elongate, considerably more than twice as long as broad. Fourth longitudinal vein running scarcely nearer the first than the fifth longitudinal vein, the sixth longitudinal vein moderately distant from the fifth. Legs slender, the tibiæ distinctly more so than the femora, the latter nearly or quite three fifths as long as the wings, the tibiæ distinctly, though but little, longer than the femora, the tarsi nowhere completely preserved. Abdomen with a light-colored ground with dark markings, which are not wholly linear, but consist, first, of a series of short and rather stout, briefly linear dashes along the middle of the dorsum, or an interrupted stripe; and next, of oblique oval lateral patches on each segment, deepest anteriorly, and posteriorly more or less blending with the median stripe.

Length of wings, 14.25–16 mm.; fore femora, 8–9 mm.; tibiæ, —?–10.75 mm.; mid femora, 8.75–9.5 mm.; hind femora, 9– —? mm.; tibiæ, 9.75– —? mm.

Florissant, Colorado. Two ♀ specimens; No. 8588 of my collection; No. 1.760 of the Princeton collection.

Tipula maclurei.

Pl. 7, fig. 6.

Wings nearly four times as long as broad, with a dark and rather large oblong stigma and many of the veins broadly discolored with dark fuliginous, which forms patches or clouds in places; in particular, the fifth longitudinal vein (with the great cross vein) is heavily bordered, though interrupted by pallid clouds just before and just after the middle of the wing; a brief slender dark patch descends from the stigma, and is separated from the fuscous clouds beyond by pallid clouds which intervene in the discal cell and all the cells above it; except as it nears the discal cell, the fourth longitudinal vein is unstained though faint slender fuliginous streaks follow the first and second basal cells. Auxiliary vein terminating at the middle of the inner marginal cell; poststigmatal cross vein transverse, brief; trapezoidal cell rather short. Præfurca of normal length. Petiole of second posterior cell not more than half as long as the discal cell; fifth posterior cell but little broader at base than at margin. Discal cell rather small and brief, not more than half as long again as broad. Sixth longitudinal vein distant from the fifth; seventh longitudinal vein less than half as long as the wing. Legs relatively stout, the tibiæ considerably slenderer than the femora and a little longer than they, the femora less than three fifths the length of the wings, and the tarsi apparently not greatly longer than the tibiæ. Abdomen pale beneath; above covered heavily with dark transverse markings, consisting on each of the principal segments of a broad bow, open anteriorly, and a couple of subconfluent or confluent median rounded spots united therewith, these leaving a pair of anterior laterodorsal pallid spots and the outer posterior corner of each segment pallid; the markings become confused on the basal and apical segments, the latter of which are wholly dark.

Named in memory of the early American naturalist, William Maclure.

Length of wings, 23 mm.; fore and mid femora, 10.5 mm.; fore and mid tibiæ, 12 mm.; mid tarsi, 15 mm.; hind femora, 13 mm.

Florissant, Colorado. One ♀ specimen, No. 7783.

Tipula heilprini.

Pl. 8, fig. 2.

Wings nearly four times as long as broad, with generally very faint, occasionally tolerably distinct clouded dark markings disposed much as in *T. maclurei*, and brought into relief by similarly faint pallid markings above the discal cell. Auxiliary vein terminating at the middle of the inner marginal cell; poststigmatal cross vein slightly oblique, brief; trapezoidal cell moderately elongate. Præfurca of normal length. Petiole of second posterior cell short, not more, generally much less, than half the length of the discal cell; fifth posterior cell generally, but not always, considerably broader at base than at margin, the sides straight. Discal cell of medium size, twice as long as broad. Sixth longitudinal vein moderately distant from the fifth; seventh longitudinal vein half as long as the wing. Legs very slender, the femora about three fifths the length of the wings, and stouter than the tibiæ, which slightly exceed them in length; while the tarsi, or at least the fore tarsi, are but a little more than a fourth longer than the tibiæ. Abdomen light colored, with dark linear markings somewhat variable in their width; in general there is a median and, on either side, a lateral stripe, with another midway between them or approaching one or the other; and excepting the subdorsal stripes, which are sometimes hardly seen and always slender when present, the others may vary in breadth; the incisures also are infuscated.

Named for Prof. Angelo Heilprin, of Philadelphia, whose work on tertiary fossils is well known to all naturalists.

Length of wings, 20–23 mm.; length of legs, in a specimen whose wing is 22.5 mm. long, as follows: fore and mid femora, 12.75 mm.; fore and mid tibiæ, 14 mm.; fore tarsi, 18 mm.; hind femora, 13 mm.; tibiæ, 14 mm.

Florissant, Colorado. Eight ♀ specimens; Nos. 3596, 4425, 4761, 7809, 11670, 11806, 13114 and 14101, 13725.

Tipula tartari.

Pl. 8, fig. 1.

Wings scarcely three and a half times longer than broad, faintly infumated throughout but more deeply in places, such as the inner and outer margins of large pallid patches found crossing the wing (bounded above and below by the first and fifth longitudinal veins), the apical portion just beyond the stigma, and the narrowing infuscated patch depending from it; a similar pallid patch occupies the middle half of the inner marginal cell; the veins are very narrowly infuscated throughout. Auxiliary vein terminating at the middle of the inner marginal cell; poststigmatal cross vein transverse, moderately long; trapezoidal cell rather elongate. Præfurca of exceptional length, exceeding the breadth of the first and second basal cells at its base, together with the anal cell, or three fourths the breadth of the unusually broad wings. Petiole of second posterior cell very short, scarcely a quarter the length of the discal cell; fifth posterior cell subequal in breadth. Discal cell rather large, about twice as long as broad. Sixth longitudinal vein rather distant from the fifth; seventh longitudinal vein hardly half as long as the wing. Legs moderately slender, the tibiæ not much slenderer and not much longer than the femora, and these scarcely more than half as long as the wings. Abdomen light colored, with rather slender mediodorsal and lateral dark stripes.

Length of wings, 20.75 mm.; fore femora, 10 mm.; tibiæ, 10.5 mm.; mid and hind femora, 10.75 mm.

Florissant, Colorado. One ♀ specimen, No. 12109.

Tipula carolinæ.

Pl. 7, fig. 5.

Wings almost exactly four times as long as broad, with dark markings, besides the distinct ovate stigma, consisting of scarcely more than an infuscation of the zigzag veins crossing the wing below the stigma, the margination of the apical half of the fifth longitudinal vein, and in a less degree of all the apical veins, but brought slightly into relief by a pallid cloud above and partially including the discal cell; in one of the two specimens these markings are very faint. Auxiliary vein terminating barely before the middle of the inner marginal cell; poststigmatal cross vein transverse, moderately short; trapezoidal cell not much elongated. Præfurca of normal length. Petiole of second posterior cell relatively long, much more than half the length of the discal cell; fifth posterior cell considerably broader at base than at margin. Discal cell relatively short and broad, less than twice as long as broad, rather small. Sixth longitudinal vein rather distant from the fifth; seventh longitudinal vein less than half as long as the wing. Legs slender, the tibiæ but slightly slenderer than the femora and a little longer than they, while the femora are but little more than half as long as the wings. Abdomen with rather broad mediodorsal and lateral dark stripes.

Length of wings, 15.5–17.5 mm.; of legs, in the smaller specimen, as follows: fore femora, 8.5 mm.; mid femora, 7.5? mm.; hind femora, 9 mm.; tibiæ, 9.75 mm.

Florissant, Colorado. Two ♀ specimens; Nos. 7298, 14715, the latter collected by Miss Caroline H. Blatchford, for whom the species is named.

Tipula limi.

Pl. 8, fig. 4; pl. 9, fig. 1.

Wings four or a little less than four times as long as broad, the stigma moderately large, rounded, distinct, followed beneath by a small deeply infuscated patch at the base of the submarginal and first posterior cells, often as a triangular dependence of the stigma and as deeply stained as it; besides this, dark markings occur all over the wing, disposed much as in *T. maclurei*, but without the pallid clouds, or at most but extremely faint ones, and with the addition of a dark cloud at the base of the præfurca; the markings vary much in breadth and in depth of coloring in different individuals, but are generally as in the specimens figured. Auxiliary vein terminating at or scarcely before the middle of the inner marginal cell; poststigmatal cross vein transverse, brief; trapezoidal cell rather elongate. Præfurca of normal length. Petiole of second posterior cell relatively short, not more, generally much less, than half as long as the discal cell; fifth posterior cell usually much broader at base than at margin. Discal cell relatively long and narrow, at least twice as long as broad. Sixth longitudinal vein pretty closely approximated to the fifth; seventh longitudinal vein much less than half as long as the wing. Legs slender, the femora only a little more than half as long as the wings, and scarcely stouter than the tibiæ, which barely exceed them in length. Abdomen with moderately broad and similar mediodorsal and lateral dark stripes.

Length of wings, 16–19 mm.; of legs in a specimen of largest size: femora, 10 mm.; fore and mid tibiæ, 10.5 mm.; hind tibiæ, 10.3 mm.

Florissant, Colorado. Twelve specimens, of which two are ♂, one indeterminate, the remainder ♀; Nos. 1611, 1892, 2839, 5206, 5544, 5584, 7786, 8166, 8170, 8479, 13759 of my collection; No. 1.788 of the Princeton collection.

Tipula internecata.

Wings nearly four and a half times longer than broad, the stigma rather small and followed below by a dark fuliginous patch, as in the preceding species, the veins discolored along their edges, and occasionally, and especially at and beyond the middle of the fourth longitudinal vein, enlarging into discolored cloudy patches separated by the faintest possible pallid cloud; similar pallid clouds occupy the discal and fifth posterior cells. Auxiliary vein attaining the middle of the inner marginal cell; poststigmatal cross vein transverse, moderately brief; trapezoidal cell not much elongated. Præfurca of normal length. Petiole of second posterior cell less than half the length of the discal cell; fifth posterior cell much broader at base than on margin. Discal cell of medium size, fully twice as long as broad. Sixth longitudinal vein moderately approximated to the fifth; seventh longitudinal vein less than half as long as the wing. Legs slender, the femora but little stouter than the tibiæ, the middle pair, intermediate in length as in position, about three fifths the length of the wing; tibiæ scarcely longer than their respective femora, the tarsi unusually short, being only a little longer than the tibiæ. Abdomen dark above and light below.

Length of wings, 16–17.5 mm.; of legs in the largest specimen: fore femora, 9.75 mm.; tibiæ, 10 mm.; tarsi, at least 11 mm.; mid femora, 10.5 mm.; hind femora, 11.5 mm.; tibiæ, 11.75 mm.; tarsi, 13 mm.

Florissant, Colorado. Two ♀ specimens; Nos. 6062, 13075; besides which there is a specimen belonging to the U. S. Geological Survey, also a ♀ (No. 1482), from which the measurements of the legs were taken.

Tipula subterjacens.

Pl. 8, figs. 3, 5.

Wings about four times as long as broad, generally rather less than more than that, uncolored except for the rather faint and rather small stigma. Auxiliary vein terminating well before the middle of the inner marginal cell; poststigmatal cross vein variable, sometimes short and transverse, at others distinctly oblique and moderately long; trapezoidal cell rather short. Præfurca distinctly shorter than the width of the first and second basal cells at its base. Petiole of second posterior cell about half as long as the discal cell; fifth posterior cell much broader at base than at margin. Discal cell moderate, about twice as long as broad. Sixth longitudinal vein moderately distant from the fifth. Legs slender, the tibiæ distinctly slenderer than the femora and scarcely longer than they, while the femora are rather less than two thirds as long as the wings, and the tarsi are half as long again as the tibiæ. Abdomen pale, with more or less distinct, sometimes almost wholly obliterated, dark narrow median and lateral stripes.

Length of wings, 17.5–20 mm.; of legs in one ♀ (No. 9157) as follows: fore femora, 9? mm.; mid femora, 10 mm.; tibiæ, 9.75 mm.; tarsi, 14.5 mm.; hind femora, 11 mm.; tibiæ, 8.5 mm.; tarsi, 14.5 mm.

Florissant, Colorado. Described from seven specimens, one ♂, five ♀, one uncertain; Nos. 1866, 4437, 4632, 7222, 8539 and 9157, 13737, 14972. Besides these No. 2083 and probably 2063 of the U. S. Geological Survey collection belong here.

Tipula lethæa.

Pl. 9, fig. 2.

Wings four times as long as broad, uncolored except for the small, generally distinct, triangular stigma. Auxiliary vein reaching the middle of the inner marginal cell; poststigmatal cross vein transverse, of moderate length; trapezoidal cell not very long. Præfurca distinctly shorter than the width of the first and second basal cells next its base. Petiole of second posterior cell not half, generally not nearly half, so long as the discal cell; fifth posterior cell somewhat wider at base than at margin. Discal cell rather small, about twice as long as broad. Sixth longitudinal vein moderately distant from the fifth; seventh longitudinal vein scarcely half as long as the wing. Legs slightly less slender than usual, the tibiæ distinctly slenderer than the femora, the latter about two thirds as long as the wings, the other members not sufficiently preserved in any specimen for measurement. Abdomen pale, with dark longitudinal median and lateral stripes, the latter less distinct and all sometimes obliterated.

Length of wings, 15.5–16.5 mm; fore femora, 8.5 mm.; mid femora, 9 mm.; hind femora, 10 mm.

Florissant, Colorado. Five specimens, two ♂, three ♀; Nos. 402, 3146, 4773, 11112, 13754.

Tipula lapillescens.

Pl. 9, fig. 3.

Wings from three and a half to four times as long as broad, the stigma small, distinct, rounded, lying opposite the basal half of the discal cell, followed by a fuliginous stain in the outer half of the marginal cell, and accompanied by a slender but more or less distinct infuscation of the fifth and seventh longitudinal veins, and sometimes of all or nearly all the veins of the apical fourth of the wing; there is also sometimes a faint cloud in the middle of the basal cells. Auxiliary vein terminating a very little before the middle of the inner marginal cell; poststigmatal cross vein slightly oblique, moderately long; trapezoidal cell moderately short. Præfurca very distinctly shorter than the first and second basal cells next its base. Petiole of second posterior cell about half as long as the discal cell; fifth posterior cell considerably broader at base than at margin. Discal cell rather small, about twice as long as broad. Sixth longitudinal vein pretty closely approximated to the fifth; seventh longitudinal vein nearly or quite half as long as the wing. Legs very slender and long, the femora almost two thirds as long as the wings, the tibiæ distinctly longer than they, and the tarsi nearly or quite two thirds as long again as the tarsi. Abdomen obscure in the specimens seen.

Length of wings, 14.5 mm.; fore femora, 8.5 mm.; tibiæ, 10.5 mm.; tarsi, 16 mm.; mid femora, 9 mm.; tibiæ, 9.75 mm.; tarsi, 16 mm.; hind femora, 9 mm.; tibiæ, 10 mm.; tarsi, 17 mm.

Florissant, Colorado. Two specimens, one ♂, one uncertain; Nos. 8300 and 8831, 11335.

Tipula spoliata.

Tipula spoliata Scudd., *Tert. Ins. N. A.*, 577–578, pl. 10, fig. 4 (1891).

This species forms a close link between the preceding three species of Tipula and the species of Tipulidea which follow, the præfurca being intermediate in length. In size, it agrees with *T. lapillescens*.

Green River, Wyoming.

TIPULIDEA (Tipula, nom. gen., εἶδος) gen. nov.

I venture to separate from Tipula, to which it is otherwise closely related, a group of species, all the members of which are smaller than the smallest true Tipulæ, living or fossil,* known to me, and which are peculiar for the extreme brevity of the præfurca; in this respect they closely resemble Pachyrhina, though in the petiolate character of the second posterior cell they agree with Tipula and not with Pachyrhina. They evidently form a group intermediate between these two genera. The apical cells are slenderer than in Tipula; the præfurca is very oblique, as in Pachyrhina, and is no longer, or scarcely longer than the greatest width of the first basal cell; in consequence the inner marginal is but little if at all larger than the discal cell; the petiole of the second posterior cell is rather short, but the cell is never sessile. It may be added that the fifth longitudinal vein is scarcely bent at the great cross vein, but is apically curved downward; more distinctly and more uniformly than in Tipula, it is accompanied throughout its course by a spurious vein beneath it; and the first longitudinal vein runs so close to the margin as to leave

* Except *T. angustata* Novák from the Egerer tertiary basin, the wing of which is only about 9 mm. long. It should also be remarked that Loew, in his too brief account of the amber Diptera, says that the species of Tipula entombed therein are remarkable for their small size and specifies two which are only about 7 mm. long. Perhaps they may prove to belong to Tipulidea.

scant space for the auxiliary vein. The legs are long and slender, with exceptionally long tarsi.

Both from their size and the brevity of the præfurca it is tolerably plain that both the unnamed species from the upper oligocene of Brunstatt, referred by Foerster (*Abhandl. Specialk. Elsass-Lothr.*, iii, pl. xiv, figs. 2, 3) to Tipula, are to be considered as belonging to the present genus.

Four species are known from Florissant, which may be separated by the following table:

Table of the Species of Tipulidea.

Abdomen with complete transverse bands at the apices of the segments.
- The longitudinal markings of the dorsum of the abdomen mediodorsal and heavy . . . . *consumpta.*
- The longitudinal markings of the dorsum of the abdomen subdorsal and light . . . . *bilineata.*

Abdomen with longitudinal markings only.
- Mediodorsal stripe on abdomen heavy and broad, expanding at the apices of the segments . . . . *picta.*
- Mediodorsal stripe on abdomen very light, often obliterated and generally slender, not apically expanded at the apices of the segments. *reliquiæ.*

Tipulidea consumpta.

Wings generally four times as long as broad sometimes a little less than that, in one instance (No. 11686, which may possibly not belong here) only three and a half times as long as broad, uncolored, except for the stigma. The inner marginal cell is pretty regularly fusiform, about three times as long as broad. The discal cell is also about three times as long as broad, and of just about the size of the inner marginal cell. The petiole of the second posterior cell is usually about half as long as the discal cell, but sometimes not more than one third as long, while the second posterior cell itself is about half as long as the whole of the intersected apical area of the wing, which, measuring from the end of the basal cells, is about equal to the breadth of the wing. The fifth posterior cell is considerably wider at base than just before the margin. The sixth longitudinal vein is moderately distant from the fifth. Legs very long and slender, the femora nearly three fourths as long as the wings, the tibiæ scarcely longer and a little slenderer, the tarsi two thirds as long again as the tibiæ. Abdomen rather heavily traversed by dark bands at the apices of the segments, occupying from a fourth to a third of the length of the same, and also marked with slenderer, and sometimes not so deeply colored mediodorsal and lateral longitudinal stripes, which, especially the lateral, are apt to expand as they approach the transverse bands; there are signs on some specimens (which may be due to the nature of the surface of the stone) of a coarse and sparse punctuation on the upper surface.

Length of wings, 9.5–11 mm.; of legs in a specimen whose wing measures 10.5 mm. in length, as follows: femora, 8 mm.; tibiæ, 9 mm.; fore tarsi, 14 mm.; hind tarsi, 15 mm.

Florissant, Colorado. Eight specimens, 6 ♂, 2 ♀ (the great proportion of males is exceptional among Tipulinæ); Nos. 2117 and 7010, 11668, 11686, 13054 and 13720, 14144, 16402, 16403, 16405.

Tipulidea bilineata.

Pl. 9, fig. 8.

Wings a little less than four times as long as broad, uncolored except for the stigma. Inner marginal cell not regularly fusiform, tapering much more rapidly proximally than distally, not more than three times as long as broad. Discal cell scarcely smaller than the inner marginal cell, also about three times as long as broad. Petiole of the second posterior cell fully half as long as the discal cell, the second posterior cell itself slightly less than half as long as the whole intersected apical area of the wing, which is rather longer than the breadth of the wing; fifth posterior cell considerably wider at base than just before the margin. The sixth longitudinal vein moderately distant from the fifth. Legs very slender, the femora increasing slightly in length from the front pair backward, the middle pair about half as long again as the wings, the tibiæ slightly shorter than the femora, excepting in the fore legs where the reverse is the case, the tarsi excessively long, nearly double the length of the tibiæ. Abdomen with the hinder edges of the segments narrowly edged with fuscous and with distant, subdorsal, slender, fuscous, longitudinal lines, between which the basal segment is wholly fuscous.

Length of wings, 11–11.5 mm.; of legs in the larger specimen: fore femora, 7.25 mm.; tibiæ, 7.6 mm.; mid femora, 7.6 mm.; tibiæ, 7.25 mm.; tarsi, 14 mm.; hind femora, 8 mm.; tibiæ, 7.6 mm.

Florissant, Colorado. Two ♀ specimens, Nos. 7998, 11333.

Tipulidea picta.

Pl. 9, figs. 4, 6.

Wings nearly or quite four times as long as broad, uncolored except for the unusually distinct stigma. Inner marginal cell subfusiform, nearly or quite four times as long as broad. Discal cell considerably smaller than the inner maginal cell, from three to four times as long as broad, the petiole of the second posterior cell brief or very brief, rarely one half, usually hardly if at all more than one fourth, the length of the discal cell, the second posterior cell itself half or more than half the length of the apical intersected area of the wing, the latter about as long as the breadth of the wing; fifth posterior cell much wider at base than just before the margin. Sixth longitudinal vein moderately approximate to the fifth. Legs very slender, the femora distinctly stouter than the tibiæ, about three fifths the length of the wings, the tibiæ slightly longer than the femora, and the tarsi of great length, being nearly three fourths longer than the tibiæ. Abdomen with a heavy interrupted or subinterrupted mediodorsal stripe, consisting on each segment of a subtriangular patch, which abruptly broadens at the posterior margin to a greater or less extent, and fails, at least distinctly, to reach the anterior margin; there is besides a slender inconspicuous lateral line on either side.

Length of wings, 10.5–13 mm.; of legs in the largest specimen: fore femora, 8 mm.; tibiæ, 8.5 mm.; tarsi, 14 mm.; mid femora, 7 mm.; tibiæ, 8 mm.; tarsi (not quite perfect), 12.5 mm.; hind femora, 7.5 mm.; tibiæ, 8.5 mm.; tarsi, 13.5 mm.

Florissant, Colorado. Fourteen specimens, 3 ♂, 9 ♀, 2 uncertain; Nos. 1040, 5368, 8192, 8205, 8386, 8598, 8826, 8850, 9000, 9129, 13708, 13745, 13749, 16421.

Tipulidea reliquiæ.

Pl. 9, fig. 5.

Wings barely four times as long as broad, uncolored except for the distinct stigma. Inner marginal cell pretty regularly subfusiform, about four times as long as broad. Discal cell somewhat smaller (not quite correctly given in the figure), about three times as long as broad. Petiole of second posterior cell generally very brief, and not one fourth the length of the discal cell, but sometimes longer and nearly or quite half its length; the second posterior cell itself generally distinctly, sometimes very considerably, more than half as long as the intersected apical area of the wing, which is fully equal to, if it does not exceed, the breadth of the wing; fifth posterior cell considerably broader at base than just before the margin. Sixth longitudinal vein rather closely approximated to the fifth. Legs very slender, the femora stouter and slightly shorter than the tibiæ, three fourths as long as the wings, and the tarsi, or at least the hind pair, nearly three fourths as long again as the tibiæ. Abdomen light colored, with feeble markings, consisting of feeble and simple, generally rather narrow, mediodorsal and lateral dusky stripes.

Length of wings, 10–13.5 mm.; of legs in a ♀ having wings 13 mm. long, as follows: fore femora, 7 mm.; tibiæ, 7.75 mm.; tarsi (probably incomplete), 10 mm.; mid femora, 7.5 mm.; tibiæ, 8 mm.; tarsi (perhaps incomplete), 12.5 mm.; hind femora, 7.5 mm.; tibiæ, 8.5 mm.; tarsi, 14 mm.

Florissant, Colorado. Eight specimens, 5 ♂, 3 ♀; Nos. 4732, 8066, 8385, 8480, 8869, 10105, 11841, 14145.

MICRAPSIS (μικρὸς, ἀψίς) gen. nov.

This genus differs strikingly from Tipula in the character of the discal cell, which is somewhat remarkable; not only is it of exceedingly small size, but it is entirely removed from the fifth posterior cell, the forking of the fourth longitudinal vein not taking place where the great cross vein unites with the final branch of the fourth longitudinal vein, but at the inner inferior base of the discal cell, which thus becomes quadrilateral and is separated from the anterior basal angle of the fifth posterior cell by the width of the fourth posterior cell.

The genus is evidently allied to Tipulidea by the brevity and obliquity of the præfurca, and should directly follow it. In the lack of contact of the discal cell with the fifth posterior cell it is like Megistocera, but it differs from that in all the other characters by which Tipula is distinguished from Megistocera, and does not indeed belong to the Dolichopezini to which Megistocera is referred.

A single species is known, unfortunately represented only by a single imperfect specimen.

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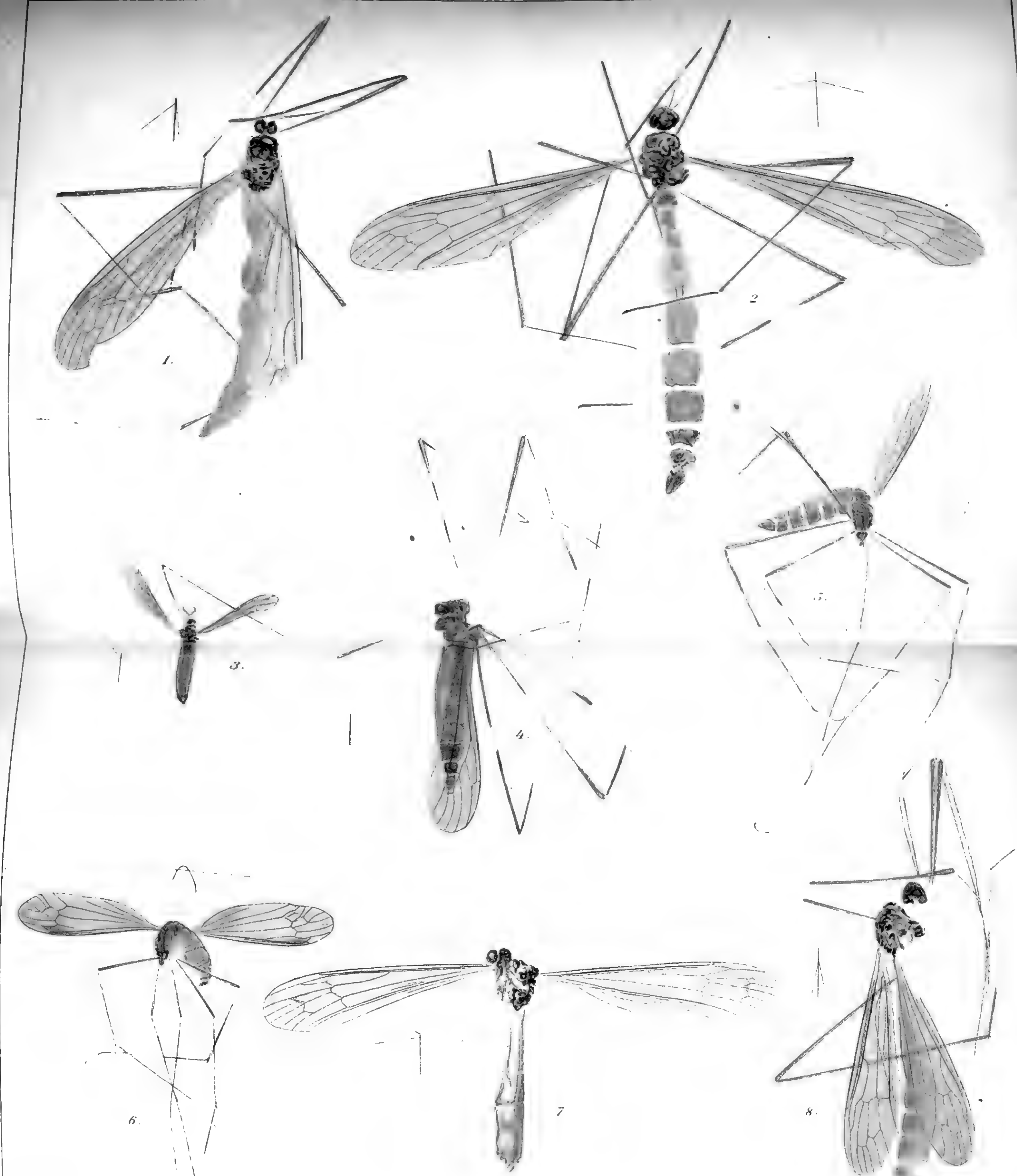
JHB. del.

B Meisel, lith. Boston.

TERTIARY TIPULIDÆ OF COLORADO.

Plate I (Scudder).

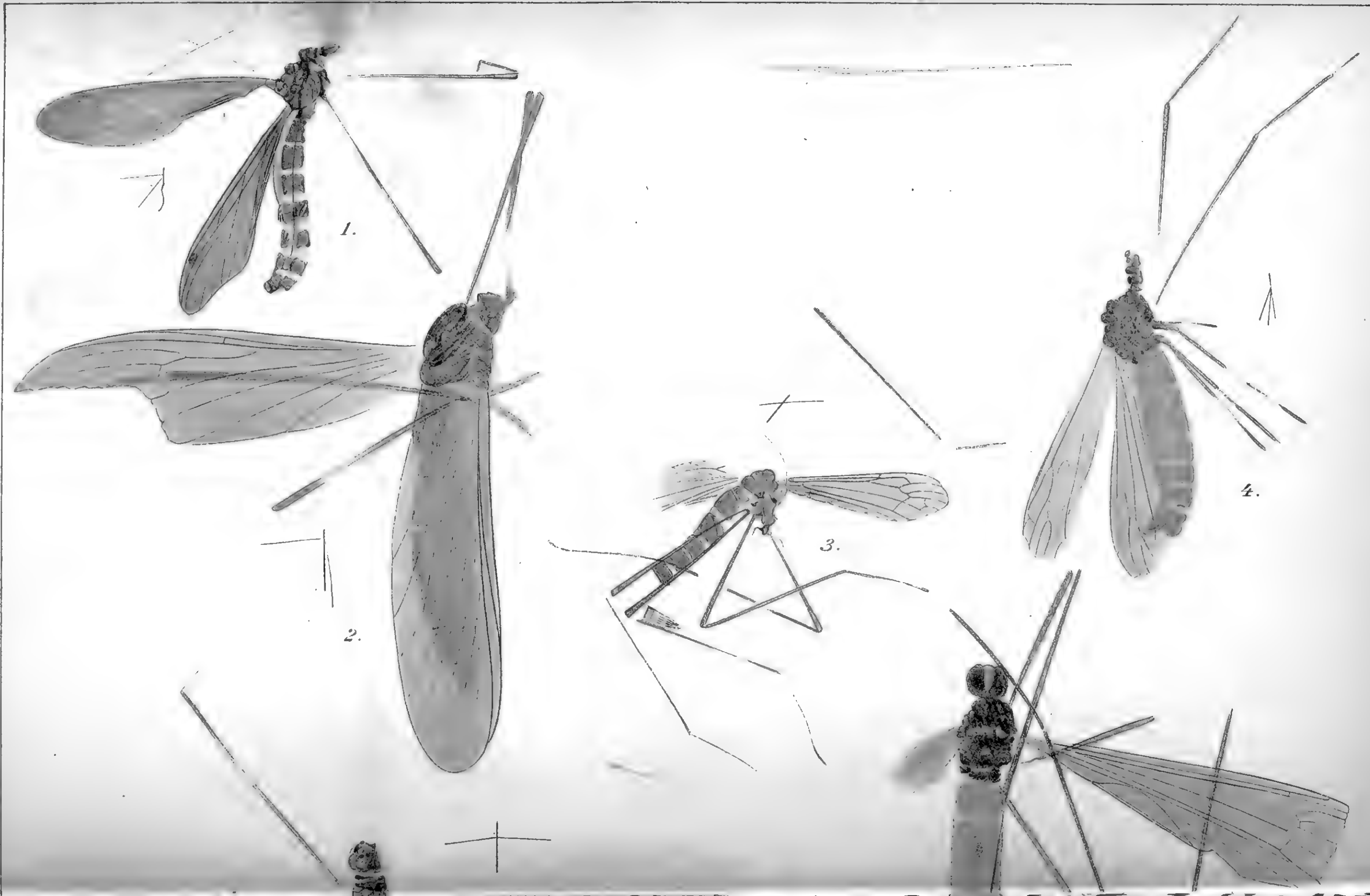


J.H.B del.

B. Meisel, lith. Boston

TERTIARY TIPULIDÆ OF COLORADO.

Plate I (Scudder)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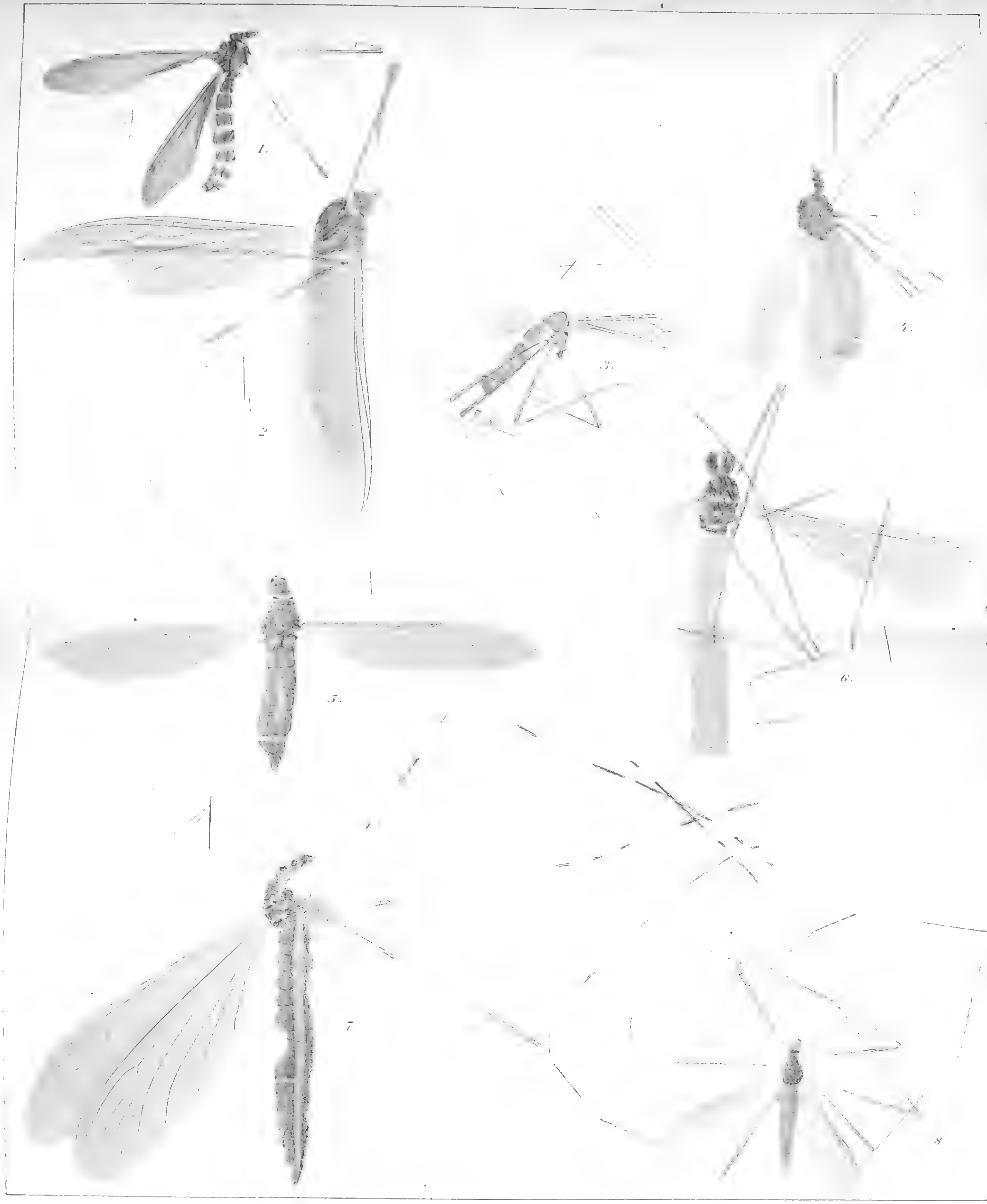
JHB. del

B. Meisel, lith. Boston.

TERTIARY TIPULIDÆ OF COLORADO.

Plate II (Scudder).



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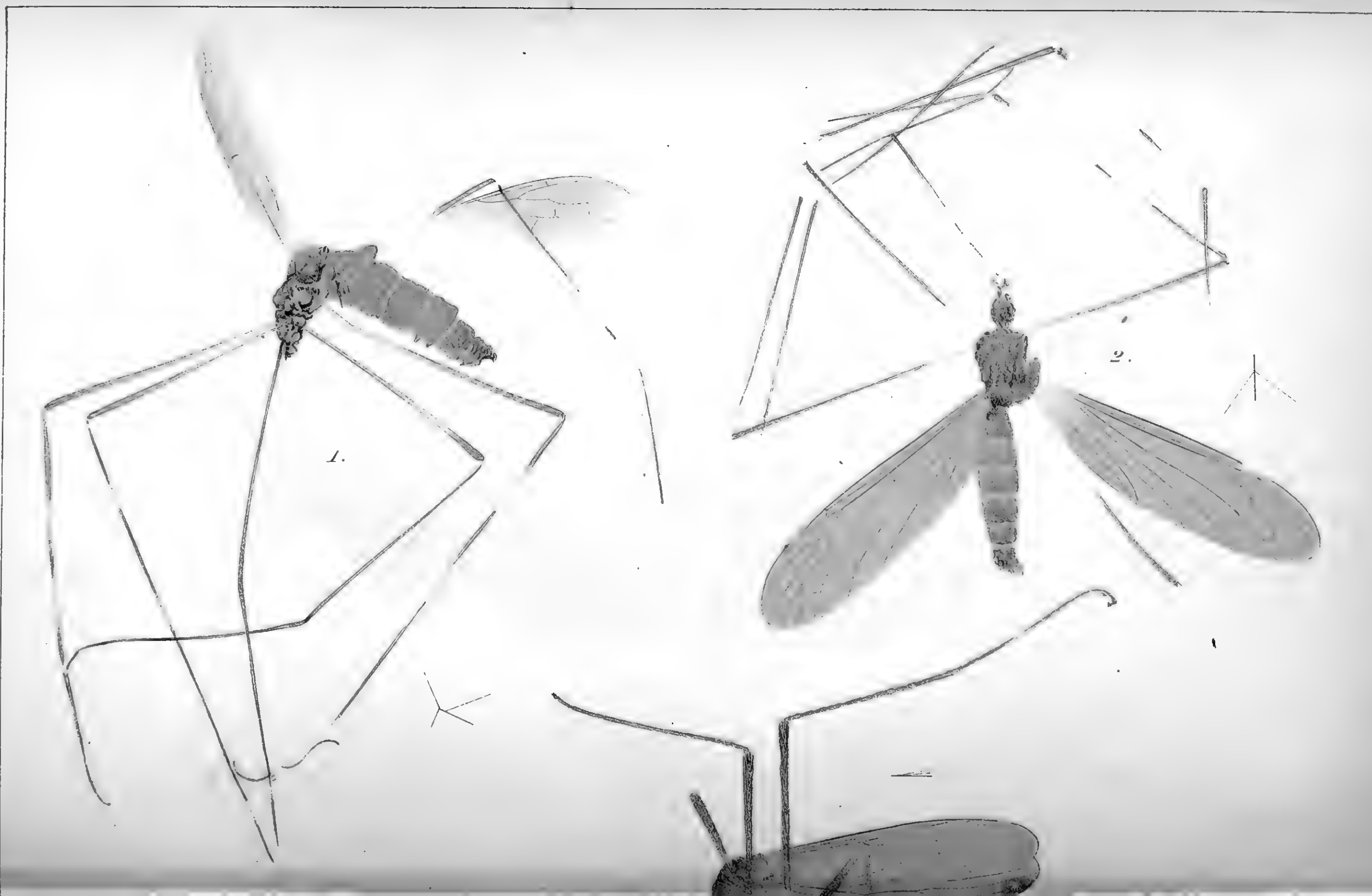
H. Hatch & Co. Boston

TERTIARY TIPULIDÆ OF COLORADO.

Plate II (Scudder).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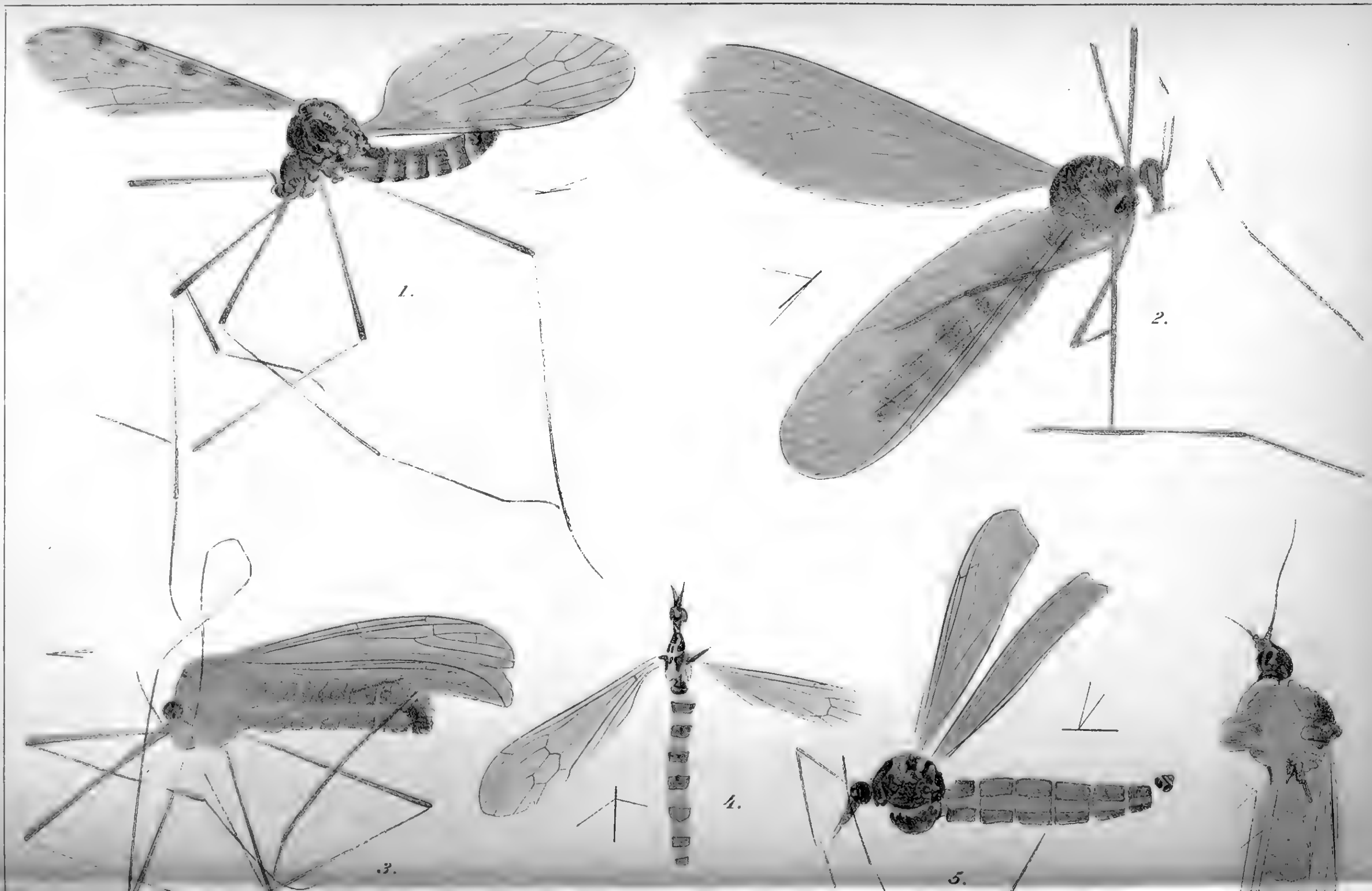
B Meisel, lith. Boston

TERTIARY TIPULIDÆ OF COLORADO.

Plate III (Scudder)

TERTIARY TIPULIDÆ OF COLORADO.

Plate III (Scudder)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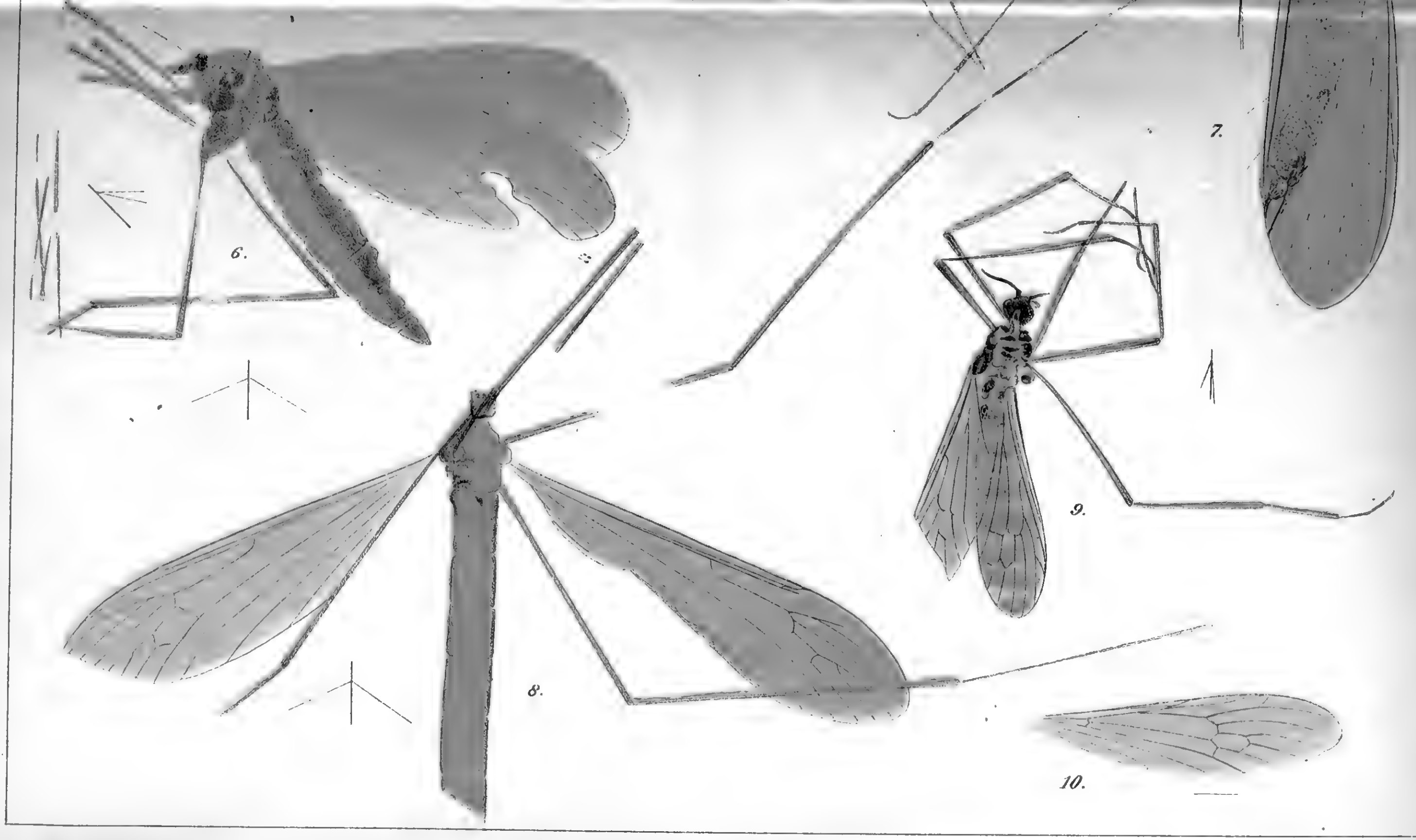
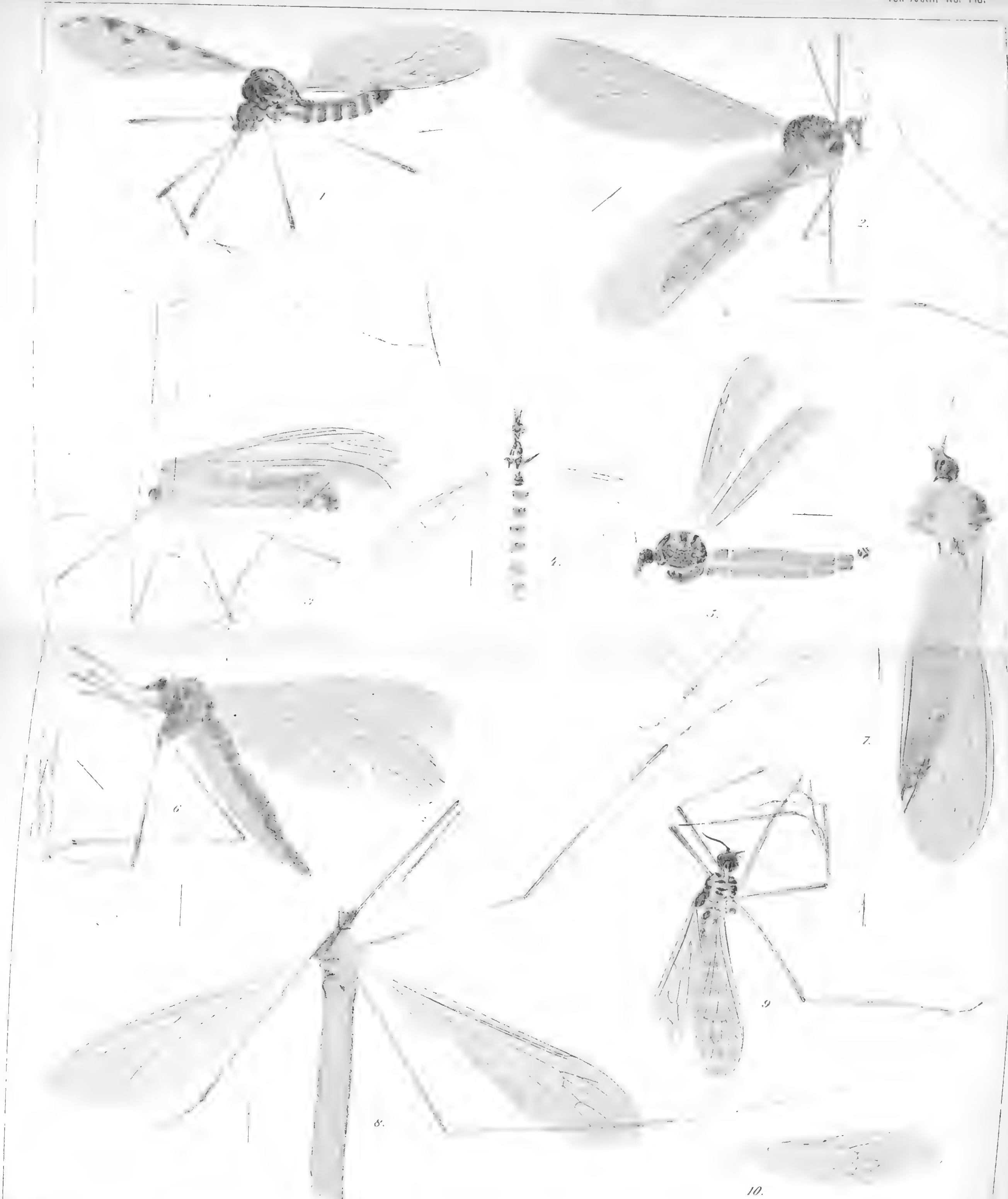


J.H.B. del. B. Meisel, lith. Boston.

TERTIARY TIPULIDÆ OF COLORADO.

Plate IV (Scudder).



TERTIARY TIPULIDÆ OF COLORADO.

Plate IV (Scudder).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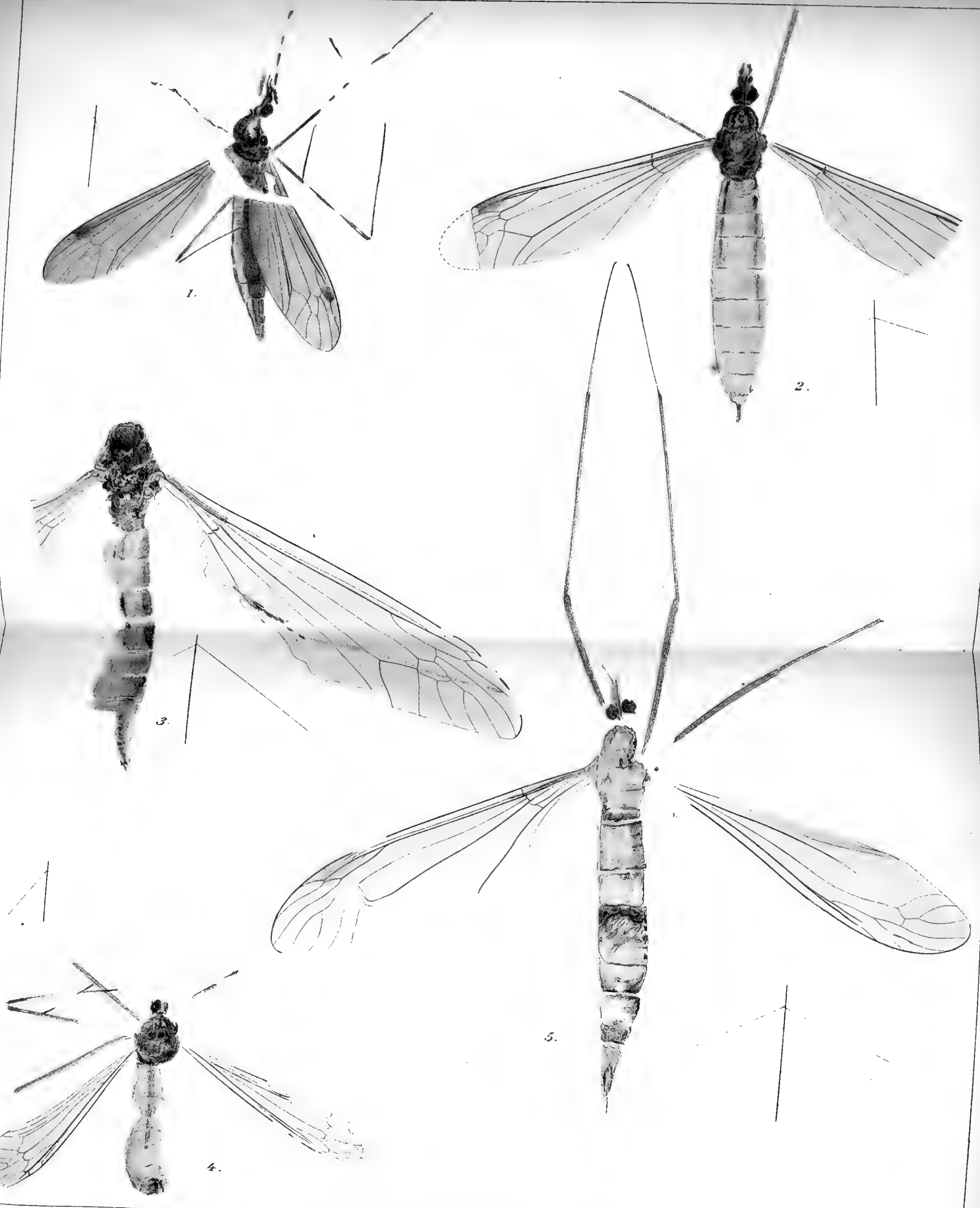
B Meisel, lith. Boston

TERTIARY TIPULIDÆ OF COLORADO.

Plate V (Scudder).



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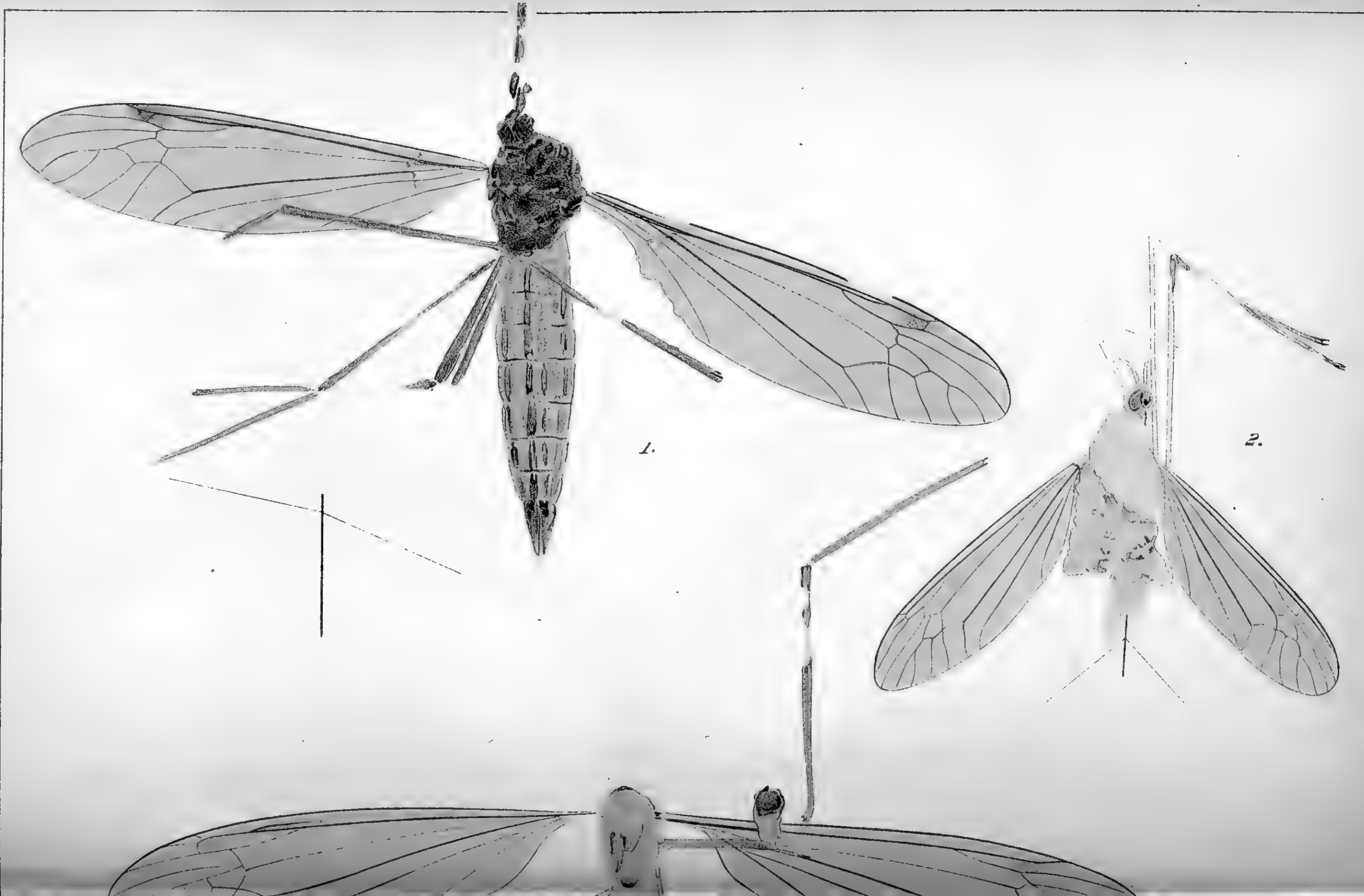
B Meisel lith. Boston

TERTIARY TIPULIDÆ OF COLORADO.

Plate V (Scudder).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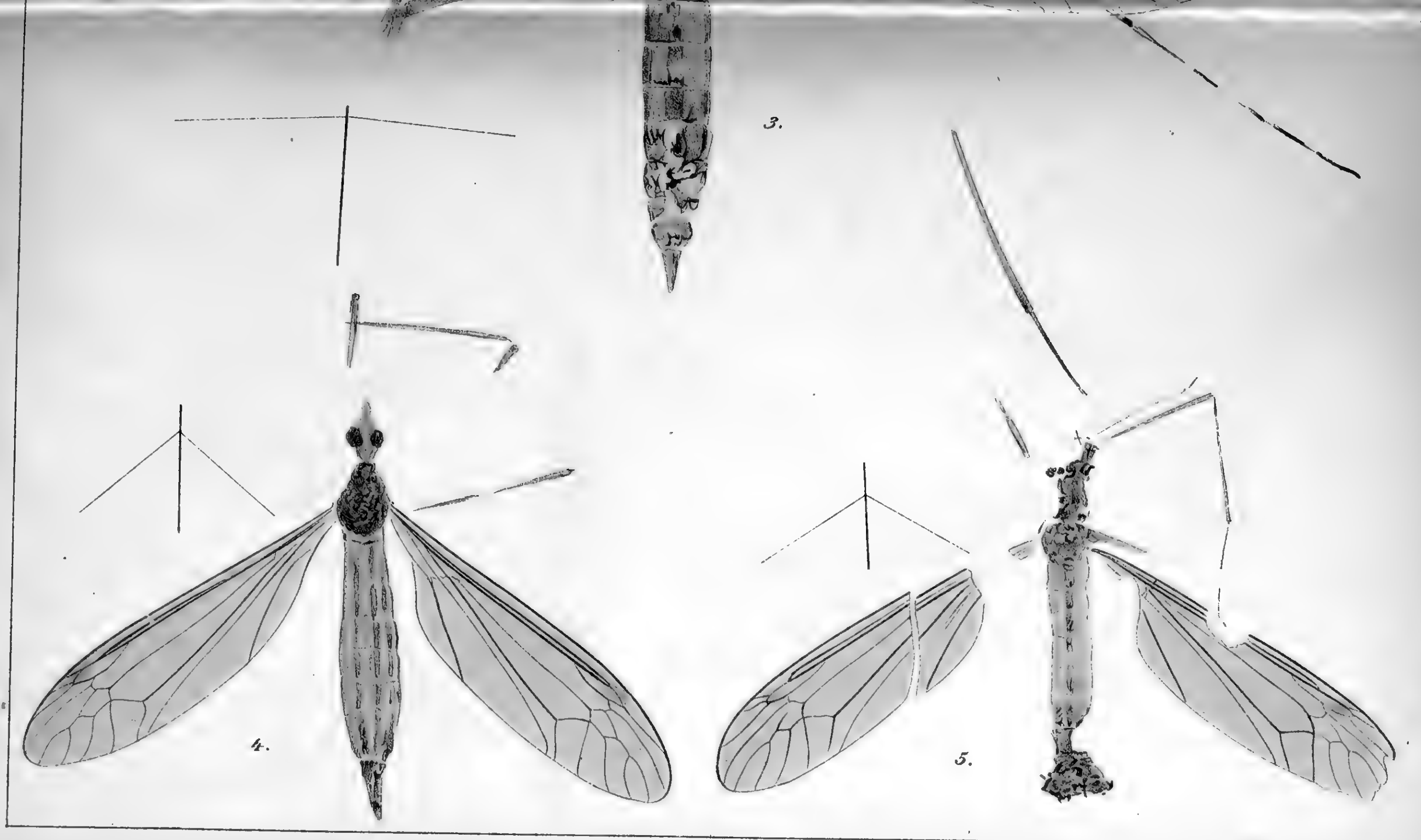

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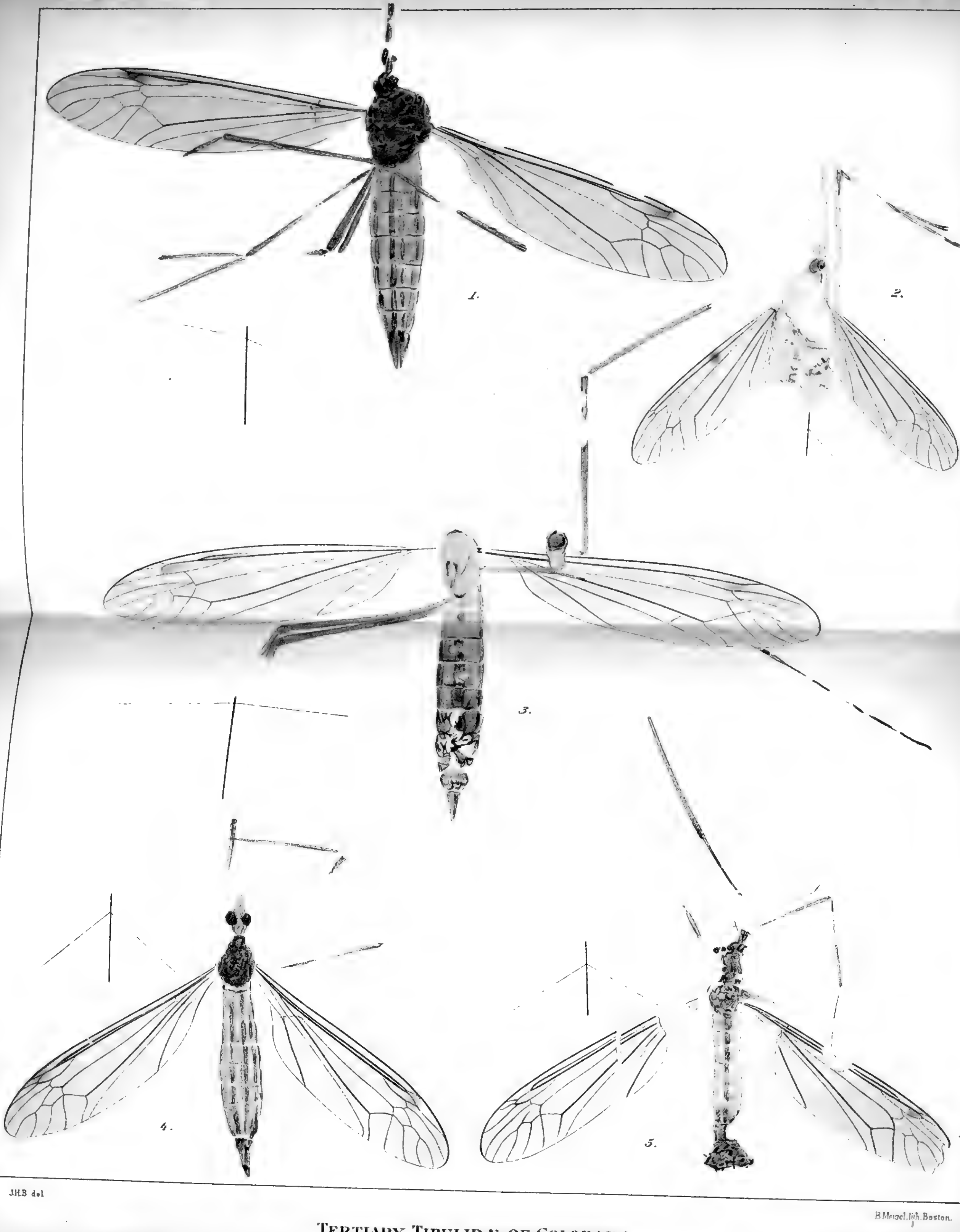
B. Meisel, lith. Boston

TERTIARY TIPULIDÆ OF COLORADO.

Plate VI (Scudder).



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B. Meisel, lith. Boston.

TERTIARY TIPULIDÆ OF COLORADO.

Plate VI (Scudder).


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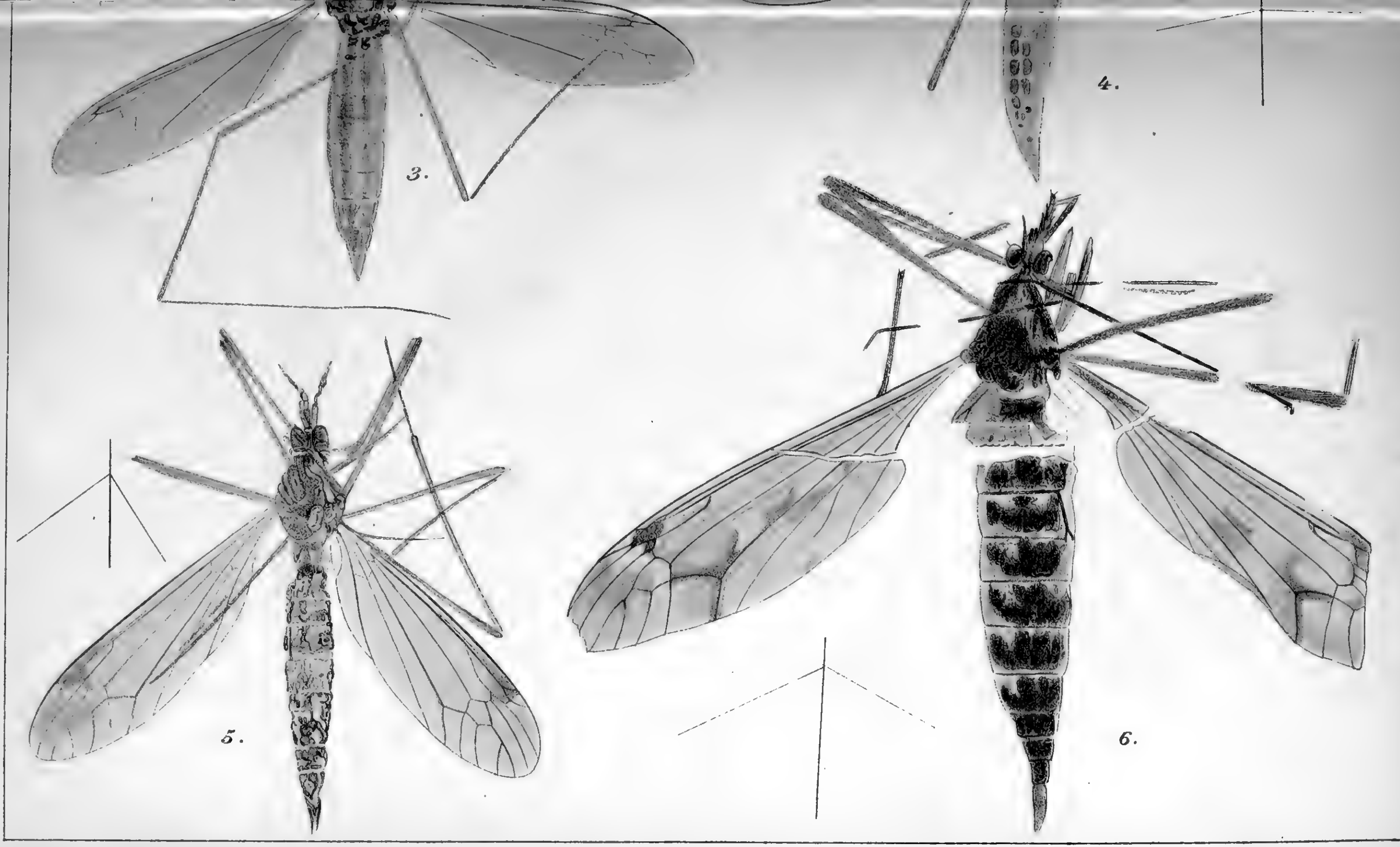
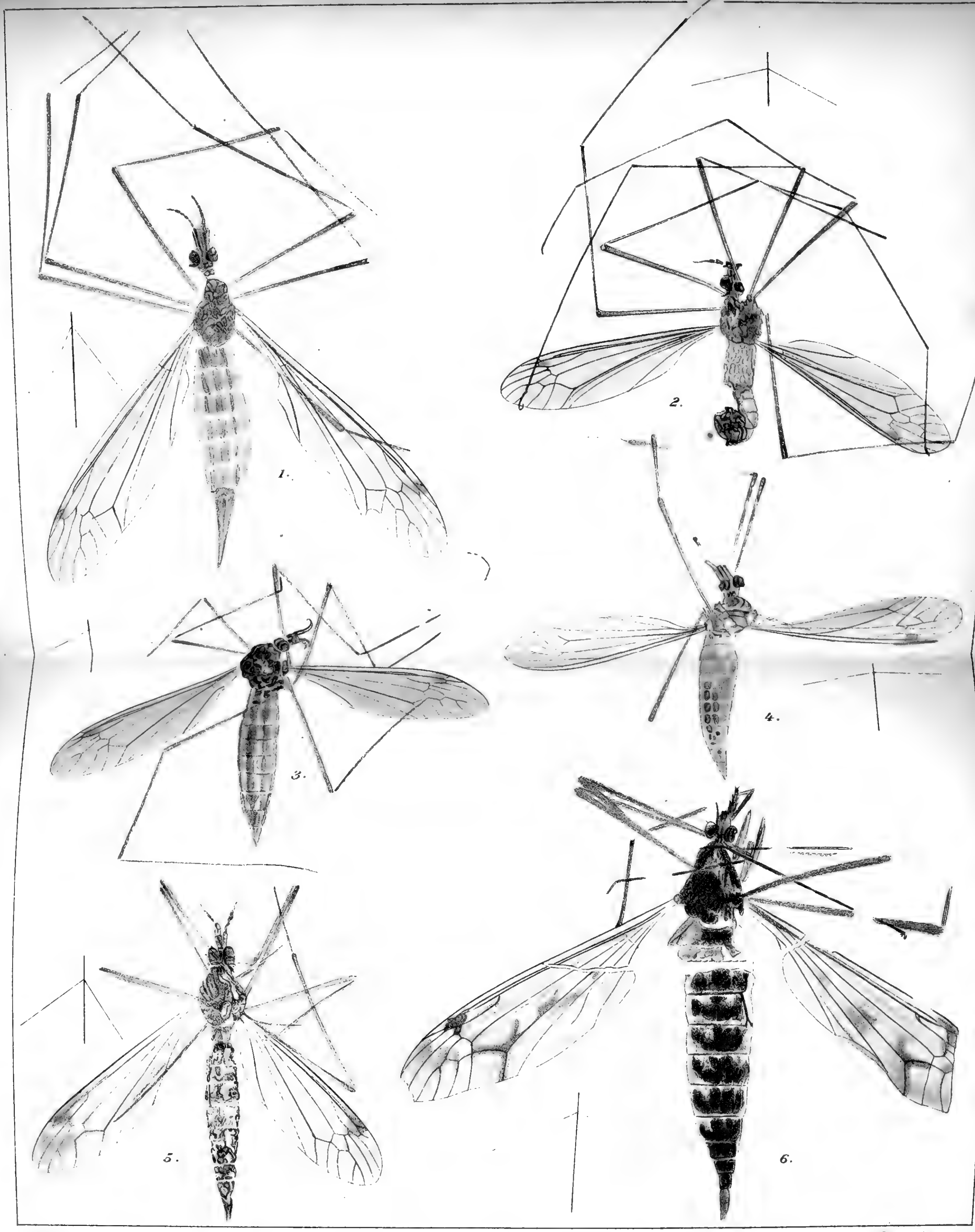


J.H.B. del. B Meisel, lith. Boston.

TERTIARY TIPULIDÆ OF COLORADO.



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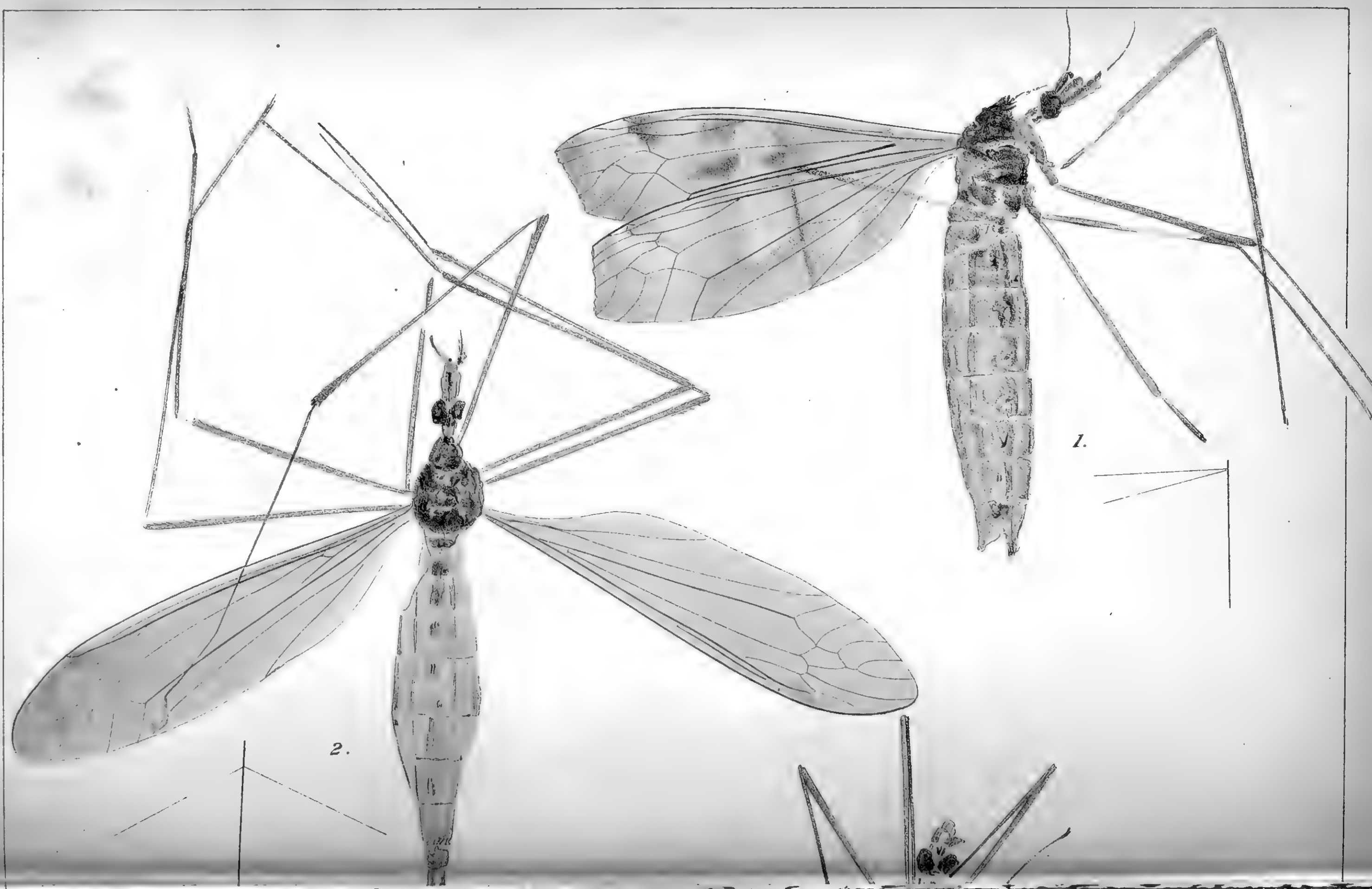
B Meisel, lith. Boston

TERTIARY TIPULIDÆ OF COLORADO.

Plate VII (Scudder).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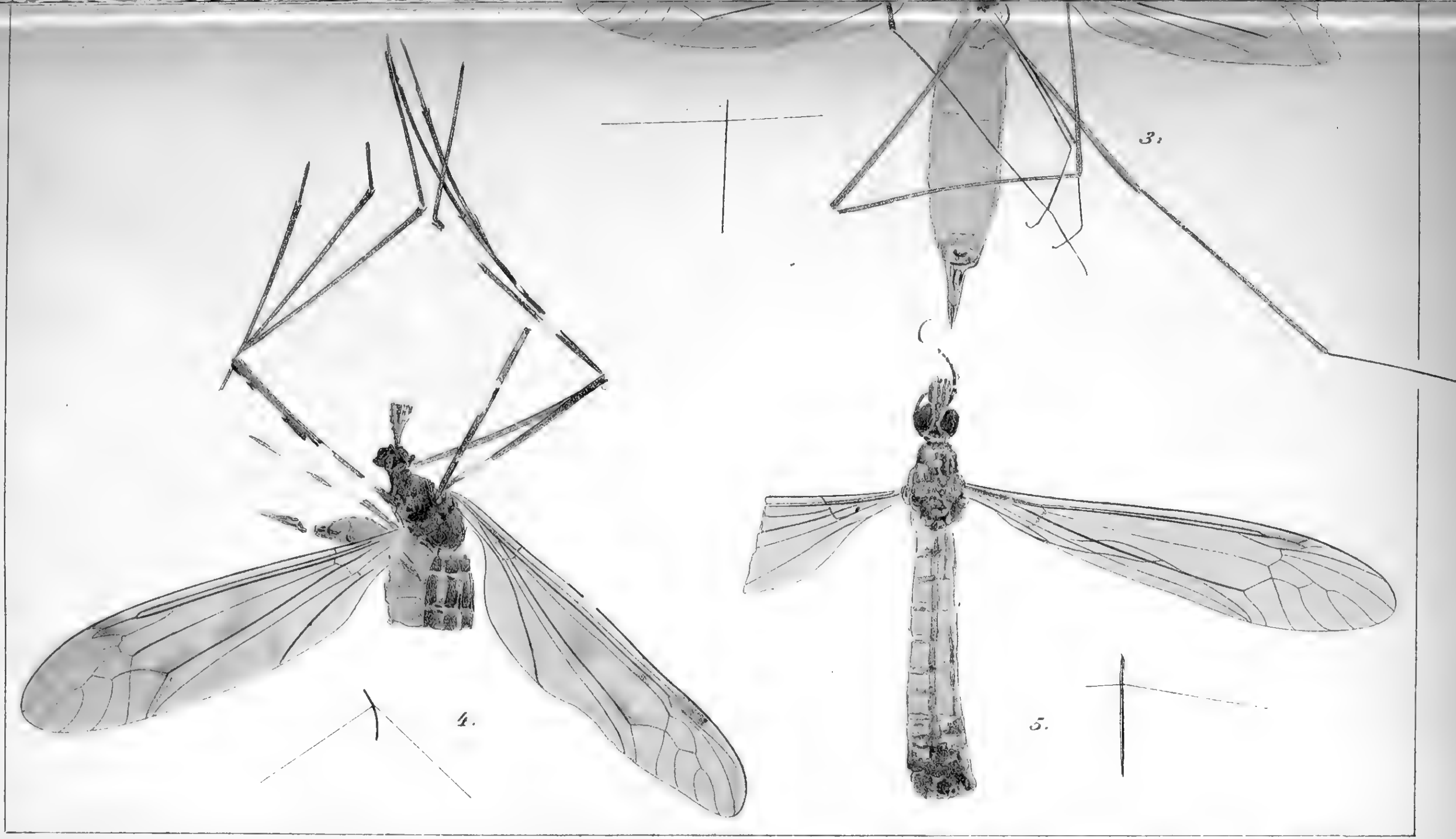

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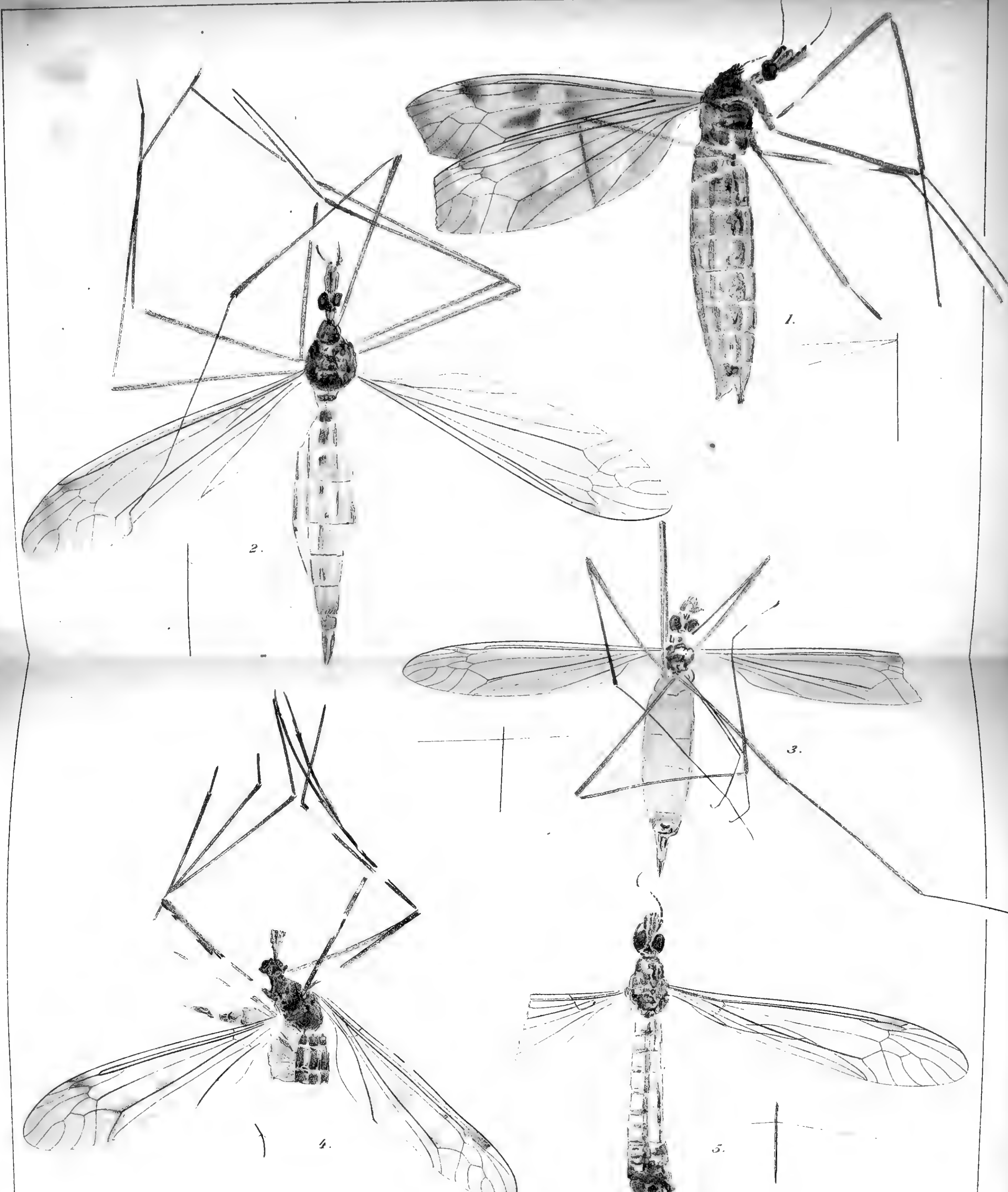
B Meisel lith. Boston

TERTIARY TIPULIDÆ OF COLORADO.

Plate VIII (Scudder).



J.H.B. del. B. Meisel lith. Boston

TERTIARY TIPULIDÆ OF COLORADO.

Plate VIII (Scudder).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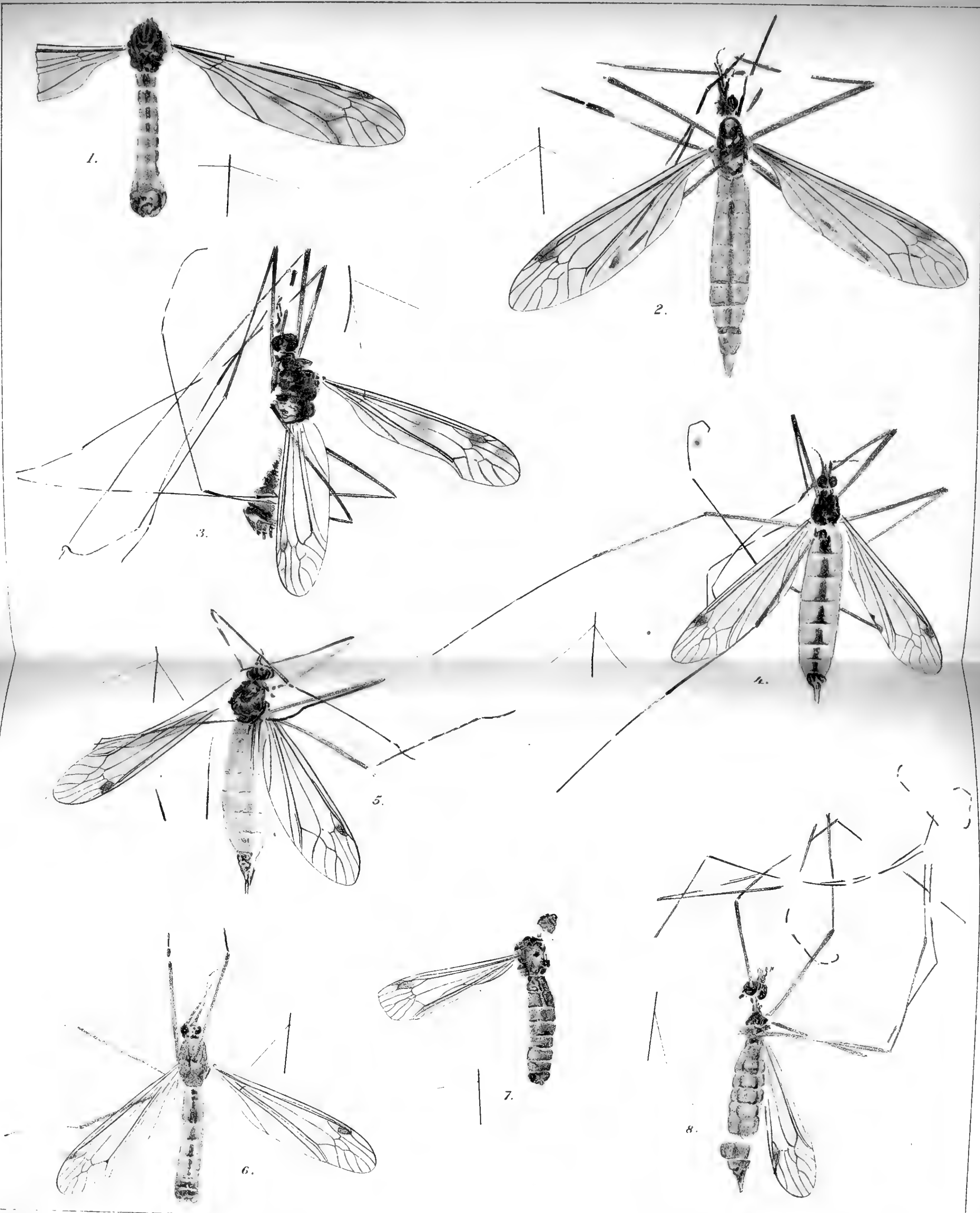
R Meisel, lith. Boston.

TERTIARY TIPULIDÆ OF COLORADO.

Plate IX (Scudder).



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B Meisel lith Boston

TERTIARY TIPULIDÆ OF COLORADO.

Plate IX (Scudder).

Micrapsis paludis.

Pl. 9, fig. 7.

Wings apparently about three and a half times longer than broad, uncolored except for the stigma occupying the outer half of the inner marginal cell and the parts above. Auxiliary vein terminating at the middle of the inner marginal cell; poststigmatal cross vein transverse, not very brief; trapezoidal cell brief. Præfurca short and oblique, scarcely longer than the width of the first basal cell. Petiole of second posterior cell long, longer than the præfurca; fifth posterior cell slightly broader at base than at margin, but relatively long. Discal cell minute, quadrangular, about twice as long as broad, but no longer than the width of the fourth posterior cell. Legs not preserved. Abdomen apparently without markings.

Length of fragment of wing, 9.2 mm.; probable length of wing, 10 mm.

Florissant, Colorado. One specimen, No. 9039.

Explanation of the Plates.

Excepting Pl. 4, fig. 10, which is a camera lucida sketch by S. H. Scudder, all the drawings were made by J. Henry Blake for the U. S. Geological Survey, and are used here by the kind permission of the Director of the Survey. The line beside each figure indicates the natural size, and the enlargement is further specified under the explanation of each figure. The particular specimen figured is indicated by number. All the specimens figured are from Florissant, Colorado.

Plate I.

Fig. 1. (1.770) Cyttaromyia princetoniana, $\frac{8}{1}$.
" 2. (13259) Cyttaromyia oligocena, $\frac{6}{1}$.
" 3. (3751) Dicranomyia inferna, $\frac{3}{1}$.
" 4. (5582) Dicranomyia longipes, $\frac{6}{1}$.
" 5. (214) Dicranomyia longipes, $\frac{4}{1}$.
" 6. (206) Oryctogma sackenii, $\frac{2}{1}$.
" 7. (86) Cyttaromyia cancellata, $\frac{5}{1}$.
" 8. (8649) Cyttaromyia clathrata, $\frac{6}{1}$.

Plate II.

Fig. 1. (173) Dicranomyia fontainei, $\frac{6}{1}$.
" 2. (11817) Limnocema lutescens, $\frac{6}{1}$.
" 3. (12127) Dicranomyia fragilis, $\frac{4}{1}$.

Fig. 4. (8751) Dicranomyia stagnorum, $\frac{6}{1}$.
" 5. (8215) Limnocema mortoni, $\frac{6}{1}$.
" 6. (11389) Limnocema styx, $\frac{6}{1}$.
" 7. (13069) Limnocema marcescens, $\frac{6}{1}$.
" 8. (9127) Dicranomyia stagnorum, $\frac{4}{1}$.

PLATE III.

Fig. 1. (215) Antocha principialis, $\frac{6}{1}$.
" 2. (1369) Rhamphidia loewi, $\frac{6}{1}$.
" 3. (7461) Gonomyia profundi, $\frac{8}{1}$.
" 4. (10490) Rhamphidia saxetana, $\frac{6}{1}$.
" 5. (9399) Rhamphidia fæcaria, $\frac{6}{1}$.

PLATE IV.

Fig. 1. (10399) Cladura maculata, $\frac{6}{1}$.
" 2. (12688) Cladoneura willistoni, $\frac{8}{1}$.
" 3. (13732) Limnophila rogersii, $\frac{6}{1}$.
" 4. (147) Gonomyia labefactata, $\frac{4}{1}$.
" 5. (8178) Limnophila strigosa, $\frac{6}{1}$.
" 6. (9575) Limnophila ruinarum, $\frac{6}{1}$.
" 7. (7021) Limnophila vasta, $\frac{6}{1}$.
" 8. (1590) Cladura integra, $\frac{6}{1}$.
" 9. (8656) Gonomyia frigida, $\frac{6}{1}$.
" 10. (8161) Gonomyia primogenitalis, $\frac{6}{1}$.

PLATE V.

Fig. 1. (8200) Manapsis anomala, ♀, $\frac{3}{1}$.
" 2. (8210) Tipula florissanta, ♀, $\frac{3}{1}$.
" 3. (5481) Tipula magnifica, $\frac{3}{1}$.
" 4. (8847) Rhadinobrochus extinctus, ♂, $\frac{3}{1}$.
" 5. (11669) Tipula rigens, ♀, $\frac{3}{1}$.

PLATE VI.

Fig. 1. (16314) Tipula rigens, ♀, $\frac{3}{1}$.
" 2. (88) Tipula clauda, $\frac{3}{1}$.
" 3. (14699) Tipula rigens, ♀, $\frac{3}{1}$.
" 4. (1.750) Tipula florissanta, ♀, $\frac{3}{1}$.
" 5. (14004) Tipula florissanta, ♂, $\frac{3}{1}$.

PLATE VII.

Fig. 1. (7221) Tipula florissanta, ♀, $\frac{3}{1}$.
" 2. (3820) Tipula clauda, ♂, $\frac{3}{1}$.
" 3. (1.753) Tipula clauda, ♀, $\frac{3}{1}$.
" 4. (100) Tipula clauda, ♀, $\frac{3}{1}$.
" 5. (14715) Tipula carolinæ, ♀, $\frac{3}{1}$.
" 6. (7783) Tipula maclurei, ♀, $\frac{3}{1}$.

PLATE VIII.

Fig. 1. (12109) Tipula tartari, ♀, $\frac{3}{1}$.
" 2. (11806) Tipula heilprini, ♀, $\frac{3}{1}$.
" 3. (9157) Tipula subterjacens, ♀, $\frac{3}{1}$.
" 4. (2839) Tipula limi, ♀, $\frac{3}{1}$.
" 5. (13737) Tipula subterjacens, ♂, $\frac{3}{1}$.

PLATE IX.

Fig. 1. (1611) Tipula limi, ♂, $\frac{3}{1}$.
" 2. (402) Tipula lethæa, ♀, $\frac{3}{1}$.
" 3. (8831) Tipula lapillescens, ♂, $\frac{3}{1}$.
" 4. (8598) Tipulidea picta, ♀, $\frac{3}{1}$.
" 5. (8480) Tipulidea reliquiæ, ♀, $\frac{3}{1}$.
" 6. (13745) Tipulidea picta, ♂, $\frac{3}{1}$.
" 7. (9039) Micrapsis paludis, ♂, $\frac{3}{1}$.
" 8. (11333) Tipulidea bilineata, ♀, $\frac{3}{1}$.

Some of the Work of the Wagner Free Institute of Science of Philadelphia. By Joseph Willcox.

As the representative of the Wagner Free Institute of Science invited to participate in the celebration of the 150th anniversary of the American Philosophical Society, I have thought it proper to make a few statements concerning some of the work of the Wagner Institute, a colaborer with this Society in the same field of usefulness.

Though young in age, the Wagner Institute has endeavored to profit by the experience of older institutions. It was established by the late Prof. William Wagner who, in the year 1847, gave a course of free lectures on scientific subjects at his house. The success of this experiment encouraged him to found an institution for instruction in science, to include a museum of natural history specimens, a laboratory for physical and chemical students, a library and a lecture department.

The building of the Wagner Free Institute of Science was completed in 1864, and from that time until Prof. Wagner's death in 1885 courses of free lectures were maintained on scientific subjects during each succeeding winter.

Prof. Wagner spent a large portion of his life in accumulating and husbanding resources for the future use of the Institute.

Among other favorite pursuits, he collected minerals in northern New York and Nova Scotia, and fossils in Maryland and Virginia, at a time when those localities were difficult of access.

After the death of Prof. Wagner in 1885, the Trustees proceeded, as rapidly as the funds at their command permitted, to open the museum and library for the use of the public. The library was opened for use in 1889, and the museum in 1891. The lectures have also been maintained since the death of Prof. Wagner. These schemes are, of course, a source of benefit only to the people living in the vicinity of the Institution. In order to enlarge the domain of its usefulness, the Trustees determined to promote the work of original investigation both in the laboratory and in the field, and to publish the results in the form of its *Transactions*. It was concluded to take up either a new or a long neglected subject for the pursuit, rather than to direct the energies of the Institute into a field already occupied by competent explorers.

Since the time when Messrs. Lea, Conrad, Say, Morton, Emmons, Rogers, Tuomey and Holmes maintained great activity in the study of our Tertiary formations, the subject has practically been permitted to lie dormant, especially in relation to the middle and the later beds, until the year 1886. During that year the attention of the Trustees of the Wagner Free Institute having been directed to the State of Florida as affording a new and inviting field for investigation, a small party was organized and spent a few weeks there under the auspices of the Institute. The most important of the results was the discovery of a Pliocene shell bed, rich both in numbers and species; the first undoubted deposit of that age that has been discovered in the eastern portion of the United States. The material collected in the bed was productive of many new forms.

The results of the first exploration prepared by Prof. Heilprin were published by the Wagner Institute, and formed the first volume of its *Transactions*. During the following winter further explorations were made in Florida, and, among other fossils, many vertebrate remains were collected, including several new species. The descriptions of these were written by the late Prof. Joseph Leidy, and were published in the second volume of the *Transactions* of the Institute.

These explorations were subsequently prosecuted in Florida by several friends of the Institute, including Prof. William H. Dall, of the U. S. Geological Survey; each year affording a more extensive knowledge of the geology of that State, which has been found to include all the Tertiary formations. Prof. Dall has since been engaged in examining and writing upon these additional collections. Two volumes of his papers have already been published by the Wagner Institute, containing twenty-two plates of illustrations; and another, by the same author, is in the course of preparation.

Until recently, the question of the existence of Tertiary beds of Pliocene age in North and South Carolina had never been determined, as geologists held different opinions, based upon the fossils that had been collected in those States in a desultory, unsystematic manner. In order to solve this question, the Wagner Institute authorized the Curator of its museum to explore the fossil beds in the eastern portion of those States in November, 1891. After four weeks' work in the field, the question was satisfactorily determined that Pliocene beds exist in each of those States. This matter was fully discussed by Prof. Dall in Vol. iii, Part ii of the *Transactions of the Wagner Institute.*

The U. S. Geological Survey has generously cöoperated with the Wagner Institute in this work, not only in the researches in the field, but in permitting one of its specialists, Prof. William H. Dall, to investigate the collections and to edit the volumes of the *Transactions* in which they are described. A new interest has been awakened in the study of our American Tertiary invertebrate palæontology by the publications referred to.

In order to further stimulate the study of that department of geology, the Wagner Free Institute of Science proposes, at an early date, to reprint T. A. Conrad's book, the *Medial Tertiary Fossils of the United States*, the most important work pertaining to our Miocene formation. This book was published in the year 1838. It has been out of print for many years; a very limited number of copies only having been printed.

A large portion of the specimens collected during these explorations are now arranged in the Free Museum of the Institute for the use of students. These explorations have been supplemented by others, in the Miocene beds of Maryland, Virginia and North Carolina, in order to supply additional subject-matter for the publications and to enrich the museum.

Catalogue of Works on Atmospheric Physics and Climatology.

Library of Lorin Blodget.

The several titles and volumes represented in this collection have all been in actual use in the preparation of my own works and in the various discussions of the Science of Atmospheric Physics, which I have had occasion to undertake.

1635 PLINY: Natural History. C. Plinius Secundus. Translated by Philemon Holland. London, 1635. Folio.

1659 LIVY: The Roman History. Titus Livius of Padua. At pp. 844–850 are described "Violent Tempests," which destroyed buildings in Rome, etc. Philemon Holland's translation. London, 1659. Folio.

1667 KIRCHER: Magneticum Naturæ Regum. Athanasius Kircher. Amsterdam, 1667. (Cited.)

1671 MORE: Enchiridion Metaphysicum sive de Rebus Incorporeis. Chap. xx, etc., treat of "Cœlestia Phænomena quales sunt Nubes, Guttæ pluvie, Venti ac Tonitrua" (Clouds, Rain, Winds and Thunder). With illustrations. Henricus Morus. London, 1671. 4to, pp. 403 and 28.

1692 BOYLE: The General History of the Air. Designed and begun by the Hon. Robert Boyle. London, 1692. Small 4to, pp. 259. (Original publication by Robert Boyle in 1656. Boyle died Jan. 1, 1659.) At p. 103 is Townley's Register, 1670–1671. At pp. 104–132 is Locke's Register, 1666 to 1683.

1726 MOLL: Geography of the Ancients. Herman Moll. The several editions of Moll are valuable as showing the limitations to knowledge of Atmospheric Physics on the part of early writers.

1749 KALM—BARTRAM: Kalm's Travels in North America. In Vol. ii, at pp. 146–180, this Swedish author gives a series of meteorological observations by John Bartram, August, 1748, to September, 1749, taken at Bartram's house on the Schuylkill, Philadelphia.

1749 CLARE: A General Chronological History of the Air, Weather, Seasons, etc. In 2 vols. London, 1749. 8vo, pp. 495 and 536. In Vol. ii, pp. 163–215, is the General Table. 2407 A.M. to 1730 A.D.

1758 AMERICAN MAGAZINE: "A Monthly Chronicle for the British Colonies," 1757–1758. Contains scientific papers of value on Auroras, Electricity, etc. 1757 to 1770. 8vo.

1764 BELL: Travels from St. Petersburg in Russia, etc. 1. Journey to Ispahan, 1715. 2. Journey to Pekin in China, 1719–1721. London, 1764. 8vo, pp. 387.

1770 CARVER: Travels Through the Interior Parts of North America, more than 5000 miles, in 1766–1768. By Jonathan Carver. Dedicated to Sir Joseph Banks, President of the Royal Society. London, 1770. 8vo, pp. 280.

1770 PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY OF LONDON: The early numbers of this valuable series, at least from 1664, were consulted at the Library of the American Philosophical Society. They are especially valuable for early records of observation for the construction of instruments and for philosophical discussions. I quote at p. 18 of "Climatology" the experiments of Dr. Beal and Dr. Wallis, 1664–1675, on the construction of the barometer and its adaptation to climatological purposes. Robert Boyle is accredited with this "most extraordinary invention of the world." Dr. Halley, Mr. Townley, Dr. Plot, of Oxford, and Dr. Lister engaged in these experiments, kept the record, and began predicting the weather. In 1723 a form for daily observations is given and reference is made to registers kept by Dr. Lining and Isaac Greenwood in the United States.

1774 RAYNAL: "Historie Philosophique et Politique des Establissemens du Commerce des Europeens dans les deux Indies." Abbe Raynal. In French. Printed at The Hague, 1774. Vol. v relates wholly to North America. 8vo, pp. 405.

1781 CAVALLO: A Treatise on the Natural Properties of the Air. By Tiberius Cavallo. London, 1781. 4to, pp. 835.

1798 RUMFORD: Essays by Count Rumford. First American Edition. Boston, 1798. Essay iv and others on Heat, Smoke, Draft of Fire Places, etc. 8vo.

1799 WEBSTER: On the Supposed Change in the Temperature of

Winter. By Noah Webster. Read before the Connecticut Academy of Arts and Sciences. In collection of Webster's papers. New York, 1843.

1803 REDFIELD: Prevailing Storms of the Atlantic Coast. By C. Redfield. New York, 1803.

1804 VOLNEY: A View of the Soil and Climate of the United States of America. By C. F. Volney. Translated by C. B. Brown. Philadelphia, 1804. 8vo, pp. 446.

1801 CAPPER: Observations on the Winds and Monsoons. With a chart. By James Capper. London, 1801. 4to, pp. 234.

1805 PIKE: Expeditions to the Sources of the Mississippi, Arkan-
–1810 sas, Kansas, and La Platte Rivers. Also a Tour through New Spain during 1805–1807. By Major Zebulon M. Pike. Philadelphia, 1810. 8vo, pp. 277, and Appendices 65 and 87, with many maps.

1811 WILLIAMSON: The Climate of America Compared with that of Corresponding Parts of the Eastern Continent. By Hugh Williamson, M.D. New York, 1811. 8vo.

1811 HUMBOLDT: Political Essay on the Kingdom of New Spain. With physical sections and maps, etc. By Alex. de Humboldt. Translated by John Black. New York, 1811. 8vo, pp. cxv and 221.

1815 DE MALORTIE: A Treatise on Topography. By C. S. De Malortie. London, 1815. 2 vols., 8vo.

1818 HOWARD: The Climate of London, etc. By Luke Howard. London, 1820. 2 vols., 8vo.

1823 DALTON: Meteorological Observations and Essays. By John Dalton. London, 1823. 8vo, pp. 480.

1826 LOVELL: Army Meteorological Register for the years 1822 to 1825, from observations by Surgeons of the U. S. Army, By Joseph Lovell, M.D. Washington, 1826. 8vo. See a report for 12 years, 1831 to 1842, made in 1851, and another for 1843 to 1854, made in 1856, both under direction of Surgeon-General Lawson.

1835 HARE: Brief Exposition of the Science of Electricity, etc. By Robert Hare, M.D. Philadelphia, 1835. 8vo, pp. 113.

1837 DOVE: Meteorologische Untersuchungen, Von H. W. Dove. Berlin, 1837. 8vo, pp. 344.

1837 EPSY: Directions for Making Meteorological Observations.

By the Joint Committee of the American Philos. Society and the Franklin Institute. Printed for the Committee, 1837. Philadelphia. 8vo, p. 7.

1837 ESPY: Hints to Observers on Meteorology. By James P. Espy, Meteorologist. Philadelphia, July 7, 1837. 8vo, pp. 12.

1840 LAWSON: Army Meteorological Register for the years 1826 to 1830. By Thomas Lawson, M.D., Surgeon-General. Philadelphia, 1840. 8vo, pp. 161.

1840 FORRY: Statistical Report on the Sickness and Mortality of the Army of the United States. By Samuel Forry, M.D. Washington, 1840. 8vo, p. 346.

1841 ESPY: The Philosophy of Storms. By James P. Espy, A.M. Boston, 1841. 8vo, pp. 552. "Artificial Rains," pp. 492–518.

1840 HARE: Communication Faite a la Societe Philosophique Americaine, dans une de ses Seances de 1839, au sujet des Trombes, et relativement a un Memoire de Mr. Peltier sur la cause de ces Meteores, par Robert Hare, M.D. Philadelphia, 1840. pp. 12.

1840 HARE: A verbal communication from Dr. Hare respecting experiments as to the heating and cooling influence of changes in the density of the air. By Dr. Robert Hare, to the American Philosophical Society. July, 1840. Philadelphia. pp. 6.

1841 WHITE: On the Theories of the Weather Prophets and the Comparative Success of their Predictions. By W. H. White, Secretary to the Meteorological Society. London, 1841. pp. 16.

1843 HOWARD: Climate of London. Latest edition.

1843 LOOMIS: On Two Storms in the United States, in February, 1842. By Elias Loomis, Hudson, Ohio, 1843. 4to, pp. 25, and 15 plates. Printed as pp. 161–184 of Proceedings of American Academy.

1843 NICOLLET: Report and Map of the Hydrographical Basin of the Mississippi. By J. N. Nicollet. Washington, 1843. Senate Document, 26th Congress, 2d Session.

1844 AMERICAN ALMANAC: Second series, 1839 to 1850. Meteor-
–1850 ological Observations from 12 Stations in American

Almanac for 1844, pp. 85–93, and in each issue to the end of this series: viz., 1845 to 1850.

1844 GREENHOW: History of Oregon and California, and other Countries of the North West Coast of North America. By Robert Greenhow. Boston, 1844. 8vo, pp. 482, with map.

1844 FORRY: Researches on the Distribution of Heat over the Globe, etc. By Samuel Forry, M.D. Reviewed in Silliman's Journal, Vol. xlvii, pp. 18 to 50, and 222 to 241, with isothermal chart.

1845 GILLISS: Magnetic and Meteorological Observations made at Washington, July, 1838, to July, 1842, at the Observatory, Capitol Hill. By Lieut. J M. Gilliss, U. S. N. 8vo, pp. 648.

1845 KÆMTZ: A Complete Course of Meteorology. By L. F. Kæmtz. Translated by C. V. Walker. London, 1845. 8vo, pp. 595, and plates.

1846 REDFIELD: Hurricanes and Northers. On Three Several Hurricanes of the Atlantic, and their Relations to the Northers of Mexico and Central America. By W. C. Redfield. New Haven, 1846. 8vo, pp. 117, and plates.

1847 HOBBS: Sailing Directions for the Mediterranean Sea. By J. S. Hobbs, F.R.S. London, 1847. 8vo, paper, pp. 195.

1847 PIERCE: A Meteorological Journal of the Weather in Philadelphia from January, 1790, to January, 1847. By Charles Pierce. Lindsay & Blakiston, Philadelphia, 1847. 8vo, pp. 300.

1847 BACHE: Magnetic and Meteorological Observations at Girard College, 1840 to 1845. By A. D. Bache. Washington, 1847. 3 vols.

1847–1849 DOVE & SABINE: Isothermal Lines. Remarks by Prof. H. W. Dove, on his Recently Constructed Maps of the Isothermal Lines of the Globe. With an Introductory Notice by Lieut. Col. Edward Sabine, General Secretary British Association for the Advancement of Science, 1848. London, 1849. 8vo, pp. 19.

1848 MULLER: Principles of Physics and Meteorology. By J. Muller. Lee & Blanchard, Philadelphia, 1848. Large 8vo, pp. 638.

1849 GUYOT: Earth and Man. Lectures on Comparative Physical

Geography, etc. By Arnold Guyot. From the French, by C. C. Felton. Boston, 1849.

1849 REID: Progress of the Development of the Law of Storms. By Lieut. Col. W. C. Reid. London, 1849. A first edition in 1838. 8vo, pp. 431. Second edition, pp. 424.

1850 SMITHSONIAN INSTITUTION: Directions for Meteorological Observations. Prepared by Arnold Guyot. Washington, 1850. 8vo, pp. 40.

1850 HUMBOLDT: Cosmos. By Alex. von Humboldt. Translated by E. Cotte. Harper Bros., New York, 1850. 2 vols, 8vo, pp. 373 and 367. There are other editions of each of these works by Humboldt.

1850 HUMBOLDT: Aspects of Nature. By Alex. von Humboldt. Translated by Mrs. Sabine. Lea & Blanchard, Philadelphia, 1850. 8vo, pp. 475.

1850 HUMBOLDT: Views of Nature. By Alex. von Humboldt. Translated by Otte & Bohn. Bohn, London, 1850. 8vo, pp. 452.

1851 MAURY: Correspondence in Relation to a Universal System of Meteorological Observations by Sea and Land. By M. F. Maury. Washington, 1851. 12mo, pp. 30.

1851 LAWSON: Meteorological Register for 12 years, 1831 to 1842 inclusive. From Observations at the Military Posts, etc. By Thomas Lawson, Surgeon-General U. S. A. Washington, 1851. 8vo, pp. 324.

1851 BROOKS: The Tornado of 1851. By Rev. Charles Brooks, of Middlesex, Mass. Boston, 1852. 12mo, pp. 12.

1852 GUYOT: Meteorological Tables, prepared for the Smithsonian Institution. I. Thermometrical Tables. II. Hygrometrical Tables. 1. Elastic Force of Vapor. By Regnault. 2. The same. By August. 3. The same. By Haeghens. III. Barometrical Tables. IV. Hypsometrical Tables. V. Horary Variations, etc. VI. Miscellaneous. By Arnold Guyot, Prof., etc. Washington, 1852. 8vo, pp. 246. These tables each separately paged but aggregating 234 pages as bound up. There are 15 divisions of Table I, 5 divisions of Table II and 6 divisions of Appendix to Table II, Table III has 12 divisions, Table IV has 8 with 13 in the Appendix, Table V has 70 divisions and Table VI has 21 divisions.

1852 DAVIS: The Law of Deposit at Flood Tide. By. Lt. Comg. Charles Henry Davis, U. S. N. Smithsonian Contribution to Knowledge. Washington, 1852. 4to, pp. 13.

1852 GUYOT: Meteorological Tables. Table VIII. Corrections to English Barometers, for Capillary Action. Table IX. Corrections for Barometers with Brass Scales to Reduce to 32 Fahr. 8vo, pp. 9.

1852 HARE: Strictures on Prof. Espy's Report on Storms. By Robert Hare, M. D. Albany, 1852. 8vo, pp. 10.

1852 HUMBOLDT: Personal Narrative of Travels to the Equatorial Regions of America, 1799 to 1804. By Alex. von Humboldt and Aime Bonpland. Written in French by Alex. von Humboldt and translated by Thomasina Ross. London, 1852. 2 vols., 8vo.

1853 RAVENEL: A Meteorological Journal, for the year 1853, kept in St. John Berkeley Parish for the Black Oak Agricultural Society. By T. P. Ravenel, Secretary. Charleston, 1854. 8vo, pp. 15.

1853 THOMPSON: Natural History of Vermont. By Prof. Zadock Thompson. Burlington, Vt., 1853. 8vo, pp. 224. Appendix, pp. 65. (Pages 9–23 and 7–11, Appendix, relate to Climate.)

1853 BLODGET: Agricultural Report of the Commissioner of Patents, "Agricultural Climatology of the United States, Compared with that of Other Parts of the Globe," by Lorin Blodget, pp. 227–432. Washington, 1854.

1853 AGRICULTURAL CLIMATOLOGY of the United States, etc. By Lorin Blodget. pp. 327 to 432 of Commissioner of Patents' Report for 1853 contains many extracts and makes acknowledgments for many series of observations, personally communicated, not cited in connection with Climatology of 1857, in part, as follows:

Gasparin Cours d'Agriculture.
Schouw's Climate of Italy.
Boussingault's Rural Economy.
Drake's Valley of the Mississippi.
Annuaire Meteorologique de France.

Kupffer's Meteorological Observations, Russia.
Many Topographical Survey Reports.
De Bow's Review.

Also the results of extended periods of observation personally communicated by their authors, as follows:

Rev. Chester Dewey, LL.D., Rochester Academy, New York.
Dr. J. H. Engelmann, St. Louis, Mo.
Dr. Hempstead, Portsmouth, Ohio.
Dr. Daniel Drake, Cincinnati, Ohio.
Prof. Ray, Cincinnati, Ohio.
Dr. E. H. Barton, New Orleans.
Dr. Darlington, West Chester, Pa.
W. A. Whitehead, Esq., Newark, N. J., Key West.
Dr. John Conrad, Philadelphia Hospital.
Prof. Jacobs, Gettysburg, Pa.
H. W. Ravenel, St. John's, Berkeley, S. C.
Henry Poole, Albion Mines, N. S.
Dr. Smallwood, Isle Jesus, Montreal.
Capt. J. H. Lefroy, Toronto.
Samuel Rodman, Esq., New Bedford.
Dr. John Redman Coxe, Philadelphia. Valuable early Records.
Major Alfred Mordecai, Frankford Arsenal, Pa.
Dr. John F. Posey, Savannah, Ga.
J. A. Lapham, Milwaukee.

1851–1853 ESPY: Report on Meteorology: Letter of the Secretary of the Navy Transmitting the Report of Prof. J. P. Espy. Embodies Second Report, Nov. 12, 1849, and Third Report, Jan. 24, 1851. Folio, pp. 65, with many charts of storms, etc. Washington, 1852. Other editions of this folio report were issued in 1851 and 1853.

1853 BARTON: Report of the Sanitary Commission on Yellow Fever of 1853 at New Orleans. By Dr. E. H. Barton, and others. Climatological records and maps. Reports of Dr. Riddell and Dr. Simonds. New Orleans, 1854. 8vo, pp. 542.

1853 BLODGET: In Proceedings American Association. Papers read at Cleveland; On the Distribution of Rain in North

America, pp. 101; On the Monsoon of Texas, pp. 109, with map; The Distribution of Heat over the Continent, and its Isothermal Lines; On the Subordination of Atmospheric Phenomena, as to the Primary Cause; Barometric Pressure in Different Latitudes; On the Earthquake of April 29, 1852; these four papers were presented and discussed at the Cleveland meeting, but are printed elsewhere than in this report.

1853 LOOMIS: Notice of the Hailstorm which Passed over New York City on the First of July, 1853. By Elias Loomis. From Silliman's Journal, 1854. pp. 21.

1853 HARE: Exposure of the Errors of the French Academicians Respecting Tornadoes. By Dr. Hare. Philadelphia, 1853. pp. 14.

1853 HARE: The Whirlwind Theory of Storms. By Dr. Robt. Hare. Philadelphia, 1853. pp. 11.

1853 HARE: Strictures on Prof. Dove's "On the Law of Storms." By Robt. Hare. Philadelphia, 1853. pp. 12.

1853 HARE: Queries and Strictures Respecting Espy's Meteorological Report. By Dr. Hare. Philadelphia, 1853. pp. 16.

1853 HARE: De la Conclusion a Laquelle Est arrive uncomite de l'Academie de Sciences de France. By Dr. Hare. New York, 1853. pp. 30.

1853 AMERICAN JOURNAL OF SCIENCE AND ARTS (Silliman's Journal): This publication from 1822 to 1853 was the favorite channel for the publication of essays concerning the several departments of climatological science, the principal ones by Dr. Robt. Hare, W. C. Redfield, Elias Loomis, Col. Reid, Prof. Bache, Prof. Espy, and others, and in these essays are cited every foreign author then reputed to be in authority.

In Vol. xxxviii of this Journal is Dr. Hare's notice of Tornadoes, with an account of one which passed over Providence and one at Chateney, near Paris. In Vol. lxii Dr. Hare's "Objections to Mr. Redfield's Theory of Storms." Also his strictures on Dove's Essay on the Law of Storms.

1853 DAVIS: American Ephemeris and Nautical Almanac for the year 1855. By Charles Henry Davis, U. S. N. Washington, 1853. Large 8vo, pp. 498. (This is the first issue of the Ephemeris prepared in pursuance of an Act of Congress of March 3, 1849.

1853 MAURY: Explanations and Sailing Directions to Accompany the Wind and Current Charts. By M. F. Maury, Lieut. U. S. N. Washington, 1853. 4to, pp. 498 and plates, 5th ed.

1853 BLODGET: Climatic Conditions of the Summer of 1853, most Directly Affecting its Sanitary Character. By Lorin Blodget. New York, 1853. 8vo, pp. 25.

1853 BLODGET: Summer Climate of 1853 in its Relation to Agricultural Production. By Lorin Blodget. Washington, November, 1853. 8vo, pp. 26.

1853 WILLIAMS: The Chinese Empire and its Inhabitants. By S. Wells Williams. New York, 1853.

1853 SABINE: On the Periodic and Non-Periodic Variations of Temperature at Toronto, 1841 to 1852. By Lieut. Col. Edward Sabine. Proceedings American Academy, 1853. 4to, pp. 141–161 and plates.

1853 BOND: Minnesota and its Resources. By J. Wesley Bond. New York, 1853. 8vo, pp. 364.

1853 SMYTH: The Mediterranean. A Memoir, Physical, Historical and Nautical. By Rear Admiral William Henry Smyth. London, 1854. 8vo, pp. 519, etc.

1854 HERNDON AND GIBBON: Exploration of the Valley of the Amazon, etc. By William Lewis Herndon and Lardner Gibbon, Lieuts. U. S. Navy. Washington, 1854. Part I, by Lieut. Herndon. 8vo, pp. 417. Part II, by Lieut. Gibbon. 8vo, pp. 339.

1854 DOBBIN: The Annular Eclipse of May 26, 1854. Authority of James C. Dobbin, Secretary of Navy. Nautical Almanac, Cambridge, 1854. 8vo, pp. 13 and map.

1855 LE FROY: Magnetical and Meteorological Observations at Lake Athabasca and Fort Simpson. By Captain J. H. Le Froy. London, 1855. Royal 8vo, with Preface by Col. Sabine. pp. 1–288. (The following title embodied in the same volume.)

1855 RICHARDSON: Magnetical and Meteorological Observations at Fort Confidence. By Sir John Richardson. London, 1855. Royal 8vo, pp. 391.

1855 BUYS—BALLOT: Meteorologische Warnemingen, etc. General Report of Meteorological Observations in Europe for 1854 to the Netherlands Meteorological Institute. Utrecht, 1855. Folio, p. 237.

1855 HOUGH: Results of Meteorological Observations at the Academies of New York, 1826 to 1850. By Franklin B. Hough. Albany, 1855. 4to, pp. 499 and plates.

1855 WILKES: Theory of the Winds. By Captain Charles Wilkes, of the United States Exploring Expedition. Washington, 1855. Printed from Vol. xvii of Reports of the Expedition. Large 8vo, pp. 116 and map.

1855 BLODGET: Army Meteorological Register, for twelve years, 1843 to 1854 inclusive, under direction of General Lawson. By Lorin Blodget. Washington, 1855. 4to, pp. 677 and plates.

1855 MAURY: The Physical Geography of the Sea. By M. F. Maury, LL.D., Lt. U. S. N. New York, 1855. 8vo, pp. 274 and plates.

1855 REDFIELD: On the Gales and Hurricanes of the Western Atlantic. By W. C. Redfield. New York, 1855. pp. 20 and chart.

1856 FORCE: Record of Auroral Phenomena, etc. Compiled by Peter Force. Smithsonian Contributions to Knowledge. Washington, 1856. 4to, pp. 118.

1856 JEWELL: Sanitary Meteorological and Mortuary Report of the Philadelphia County Medical Society for 1855, made in May, 1856. By Dr. Wilson Jewell. Philadelphia, 1856. 8vo, pp. 64.

1856 GILLISS: The United States Naval Astronomical Expedition to the Southern Hemisphere during the Years 1849–1852. By Lt. J. M. Gilliss. Vol. vi, 4to, p. 420. House of Representatives Ex. Doc., 121, Thirty-third Congress, first session, Washington, 1856. At Santiago de Chile.

1856 COFFIN: Psychrometric Table for Determining the Elastic Force of Aqueous Vapors, the Relative Humidity of the Atmosphere. By Prof. James H. Coffin. Washington, 1856.

1856 BUTLER: The Philosophy of the Weather and a Guide to its Changes. By T. B. Butler. New York, 1856. 8vo, pp. 414.

1856 HUMBOLDT: The Island of Cuba. By Alex. von Humboldt. Translated by J. S. Thrasher. New York, 1856. 8vo, pp. 397.

1857 HALL: Register of Temperature and Rainfall for thirty-six years, at Boston, Mass. By Jonathan P. Hall. Boston, 1857. 4to, pp. 229–308. Transactions, Vol. vi.

1857 BUYS—BALLOT: Meteorologische Warnemingen, etc. General Report for 1857. Utrecht, 1858. Folio, pp. 350.

1857 MAURY: Gales in the Atlantic. National Observatory. By M. F. Maury, May, 1857. 4to, pp. 2 and 24 plates.

1857 BLODGET: Climatology of the United States and of the Temperate Latitudes of the North American Continent. By Lorin Blodget. Philadelphia, 1857. Royal 8vo, pp. 536.

1857 SMITHSONIAN INSTITUTION: Meteorological Observations for the year 1855. Washington, 1857. (Printed for the examination of the Observers.) 8vo, pp. 113.

1858 MAURY: Explanations to Accompany the Winds, Currents and Charts. By M. F. Maury. Washington, 1858. 4to, pp. 383 and plates. Eighth edition.

1849 PACIFIC RAILROAD SURVEYS: These surveys authorized
–1857 by Acts of Congress of 1849 to 1852 in most cases produced a preliminary report in 8vo form for each of the principal lines. The Central Line on the Arkansas, by Captain Gunnison, came by his death to the charge of Lieutenant Beckwith. All of these reports were outfitted with barometers, purchased and tested by me, and with all other suitable instruments for determining altitudes, gradients, and climate of the line traversed by each party. All the altitudes were determined by me on the return of the several parties to Washington, and the final reports were published in thirteen volumes, 4to, from 1854 to 1858. All of the 8vo reports of these surveys, twelve in number, and the materials embodied in the 4to volumes, were necessary to the construction of the charts and the establishment of the principal conditions of climate as embodied in my Climatology. A special catalogue of all the documents and volumes relating to these surveys has been prepared.

1849 AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE:
–1857 The several reports entitled, "Proceedings of the Ameri-

can Association for the Advancement of Science," include papers of great value on climatological science by Guyot, in 1849; by Maury, Bache, Agassiz and Barton, March, 1850; by Hare, Guyot, Redfield and Espy, in August, 1850; by Loomis, Hare, Maury, Guyot, Hough, Morris, etc., at Albany, 1851; by Redfield, Loomis, Blodget, Coffin, etc., at Cleveland, 1853; by Hare, Maury, Redfield, etc., at Washington, 1854. The later volumes of the Proceedings of this Association contain very few important papers on climatological science.

1857 CANADIAN JOURNAL OF SCIENCE: The monthly issues of the Canadian Journal of Science, new series, 1856 and 1857, contain the meteorological registers at Toronto, from 1840 to 1857, and those for Montreal and Quebec for shorter periods.

1857 AMERICAN PHILOSOPHICAL SOCIETY: The annual publications of the American Philosophical Society in both quarto and octavo form, available for important papers by early writers and in all the publications down to 1857. A catalogue of the publications of the American Philosophical Society in octavo and quarto forms is separately given.

The library of the American Philosophical Society contains the entire series of Berlin Transactions (properly the transactions of the Royal Society of Berlin), also the following:

Philosophical Transactions of the Royal Society of London.
The Edinburgh New Philosophical Magazine.
British Association for the Advancement of Science.
Edinburgh Journal of Science.
Edinburgh Philosophical Magazine.
Annales Observatorie Central de Russie.
Bulletin of the Academy of St. Petersburg.
Poggendorf's Annalen.
Memoirs of the American Academy.

1857 SCIENTIFIC, TECHNICAL AND AGRICULTURAL SERIAL PUBLICATIONS: In addition to the sources elsewhere named the following series are mostly in my own collection, but in some cases are more complete in other libraries.

Journal of the Franklin Institute.
New York University Reports.

American Almanac.
California Journal of Science.
New York Journal of Medicine.
Bulletin of the American Geographical and Statistical Society.
Reports of the Metropolitan Boards of Health of New York.
Reports of the New Orleans Board of Health.
American Journal of Science and Arts.
Reports of the Department of Agriculture, Washington.
Reports of Wisconsin Agricultural Department.
Michigan Agricultural Report.
Southern Cultivator.
St. Louis Medical and Surgical Journal.
Ohio Agricultural Reports.
Transactions of the American Medical Association.
Johnston's Physical Atlas. Edition of 1856.
And others.

1858 SILLIMAN'S JOURNAL: Many numbers of this series contain valuable statistics of observation, reviews and notices of the progress of Atmospheric Science. See Forry, 1844. The most important were previous to 1858.

1858 NEILL: The History of Minnesota, from the Earliest French Explorations to the Present Time. By Edward Duffield-Neill, Secretary of the Minnesota Historical Society. Philadelphia, 1858. 8vo, pp. 628.

1858 DOVE: Tabellen und Amtliche Nachrichten über den Preussischen Staat, Statischen Bureau zu Berlin. Von H. W. Dove. Berlin, 1858, etc. Folio, pp. 179.

1859 LOWRIE: A New Theory of the Causes of the Tides, Oceanic and Atmospheric Currents. By W. H. Lowrie. Philadelphia, 1859. 8vo, pp. 9. (Chief Justice Lowrie.)

1859 LACHLAN: Paper, etc., in Favor of a Uniform System of Meteorological Observations throughout the Whole American Continent. Read at the meeting of the American Association, April, 1858. By Major R. Lachlan. Cincinnati, 1859. 8vo, pp. 14.

1859 DOVE: Ueber die nicht periodischen Aenderungen der Temperatur Vertheilung auf der Oberfläche der Erde, 1729–1855. Von H. W. Dove. VI. Theil. Berlin, 1859. With special reports of twenty-eight pages each for 1855, 1856, 1857 and 1858. 4to, pp. 427.

1859 BACHE: Discussion of Magnetic and Meteorological Observations made at Girard College, 1840–1845. By A. D. Bache. Smithsonian Contributions, etc. Washington, 1859. 4to, pp. 20.

1859 MAURY: Nautical Monographs, No. 1: The Winds at Sea. By M. F. Maury. National Observatory, Washington, October, 1859. 4to, pp. 8 and plates.

1860 DISTURNELL: On the Influence of Climate, Commercial, Social, etc. A Paper read before the American Geographical and Statistical Society. New York, 1860. 4to, pp. 24.

1860 AMERICAN ALMANAC: Third Series, 1850 to 1860. During this period the publication of carefully taken observations in various parts of the country was continued, and all these data were made use of, credit being given to each observer and to the Almanac in my "Climatology."

1860 LOWRIE: A Dynamical Theory of the Motions of the Atmosphere and of the Magnetic Needle. By W. H. Lowrie. Pittsburgh, 1860. 8vo, pp. 8. (Chief Justice Lowrie.)

1860 HARRIS, etc.: Fourth National Quarantine and Sanitary Convention, at Boston, June, 1860. 8vo, pp. 288. Dr. Elisha Harris on Disinfection by Heat, pp. 217–238.

1860 HIND: The Canadian Red River Expedition of 1857 and the Assiniboine and Saskatchewan Expedition of 1858. By Henry Youle Hind, Professor, etc., in charge. London, 1860. 2 vols., 8vo, pp. 454 and 472.

1860 DENT: Aneroid and Mercurial Barometers. By E. J. Dent, F.R.S. London and Philadelphia, 1860. 8vo, pp. 29.

1860 BELVILLE: A Complete Manual of the Thermometer. By J. H. Belville, of the Royal Observatory, Greenwich. London and Philadelphia, 1860. 8vo, pp. 56.

1860 BELVILLE: A Manual of the Barometer, etc. By J. H. Belville, of the Royal Observatory, Greenwich. London and Philadelphia, 1860. 8vo, pp. 47. (First London edition, 1849.)

1860 BACHE: Lecture on the Gulf Stream. By Prof. Bache. American Association for the Advancement of Science. Newport, 1860. 8vo, pp. 17 and map.

1861 BUYS—BALLOT: Meteorologische Warnemingen. General Report of Meteorological Observations throughout Europe for 1860. Utrecht, 1861. Folio, pp. 303.

1861 BUYS—BALLOT: Sur le Marche Annuelle du Thermometre et de Barometre. Amsterdam, 1861. 4to, pp. 116.

1861 MAURY: Nautical Monographs, No. II: The Barometer at Sea. By M. F. Maury. National Observatory, March, 1861. 4to, pp. 20 and plates.

1861 GILLISS: Astronomical and Meteorological Observations at the United States Naval Observatory during 1861. Washington, 1862. 4to, pp. 520.

1861 BELL. A Practical Illustration of the Movement of Hurricanes, etc. By Captain John H. Bell. Baltimore, 1861. 8vo, pp. 8 and maps.

1861 HENRY: Results of Meteorological Observations made under the direction of the United States Patent Office and the Smithsonian Institution from 1854 to 1859. By Prof. J. H. Coffin. Being a Report of the Commissioner of Patents, made at the First Session, 36th Congress, Vol. i. Washington, 1861. 4to, pp. 1219. This volume, prepared under the direction of Prof. Joseph Henry, Secretary of the Smithsonian Institution.

1863 OHIO AGRICULTURAL REPORT: Eighteenth Annual Report Ohio Board of Agriculture for 1863. Columbus, 1864. 8vo, pp. 512. Pomological Society, p. 64. Climatological Records, pp. 89–100.

1865 NEW YORK COUNCIL OF HYGIENE: Report of the Council of Hygiene and Public Health of the Citizens' Association of New York on the Sanitary Condition of the City. New York, 1865. 8vo, pp. 360, with maps and plates.

1866 METROPOLITAN BOARD OF HEALTH, NEW YORK: Report for 1866. Albany, 1867. 8vo, pp. 800, and contains Prof. Morris' Meteorological Record, May 1 to December 1, 1866, pp. 458–488.

1867 METROPOLITAN BOARD OF HEALTH, NEW YORK: Second Annual Report for 1867. Albany, 1868. Dr. Elisha Harris, Registrar. 8vo, pp. 480.

1867 HENNESSEY: On the Distribution of Temperature in the Lower Region of the Atmosphere, etc. By Henry Hennessey. Trans. Royal Irish Academy, Dublin, 1867. 4to, pp. 58 and isothermal chart.

1868 HILBRETH—SCHOTT: Results of Meteorological Observations at Marietta, Ohio, 1817–1859. By S. P. Hildreth. Reduced by Charles A. Schott. Smithsonian Contributions to Knowledge. 4to, pp. 46. Washington, 1868.

1866 JELINCK: Jahrbücher der K. K. Central Anstalt für Meteorologie und Erdmagnetismus. Von Carl Jelinck und Carl Fritsch. Neue Folge ii. Band Jahrgang 1864. Wien, 1866. 4to, pp. 188.

1867 JELINCK: The same for 1865. Wien, 1867. 4to, pp. 208.

1868 JELINCK: The same for 1866. Wien, 1868. 4to, pp. 206.

1869 JELINCK: The same for 1867. Wien, 1867. 4to, pp. 227.

1870 JELINCK: The same for 1868. 4to, pp. 224 and supplement reviewing 1857 to 1865. Wien, 1870. pp. 113.

1870 JELINCK AND HANN: Zeitschrift der Oesterreichischen Gesellschaft für Meteorologie. Von Dr. C. Jelinck and Dr. J. Hann. Wien, 1870. 8vo, pp. 644 and plates.

1873 JELINCK: The same Jahrbücher for 1871. Wien, 1873. 4to, pp. 208.

1874 JELINCK: The same for 1872. Wien, 1874. 4to, pp. 236.

1868 OHIO AGRICULTURAL REPORT: 23d Annual Report Ohio Board of Agriculture. Columbus, 1869. 8vo, pp. 655. And Horticultural Report, pp. 80. Cited on Climatology at p. 239 and all matter valuable for discussion of grape climates. Lake Shore, Kelley's Island, etc.

1868 METROPOLITAN BOARD OF HEALTH: New York. Report for 1868. Dr. Elisha Harris, Registrar and Secretary. Albany, 1869. 8vo, pp. 635.

1868 THE SAME: As printed by order of the Assembly. Albany, 1869. 8vo, pp. 471.

1868 BLODGET: Alaska. What is it Worth? With chart of Isothermal lines. By Lorin Blodget, in Lippincott's Magazine, February, 1868, pp. 185 to 191.

1869 METROPOLITAN BOARD OF HEALTH: New York. Fourth Annual Report for 1869. New York (Appleton & Co.), 1870. 8vo, pp. 594.

1869 JELINCK AND HANN: Zeitschrift der Oesterreichischen Gesellschaft für Meteorologie. Redigirt. Von Dr. C. Jelinck und

Dr. J. Hann. IV. Band. Wien, 1869. 8vo, pp. 615 and plates.

1870 BOARD OF HEALTH: Fifth Annual Report of the Board of Health of the City of New York, April 11, 1870, to April 10, 1871. By Emmons Clark, Secretary. New York, 1871. 8vo, pp. 628.

1871 BLODGET—WALLING: The Climate of Massachusetts. With Isothermal and rain map. By Lorin Blodget. Walling's Atlas of the State of Massachusetts. Boston, 1871. pp. 22, 23, folio.

1872 SCHOTT: Tables and Results of Precipitation in Rain and Snow in the United States and America Generally. Discussed by Chas. A. Schott. Smithsonian Contributions to Knowledge. Washington, 1872. Folio, pp. 175 and plates. (See second edition in May, 1881. Folio, pp. 249 and plates.)

1872 BLODGET—WALLING—GRAY: Climatological Map of Ohio, Isothermal and Rainfall. By Lorin Blodget, in Walling and Gray's Atlas of Ohio, pp. 34, 35. Cincinnati, 1872. Folio.

1872 MYER: Daily Bulletins of the Signal Service U. S. Army, with Synopsis of Probabilities. Divisions of Telegrams. Gen. Albert J. Myer. Large 4to, monthly bound vols. September, October, November and December, 1872. 4 vols.

Jan. to Dec., complete..........1873, 12 volumes.
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1873 BLODGET, ETC.: The Climate of Maryland. With Isothermal and rain map. By Lorin Blodget, in Atlas of Maryland, by Martenet, etc. Baltimore, 1873.

1873 BLODGET—GRAY: Climatology of the United States. With Isothermal and rain chart. By Lorin Blodget, in Gray's Atlas of the United States. Philadelphia, 1873. Folio, pp. 125–129.

1873 BLODGET: The Non-periodic Distribution of Heat in the Atmosphere. By Lorin Blodget. Read before the American

Philosophical Society, February 21, 1873. Proceedings, Vol. xiii, 8vo, pp. 3. Philadelphia, 1873.

1874 BLODGET: A Downward Atmospheric Circulation as One Cause of Extreme Cold. By Lorin Blodget. Read before the American Philosophical Society, May 1, 1874. Proceedings, Vol. xiv, p. 150.

1874 BLODGET—WALLING: Climate of British North America. With isothermal and rain charts. By Lorin Blodget, in Atlas of the Dominion of Canada, by H. F. Walling. Montreal, 1875.

1873 WOODWORTH: The Cholera Epidemic of 1873. By John M.
–1875 Woodworth, M.D., Supervising Surgeon U. S. M. H. Treasury Dept., Washington, 1875. Prepared pursuant to Joint Resolution of Congress of March 25, 1874.

1875 MCCLELLAN AND OTHERS: The Cholera Epidemic of 1873. Reports Prepared under the Direction of the Surgeon-General of the Army. A. By Ely McClellan, M.D. B. By John C. Peters, M.D. C. By John S. Billings, M D. Washington, 1875. 8vo, pp. 1025.

1873 BLODGET: A Report upon Non-periodic Changes of Heat as an Element in Sanitary Climatology. By Lorin Blodget. Read before the American Public Health Association at New York, 1873. In Vol. i of Reports, pp. 157–163.

1875 HARRIS: Reports and Papers of the American Public Health Association presented in 1873. Prepared by Dr. Elisha Harris, Secretary. Many Valuable Sanitary and Climatological Reports. New York, 1875. Large 8vo and maps, pp. 563.

1875 WARREN: Report of the Commission of Engineers on the Reclamation of the Alluvial Basin of the Mississippi. By G. K. Warren, Major Engineers, President of the Commission. Washington, 1875. 8vo, pp. 160, and maps of floods. (H. R. Ex. Doc. 25, 43d Congress, 2d Session.)

1875 JONES: Report upon Northwestern Wyoming, including Yellowstone Park, made in 1873 by William A. Jones, Captain of Engineers. Washington, 1875. 8vo, pp. 331, with valuable maps.

1876 SCHOTT: Tables, etc., of Atmospheric Temperature in the United States. Collected by the Smithsonian Institution and discussed by Chas. A. Schott, Washington. Smithsonian Contributions to Knowledge, 1876. Folio, pp. 345, with Isothermal Charts.

1877 CUTTING: Vermont Agricultural Report for 1877. Climatology of Vermont, by Dr. Hiram A. Cutting, pp. 120 to 141. Montpelier, 1877.

1881 SCHOTT: Tables and Results of Precipitation in Rain and Snow in the U. S., from collections by the Smithsonian Institution. By Chas. A. Schott. 2d edition, Washington, May, 1881. 4to, pp. 250, with large rainfall maps, for each season and the year. "Including records to 1877."

1882 GILBERT: A New Method of Measuring Heights by Means of the Barometer. By G. K. Gilbert, U. S. Geological Survey. Large 8vo, pp. 408–566, 162, with plates. Washington, 1882.

1884 RELIEF COMMITTEES: Cincinnati Chamber of Commerce; Flood in the Ohio, Feb. 1884. Cincinnati, 1884. 8vo pamphlet, pp. 193.

1888 HAYDEN: The Great Storm off the Atlantic Coast of the United States, March 11–14, 1888. By Everett Hayden, in charge of Marine Meteorology. Montreal Monograph, No. 5, U. S. Hydrographic Office. Washington, 1888. 4to, pp. 65, and plates.

1889 BLODGET: The Floods in Pennsylvania, May 31 and June 1, 1889. By Lorin Blodget, for the Department of Internal Affairs of Pennsylvania. Harrisburg, 1889. 8vo pamphlet, pp. 8, with map.

1889 GREELY: Floods in the Middle Atlantic States, May 31 to June 3, 1889. Report of the Weather Bureau, Monthly Review for May and June. Washington, 1889. 4to, pp. 6, and maps.

REPORTS OF THE CHIEF SIGNAL OFFICER U. S. A., 1871 TO 1891.

The Metorological Branch of the Signal Service was authorized by Joint Resolution No. 9, approved Feb. 9, 1870, the Secretary of War being authorized "To provide for taking Meteorological Observations at the Military Stations and at other points in the Interior," and to give notice of the approach of Storms, etc. On Nov. 1, 1870, the first synchronous reports were transmitted. The issue of Synopsis and "Probabilities" was commenced by the Office, Feb. 29, 1871, thrice daily; pp. 6–8.

1871 MYER: Report of the Chief Signal Officer to the Secretary of War for the year ending June 30, 1871. By Albert J. Myer, Brigadier General, Chief Signal Office. Washington, 1871. 8vo, pp. 166.

1872 MYER: The same for year ending June 30, 1872. 8vo, pp. 292. (See pp. 190–195 for List of Great Storms, 2 copies.)

1873 MYER: The same for 1872–3. pp. 230 to 1109, and many plates.

1874 MYER: The same for 1873–4. October, 1873 to Sept. 30, 1874, with rain maps for each month and storm maps. At pp. 286 appear the orders turning over the Smithsonian System and its observers to the Signal Office. 8vo, pp. 403, and 64 maps.

1875 MYER: The same for 1874–5; July, 1874, to June, 1875, with rain and storm maps. pp. 475, and 76 maps. At p. 130 is a full list of Smithsonian observers. At p. 362 are the orders of the Surgeon-General turning over the Meteorological Observations of the Medical Officers of the army.

1876 MYER: The same for 1875–6, fiscal year. pp. 509, and 77 plates.

1877 MYER: The same for 1876–7, fiscal year. pp. 570, with 16 plates. At p. 156 a list of publications received.

1878 MYER: The same for 1877–8, fiscal year. pp. 679, and 59 plates.

1879 MYER: The same for 1878–9, fiscal year. pp. 782, with 74 maps, isothermal, rainfall, and storms, also river gauges.

1880 DRUM—GREELY (Acting Signal Officers): Report dated Nov. 15, 1880, for fiscal year 1879–80. pp. 1120 and 820 plates. Publications received at p. 245. General Myer died Aug 24, 1880.

1881 HAZEN: The same for 1880–1. By Gen. W. B. Hazen, Chief Signal Officer, dated Oct. 1, 1881. pp. 1286 and many plates. (Refers to death of Gen. Myer at Buffalo, Aug. 24, 1880.)

1882 HAZEN: The same for 1881–2, dated September 15, 1882. Message and Doc. Series, War Department. Part i, pp. 974 and plates; Part ii, pp. 404 and plates.

1883 HAZEN: The same for 1882–3, dated October 15, 1883. As Vol. iv, Message and Doc. Series. pp. 1164 and plates.

1884 HAZEN: The same for 1883–4, dated October 15, 1884. Also as Vol. iv, Message and Doc. Series, War Department. pp. 712 and plates.

1885 HAZEN: The same for 1884–5, October 10, 1885. Part i, pp. 609; Part ii, pp. 440.

1886 HAZEN: The same for 1885–6.

1887 GREELY: The same for 1886–7. By A. W. Greely, Chief Signal Officer (succeeding General Hazen, who died January 16, 1887). Part i, pp. 361; Part ii, pp. 386 and plates.

1888 GREELY: The same for 1887–8.

1889 GREELY: The same for 1888–9.

1890 GREELY: The same for 1889–90.

1891 GREELY: Irrigation and Water Storage of the Arid Regions. Letter from the Secretary of War communicating a Report of the Chief Signal Office of the Army in response to House Resolution of May 23, 1890, relative to Irrigation and Water Storage in the Arid Regions. By A. W. Greely, February 28, 1891. H. R. Ex. Doc., No. 287, 51st Congress, Second Session. Washington, Government Printing Office, 1891. 4to, pp. 356 and 37 maps.

A Short Note upon So-called "Hereditary Optic-Nerve Atrophy"—as a Contribution to the Question of Transmission of Structural Peculiarity.

By Charles A. Oliver, A.M., M.D.

Deeming it possible that the question of "The Transmission of Structural Peculiarity" may be judiciously studied from a pathological standpoint, as shown in the peculiar disease of man generally known as Hereditary Optic-Nerve Atrophy, where certain morbid changes of optic-nerve structures of a sufficient amount for ready recognition take place during the years just previous to adolescence in subjects who frequently have consanguineous ties, extending in some instances through several generations, the writer has ventured the following terse notes of one such family that he has had the opportunity to submit several of its members to careful and prolonged clinical research extending over several years.

In 1892, he saw for the first time a man, aged twenty-seven years, who stated that for the past year the sight of both eyes had been gradually failing, this being accompanied by frontal headaches and dizziness. No history of any general sickness was given and no clinical evidences of the introduction of any toxic agents into the system could be obtained. He asserted that his mother's three brothers were similarly affected.

Examination showed that central vision for both form and color was highly defective. The ophthalmoscopic appearances were those of a semiatrophic condition of the optic-nerve head.

At irregular intervals, though especially later in the disease, variously colored phosphenes appeared in the centre of the visual fields and attacks of "fogging of vision" during perspiration without watering of the eyes came on. Ocular pain upon exposure to light, with gradual decreasing color perception, passing through the failure of recognizing green, red, blue and yellow ensued, until at last nothing but equal intensities of "color" were laid side by side without reference to tint.

This peculiar history and the patient's assertion that his three maternal uncles had suffered in the same manner induced a careful ocular examination to be made of as many of the family as possible. This resulted in the finding of more or less similar ocular symptoms and conditions in all that could be seen. It also elicited the fact that the disease with one exception had passed from unaffected mothers to affected sons through six generations on the maternal side; a family that the writer had the privilege to study in a number of its members ten years ago and had careful clinical notes of several in the earlier generations.

This brief history of a gross pathological condition first appearing about or a short time before adolescence, and eventuating in permanent partial blindness at about twenty-seven years of age, is here given as one among many facts based upon pathological changes that may be placed side by side with those so-called normal physiological acts and physical peculiarities of structure which are so often seen passing through several generations especially by ties of consanguinity.

In other words, this fault of optic-nerve structure, which does not show itself for several years after the birth of the individual, indicates to the writer's mind at least that here there is an inheritance of a physical material which is not only shorter lived than that which is found in the same organ in other organisms, but that it has a briefer existence than the other organs in the same general organism ; a fault which shows that an imperfect material has been born, and dies prematurely because it is subjected to an amount of wear and tear that would not seriously disturb or injure a properly formed substance. Further, it serves as a living evidence that a substance has been improperly made most probably on account of physical imperfection and repetition of faulty cell combination of similar kind extending through several generations ; an evidence which in measure says that primarily acquired pathological characteristics of structural form may be transmitted through forthcoming generations as imperfect formation of similar structure in due proportion to both the want of hygiene and care given to the afflicted subjects and the reassociation of similarly degraded developmental cells ; an evidence which gives answer in part to the transmission of ordinary structural characteristics, which, if acted upon in the same way as those which are not made, as it were, in the same peculiar manner, will produce far different and even what may be termed idiocratic results.

In other words, this disease, for example, which manifests itself as faulty transmission, teaches us conversely that a peculiar physical condition which has been obtained from frequently repeated physiological acts during the life existence of some antecedent containing animal form, may be transmitted to the offspring (more particularly by consanguineous ties of the parents) and thus render the new organism more capable of evolving certain definite acts that are the physiological representatives of heredity of physical structure ; the partial answer at least for so-termed hereditary genius.

The Adaptive Forms and Vortex-Motion of the Substance of the Red Blood-corpuscles of Vertebrates.

By John A. Ryder.

The fact that the red blood-corpuscles of vertebrates are discoidal or elliptical flattened bodies seems to have had very little of import to physiological writers. I shall now attempt to show that not only has the shape of these bodies very great physiological significance, but that these shapes are also adaptive. The attempt will also be made to show that it may be that there is a vortical flux of substance from the centre to the periphery, or from the periphery to the centre of every such corpuscle during life on both sides of it; that, moreover, such a flux taken in conjunction with the viscosity of the substance of the corpuscle and its original or embryonic globular form is responsible for its shape. The flattening and vortical flux of the substance of the corpuscle may be regarded as adaptive physiological devices by means of which its respiratory efficiency is vastly increased. That such a flux has never been seen and may never be seen, owing to the practical impossibility of observing these bodies in a perfectly normal living condition, is no proof that such a flux does not occur. Other practical difficulties also present themselves in the demonstration of the vortical flux of the substance of red blood-corpuscles, namely their optical homogeneity, as a result of which also the very highest powers of the microscope become useless in this investigation, since the particles of the substance lie beyond the limits of microscopic vision and cannot therefore be differentiated microscopically so as to demonstrate such a motion, even were it possible to observe the corpuscle in an active living state under perfectly normal conditions.

The first condition satisfied by the flattened form of the red blood-corpuscle is an increase of its superficial area. This would also be achieved if the corpuscle were elongated into a filament. But it can be shown that if these corpuscles were filaments they would inevitably tend to choke up or occlude the vessels, because of becoming tangled amongst one another and thus bringing the circulation to a stand-still with consequent death. It can also be shown, with all the rigor of mathematical demonstration, that the superficial area of a filament of the same volume as a disk of the same substance does not increase at anything like the same rate, if the filament is indefinitely and progressively lengthened, as compared with the rate of increase of the surface of a disk of similar volume indefinitely and progressively flattened. Everything is therefore in favor physiologically of the discoidal form of a mass of plasma as a hæmoglobin bearer over and above that of a filament or any other shape whatever. The advantages which accrue to the discoidal form of the blood-corpuscle over a hypothetical filamentous form are thus seen to be conditioned by the geometrical laws which hold in respect to the progressive and equal change of the ratios of two of the dimensions of a solid or fluid body as compared with an unequal change in its third dimension, provided there is no change of volume.

This form of the blood-corpuscle by means of which its area is increased is also one which involves the conception that the average path traversed by all of its constituent particles is less than that by means of which it would be transformed into a filamentous body. A further conclusion derivable from this fact is that in the transformation of the globular embryonic blood-cell there is less expenditure of energy involved in transforming it into a disk than if it were transformed into a filament. There is therefore an actual saving of energy consequent upon transforming the primitively globular blood-cells into disks instead of into filaments. Viewed, therefore, as a kinetic problem alone, it can be proved that the discoidal shape of the blood-corpuscles of vertebrates requires the expenditure of a relatively small amount of energy as compared with that of any other form that might be assumed.

Notwithstanding this fact, however, there has been an extension of the disks of many forms in one of their dimensions, so that in the greater proportion of vertebrates, including birds, reptiles, batrachia and fishes, the red corpuscles are elliptical, while in a mollusc *Arca* they are flattened and pyriform in outline. Nowhere, however, does the eccentricity of the elliptical form of the corpuscles develop great proportions; in fact, I know of no instances in which the great diameter of an elliptical corpuscle is as great as twice its least diameter. The law enunciated in the preceding paragraphs therefore still holds essentially even in those cases where the corpuscle becomes quite markedly elliptical, since nowhere does this ellipticity reach such an extreme as to become the expression of an extension of the substance of the corpuscle into the form of a filamentous body.

This ellipticity of the blood-corpuscles of the lower vertebrates is, moreover, again adaptive, since it is well known that in traversing the smallest capillaries in such forms as the frog, for example, every corpuscle must in traversing the latter place its long axis parallel, or nearly so, with the axis of the lumen of the vessel in order to pass through; in other words, the least diameter of the corpuscle only can traverse the lumen of capillaries. In thus adjusting its long axis to the axis of the lumen of the capillary, such a corpuscle again presents a maximum amount of surface and volume in the nearest relation to the tissues it is to oxidize, whereas if it traversed the capillary with its long diameter transverse to the axis of the lumen of the capillary, it would present the least amount of its volume and surface in the nearest relation to the tissue to be oxidized. Were this last condition prevalent it would require many more corpuscles to do the same work as is done by the elliptical corpuscles that now traverse the capillaries lengthwise, or with their long axes parallel with the axis of the lumina of the latter.

A further supposition that may be made regarding the elliptical blood-corpuscles is that, originally globular, they became at first discoidal, then elliptical, and that the elliptical form of the disks was consequent upon slight constraint within the capillaries during their passage through the latter; in other words, the elliptical form was derived from the discoidal as the discoidal was derived from the still more primitive globular form. We may also suppose that very slight mechanical constraint in passing through the capillaries would distinctly tend to develop a tendency towards converting the disks that were slightly too large to pass through the capillaries into elliptical disks. I can thus conceive a mechanical origin for the elliptical form of the red blood-corpuscle in general wherever it occurs.

It may also be assumed that the size of the corpuscle is directly related to the rate of metabolism of the organism. Thus in the sluggish batrachia the corpuscles are large; in the more active fishes and reptiles smaller; in mammals still smaller, and in the most active mammals and birds, such as the musk deer and humming bird, smallest of all, reaching minimum dimensions of $\frac{1}{4000}$ to $\frac{1}{6000}$ of an inch in these types, according to Gulliver.

The impulse that tends to develop a vortical flux of matter from opposite poles of a young globular red blood-corpuscle in every direction from the centre, it would be difficult to specify further than that it is purely physiological and adaptive, and leads to a distinct gain of surface and a consequent increase in the efficiency of each and every corpuscle in performing its function, that for such a cause has assumed the discoidal form. That such a double vortical flux must take place from two opposite poles of a primitively globular or embryonic red blood-corpuscle in passing from its primitive globular to that of its completed or adult elliptical or discoidal form is self-evident upon mere contemplation of the geometrical conditions that must on *à priori* grounds accompany the transformation of a semifluid globular mass to the form of a disk with rounded edges. If such a vortical flux of its substance were maintained by every corpuscle during its double cycle of wanderings through the systemic and pulmonary circulations and throughout life, its efficiency in the processes of metabolism must necessarily be greatly increased. The fact that Amœba cannot move without developing a vortical flux of its own substance through itself, is, it seems to me, evidence of the possibility and probability of the same thing occurring in red blood-corpuscles. If the foregoing hypothesis is true with respect to red blood-corpuscles, we have no less than ten millions of vortex rings of particles whirling together in pairs for every cubic millimeter of blood that circulates through the vessels of our bodies.

A Study of the Transformations and Anatomy of Lagoa crispata, a Bombycine Moth.

By Alpheus S. Packard.

The larva of this moth is exceptional among caterpillars, for it has the rudiments of two pairs of abdominal legs more than the five pairs common to all other known Lepidoptera. It is also remarkable for its metameric glandular abdominal processes.

A very full and careful account of the life-history of this interesting moth has been published by Dr. J. A. Lintner, in his *Entomological Contributions*, No. ii, p. 139. He describes six stages, and gives an interesting account of the cocoon and mode of pupation.*

* See also two brief articles by myself: "On the Larva of Lagoa, a Bombycine Caterpillar with Seven Pairs of Abdominal Legs; with Notes on its Metameric Glandular Abdominal Processes." *Zoologischer Anzeiger*, 27. Juni, 1892, pp. 229-234; "The Bombycine Genus Lagoa, Type of a New Family," *Psyche*, July, 1892, pp. 281, 282.

The eggs were kindly sent me by Miss Emily L. Morton from New Windsor, N. Y., and received July 2, hatching in Brunswick, Me., July 3.

Egg.—Length, about 1.5–1.8; breadth, about 0.5 mm. The shell is very thin, membranous, and entirely transparent, and under a ½-in. objective is seen to be structureless, showing no traces of polygonal areas.

They are similar to but not nearly so flat as those of *Phobetron pithecium.* They are laid in small irregular patches side by side in two rows, and are densely covered with white woolly hairs from the body of the moth. They are at first pale green, becoming yellowish as the embryo becomes mature and nearly ready to hatch.

Larva Stage I, Freshly Hatched.—Length, 1.5–1.8 mm. When first hatched they eat little holes in the upper surface of oak leaves. They have a thin soft skin; are flat oval, lying on one side, and at first are yellow. Body short and thick, rather broad, yet somewhat cylindrical, with eleven pairs of large dorsal tubercles, which are square at the tip, and give rise to very long white hairs of unequal size, some of which are nearly twice as long as the body. Besides the white hairs there are also short erect setæ, dark brown at the attenuated ends, which also arise from the large long subdorsal, not lateral, tubercles. The body, including the head, is pale straw-yellow.

It molted July 10–11, the length of the stage being from six to seven days. In this stage the head is not covered by the prothoracic segment, which though large has not yet become hoodlike. The very long fine spinulated hairs arise from all the tubercles, of which there are six on each segment, the dorsal tubercles on the second thoracic segment being slightly larger than those on any of the succeeding segments; the hairs in question are more abundant on the anterior segments, *i. e.* the second and third thoracic, and the five basal segments, than on those behind. From the dorsal and subdorsal tubercles arise about a dozen spine-like setæ, which are slender and about half as long as the body is thick; the end is acute, dusky, and thus made conspicuous in the mass of white delicate spinulated hairs clothing the body. None of these are poisonous. Stinging setæ arise from the minute infraspiracular tubercles. The spiracles are very minute and difficult to detect. On each of the abdominal legs, situated above the planta, is a pair of short clavate setæ, the seventh pair only bearing a single seta.

Fig. 1 represents the freshly hatched larva, Stage I, drawn with the tubercles, hairs and spines; *abl*[1], the first, *abl*[6], the sixth, pair of abdominal legs.

Fig. 2 represents the armature in Stage I; *a*, part of an ordinary finely spinulated hair; *b*, one of the smaller spinulated hairs situated on the head, and also on the tenth abdominal segment; *c*, a group of three venomous setæ, showing the glandular cells (*pc.*) at the base, by which the poison is secreted.

Fig. 3 represents the cells (*sc.*) in the hypodermis which secrete the setæ, and the poison-cells (*pglc*) which secrete the venomous fluid filling the setæ or spines, and which makes them so irritant and annoying when the spines break off from the tubercles bearing them. *A* is a group of setæ arising from a subdorsal tubercle; *cut.*, the cuticle; *hy.*, the hypodermis; *sc.*, the enlarged and specialized cells of the hypodermis which secrete the spines themselves; *pglc*, the nuclei which secrete the venomous fluid which fills the cavity of the seta (*s.*), seen at *p* in a broken spine. *B*, a short entire and a long broken seta; *pglc*, four poison cells; *p.*, the poison in the hollow of the spine.

Fig. 4. Section of a subdorsal tubercle from a larva in Stage I. *sc.*, the setigenous cells, one for each seta; *pglc*, nuclei by which the poison is secreted; *s.*, seta; *p.*, poison in middle of a broken spine; *cut.*, cuticle; *sd. tub.*, spinulated surface of the subdorsal tubercle. Author *del.*

Larva, Stage II.—Length, 3 mm. (Pl. V, Fig. 5). It differs from the previous stage chiefly in the head being nearly covered or overgrown by the hood-like prothoracic segment, so as to be almost as completely covered by it when extended as in the later stages. The short stiff setæ are white instead of brownish at the end; the white hairs are, perhaps, more abundant, and the body is slightly thicker. The second and third thoracic and seventh to ninth pair of abdominal tubercles are now larger than the others. There are now about twelve crotchets on the middle abdominal legs.

It molted July 16–17, hence the length of this stage is 6–7 days.

Fig. 6 represents the seventh abdominal segment of this stage. *d*, the dorsal tubercle, with 12–13 poison-bearing setæ, with brown tips, and five long very finely spinulated hairs, which are about twice as long as the segment is thick; *sd.*, the subdorsal tubercle bearing about twelve venomous setæ, and two or three long spinulated hairs; *sp.*, the spiracle, and directly behind and a little below it a lateral process (*lp.*); *i.*, the infraspiracular tubercle bearing about eight hairs, but no setæ; *pl.*, the planta; *s.*, the clavate seta.

The hairs are more numerous than before, nearly concealing the body, much as in Stage V.

Stage III.—Length, 5 mm. Of the same color as before, and with no noteworthy change in appearance.

It molted again July 25–26, the length of the stage being about nine days.

Stage IV.—Length, 7–8 mm. The larva only differs from that of the preceding stage in all the hairs being white, and in the woolly or finely spinulated ones being thicker.

It molted August 3, the length of the stage being about 7–8 days.

Stage V.—Length, 9–10 mm. Same as before, but the hairs have grown a little thicker (see Fig. 7, *a*, *b*).

I am uncertain whether the larvæ molted again before the final ecdysis, but Aug. 10–12 they had become 15 mm. long, and were the same as before, but with more long hairs in proportion to the short forked ones. This is perhaps the end of Stage V.

This stage lasted about ten days, as they molted again Aug. 22–23, and some as late as Aug. 30.

Last Stage (*VI*).—Length, of body alone, 20 mm.; but including all the hairs before and behind 30 mm.; breadth of body, 10 mm.

Mature larval characters being acquired only at the last molt, it is now entirely different in shape and color from the preceding stages. The hairs on the anterior third of the body are *slate-gray*, behind *reddish brown*, and they are so dense and fine as to lie upon the body and entirely conceal it; they rise into four longitudinal ridges. The head is not now visible, the head-end is broader than the tail end, with overarching hairs, and a few longer scattered hairs on the front and side of the thoracic segments, and a few long brown hairs on the posterior end; none of these longer hairs are as long as the body is thick, and none of the short barbed stinging hairs are to be seen through the dense pile of simple hairs. (See also Lintner's description, and my own in Report V, *U. S. Ent. Commission on Forest and Shade Tree Insects*, p. 139.)

Unusual Number of Abdominal Legs in the Larva.

In the *American Naturalist* for July, 1885, pp. 714, 715, we published the following notes in an article entitled "Unusual Number of Legs in the Caterpillar of Lagoa."*

"*Lagoa crispata* Pack. is an interesting moth forming a connecting link between the Dasychiræ (Orgyia) and the Cochlidiæ represented by Limacodes and its allies. As we remarked in our Synopsis of Bombycidæ (1864): 'When we observe the larva we would easily mistake it for a hairy Limacodes larva, for like them the head is retracted, the body is short, and the legs are so rudimentary as to impart a gliding motion to the caterpillar when it moves." After describing the transformations, we added: 'There are seven pairs of abdominal or false legs, which are short and thick. The first pair of thoracic or true legs are much shorter than the two succeeding pairs.'

"Two years ago we found the fully fed caterpillars and also those before the last molt on scrub-oaks in Providence, and again noticed them while walking, then carefully examined them after placing them in alcohol, and again examined the specimens during the past winter. It is well known that caterpillars have no more than five pairs of 'proplegs,' 'false legs' or abdominal feet, as they are variously called; and so far as we have been able to learn, the present caterpillar is the only one which has additional legs, even though rudimentary. As in all lepidopterous larvæ, there are ten abdominal segments. In the larvæ before the last molt there is a pair of rudimentary abdominal legs on the second abdominal segment, forming soft tubercles about one-third as large as the succeeding normal feet; the crown of hooks was wanting, but a tubercle on the anterior side corresponding to a similar one on the normal

*In 1879, or six years before the publication of my note, Dr. H. Burmeister (*Atlas de la description physique de la République Argentine, Lepidoptères*, Buenos Ayres, 1879, pp. xxii, Figs. 6*a*, 6*b*, 6*c*) had described and figured with details, the larva of *Chrysopyga undulata*: "Les six anneaux suivants, du cinquième au dixième, sont pourvus de deux verrues charnues qui représentent les pattes membraneuses ventrales, dont le nombre est de six chez cette chenille, ce qui constitue une exception à la regle générale de la présence de quatre paires de pattes membraneuses sur les anneaux 6 à 9. La première et la dernière de ces six paires de verrues se terminent en avant par un coussin rond aplati, noir, qui ressemble à la plante d'un pied, mais chez les quatres verrues moyennes (6 à 9), il y a un second coussin plus grand, qui ressemble à une véritable patte membraneuse pourvue d'une plante sinueuse et d'une couronne de petits crochets cornés, comme les pattes membraneuses en général (6, c). Le onzième anneau est oblitéré au milieu, ainsi que le quatrième, mais sa présence est bien reconnaissable par les deux portions latérales. Enfin, le douzième anneau est un peu plus grand que les autres et porte la dernière paire de pattes membraneuses, la septième qui est complètement conformée comme les quatres moyennes des six anneaux antérieurs, mais sans la petite plante accessoire de celles ci. Ces dernières pattes sont pourvues seulement de la plante sinueuse garnie de crochets comme les autres.

feet had five or six well-marked stout spines, also two or three scattered ones in the middle, the tubercle being rounded, convex, not flattened at the end.

"On the sixth segment, following the fourth pair of normal abdominal legs, is a pair of tubercles like those on the second segment and exactly corresponding in situation with the normal legs; situated externally are two long straight spines, but none homologous with those forming the crown. At the base in front of each tubercle is a tuft of sparse hairs, and on the outside is a chitinous spot bearing a dense tuft of hairs; these two tufts precisely agree in situation and appearance with those at the base of normal abdominal legs.

"In the fully fed caterpillar the tubercles are exactly the same. It thus appears that in the Lagoa larva the first abdominal segment is footless; the second bears rudimentary feet; segments 3–6 bear normal proplegs; the seventh bears a pair of rudimentary legs; segments 8 and 9 are footless, while the tenth bears the fully developed anal or fifth pair of genuine proplegs.

"While these two pairs of tubercles differ from the normal legs in being much smaller and without a crown of curved spines, they are protruded and actively engaged in locomotion, and in situation, as well as the presence of the basal tufts, are truly homologous with the normal abdominal legs.

"When we turn to the work of Kowalevsky on the embryology of Sphinx, we find that it has ten pairs of abdominal legs which arise in the same manner as the thoracic or chitinous, jointed legs. Of these ten pairs one-half disappear before hatching, leaving the five pairs usually present. It seems to us that the two pairs of rudimentary legs in Lagoa are survivals of these embryonic temporary feet. Although the proplegs are not popularly regarded as true legs, they are undoubtedly so, as embryology proves. In the lower Noctuidæ, such as Catocala, Aletia, etc., the larvæ are at first geometriform, having but three pairs of proplegs; in the geometrids there are but two pairs, while in the Cochlidiæ there are not even any rudimentary feet, thoracic or abdominal. As we have elsewhere observed, the primitive lepidopterous larva must have had a pair of feet on each abdominal segment, and may have descended from Neuroptera-like forms allied to the Panorpidæ as well as Trichoptera."

As this and the case of Chrysopyga are unique, no other lepidopterous larva* being known to possess more than five pairs of abdominal legs, when rearing the larva described above we again for the third time carefully and repeatedly observed the caterpillars when alive and watched the movements of the abdominal legs during locomotion, and saw how the two rudimentary pairs, viz., those on the second and seventh abdominal segments, were raised and put dôwn. With the triplet in hand, and allowing the larvæ to walk on the edge of the tin box in which they had been confined, it was easy to see that the above-mentioned proplegs were actively used, performing the same general acts of extension and retraction of the planta as the others, and like them serving to support the body. The first pair, particularly, viz., those on the second abdominal segment, were observed to be nearly as large and long as the normal legs, and to be retracted and then extended, and applied to the surface of the object on which the body was situated, in the same manner as the pair directly behind which have crotchets; and the same was observed as regards the pair on the seventh segment.

(Fig. 7. *a*, dorsal, *b*, lateral view of the larva of *Lagoa crispata*, Stage V; *c*, ventral view of the same to show the seven pairs of abdominal legs; *d*, front part of the sáme, still more enlarged to show the differences between the first and second pair of abdominal legs, also the under side of the head partly concealed by the prothoracic hood; and the three pairs of thoracic legs; *e*, a side view of the hood, completely concealing the head; *f*, a tubercle with the hairs and spines; *g*, a normal abdominal leg with the crotchets; *g'*, one of the legs on second abdominal segment, without the crotchets; *h*, side view of two abdominal segments showing the spiracle and the lateral glandular process (*lp.*) behind it. Bridgham *del.*)

To further prove to others, who might doubt whěther these mobile and extensile processes were really legs at all, I made careful camera sketches of the alcoholic specimens of the freshly hatched larva (Fig. 1), and of one after the first molt (Fig. 5). In Fig. 7 *c*, the first abdominal segment is seen to be completely apodous, but the legs on segments 2 and 7 are seen to have a well-developed extensile planta, though without crotchets, but bearing on the outside a pair of clavate setæ just like those on the other legs. In Stage II (Fig. 5) are seen the same structures; *pl.*, the planta;

*Exception, however, should be made of the larva of Phyllocnistis, and of Nepticula, which possess nine pairs of abdominal legs, which however bear no hooks.

cr., crotchets of the fully developed abdominal legs; *s.*, the pair of short clavate setæ on the rudimentary legs of the second abdominal segment. It thus appears that these legs are as well developed in the freshly hatched larvæ as in the last stage of larval life.

Their general appearance in the final stage is seen in Fig. 7*c*, which represents the larva enlarged twice as seen from beneath; at *g* is a normal leg, with the narrow elliptical oval circle of crotchets on the inner and hinder side; g^1, one of the rudimentary legs without crotchets; *d*, represents an enlarged view of the head entirely covered above, with the three abdominal segments, and the first, second and third abdominal segments, with the rudimentary leg of the second segment, and the normal legs of the third somite.

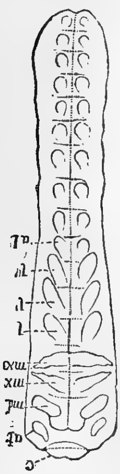


Fig. 8.—Primitive band or germ of a Sphinx moth, with the segments indicated, and their rudimentary appendages. *c*, upper lip; *at*, antennæ; *md*, mandibles; *mx*, *mx'*, first and second maxillæ; *l*, *l'*, *l''*, legs; *al*, abdominal legs.

The occurrence of temporary abdominal legs in the embryos of insects in general is now well known to students of embryology. Kowalevsky was the first to figure what seemed to be such temporary appendages, in the embryo of Sphinx, though he does not refer to these structures in the text of his work. (Fig. 8, which is copied from his work). In subsequent researches by Hatschek on the embryology of *Porthesia chrysorrhœa*, they are neither mentioned in the text nor figured. Tichomiroff, in his work on the development of *Bombyx mori*, appears, however, to have substantiated the truth of Kowalevsky's figures.

Tichomiroff represents in Fig. 26, p. 41, of his work the primitive band of *Bombyx mori*, with the temporary abdominal knob-like appendages developed on abdominal segments 2 to 10; they are in a situation homologous with that of the anterior appendages, one on each side of the median line, and within the rudiments of the stigmata of the same segments. Besides they are represented as developed on the ninth and tenth segments, where there are no traces of the stigmata. Owing in part to the rather poor impression of the colored print of the woodcut, which is inserted in the text, these delicate rudiments are faintly and obscurely printed. In Fig. 27, representing a more advanced stage, it should be observed that the author omitted to letter them; these rudimentary structures appeared to be still persistent, though not shown on segment 2, and not as distinct on segments 3 to 5 as before; but on segments 9 and 10 they seem to stand out distinctly from the surface of the segment, though the author did not letter them. In Fig. 28, representing a still more advanced step, there are no traces of these deciduous structures, but the normal abdominal legs (on segments 3–6 and 11) are distinctly drawn and lettered.

Though with some hesitation I yet regarded the figures as representing these deciduous structures, but was unable to read the Russian text.

In his valuable treatise, *Ueber die Polypodie bei Insekten-embryonen* (1888), Graber describes and figures the embryo of *Gastropacha quercifolia*, stating that there were no traces of these temporary structures to be seen. He also states that no temporary abdominal legs were found either by Buetschli, or by Grassi, in the honey bee. None have been observed in the Diptera by Weismann and others. Hence it appears, up to this date, that they only occur in the orders below those named above. Graber throws some doubt on Kowalevsky's observations, and states that Tichomiroff also did not discover them. On this account he is led to consider the abdominal appendages of caterpillars as secondary structures.

In his interesting article, "On the Appendages of the First Abdominal Segment of Embryo Insects," Mr. W. W. Wheeler * discusses this question, and gives a list of the species and orders of insects in which these deciduous abdominal appendages have been found. His list shows that in all the Orthoptera which have been studied, pleuropodia, viz., the temporary appendages of the first abdominal segment, and in general those of the succeeding segments, have been observed in the embryos of all the Orthoptera yet examined. In the Hemiptera they have not been observed in three species of Aphis, but have been detected in Cicada and Zaitha. In the Coleoptera they apparently may or may not be present, for example, they have been seen in Hydrophilus, Acilius, Melolontha and Meloë, but not in the chrysomelid genera Lina and Doryphora. The neuropterous genus Sialis and the trichopterous genus Neophylax possess them. He also states that pleuropodia do not occur in the honey-bee embryo studied by Buetschli and by Grassi.

* *Trans. Wisconsin Acad. Sciences*, etc., viii, September 20, 1890.

Graber,* in his last more elaborate and carefully considered work, however, refers more at length to Tichomiroff's memoir on the silk-worm, and quotes from him as follows: "Wood-cut 26 represents the stage in which two new structures become apparent, namely, first, seven pairs of spiracles (from the second to the eighth abdominal segment), and, second, the ventral legs. The last become visible on *all the segments*, except the first. As regards the last ones, I could not satisfy myself that they, as those Kowalevsky refers to in Hydrophilus, arise out of a common germ with the outgrowth bearing the stigmata. This outgrowth arises much later."

He adds further on (p. 42): "*The ventral legs*, which originally appear on all the abdominal segments, with the exception of the first, *exist in their complete number only a short time*. Five pairs of them, namely those which belong to the third, fourth, fifth, sixth and ninth segments, begin to develop rapidly, *while the others very imperceptibly disappear in the mass of the primitive hypodermis*" (*Stammhypodermis*).

On the other hand, in *Bombyx mori*, Selvatico† neither mentions nor figures these deciduous organs. With these facts before him, Graber concludes that the question of the presence or absence of a continuous series of abdominal appendages in view of the extraordinarily short and transitory development of these embryonic structures cannot be answered yes or no, and that the question whether these processes correspond to true appendages, to primary or secondary appendages, cannot in the present state of our knowledge be solved. He then goes on to state that in the embryo of *Bombyx mori* (in all the abdominal segments except the ninth and tenth) *faintly marked knob-like elevations are to be seen which may yet* (*immerhin*) *be considered as the first indications of rudimentary appendages* (see his Fig. 108). He adds that "they are much fainter and are also less sharply defined than those figured by Tichomiroff in wood-cut 26, although on the whole a return to the view of the observer mentioned would be in accord with the truth."‡ In a word, the observations and figures of Graber appear to confirm the text and figure of Tichomiroff, which we therefore

* Vergleichende Studien am Keimstreif der Insecten, von Vitus Graber, Wien, 1890.

† Sullo sviluppo embrionale dei Bombicini. Annuario della r. stazione bacologica di Padova, 1882.

‡ This is a clumsy translation of Graber's rather guarded endorsement of the correctness of Tichomiroff's observations, his expression being: "Obwohl sonst die betreffende Wiedergabe seitens des genannten Forschers der Wirklichkeit sehr nahe kommt."

reproduce (Fig. 9). Graber also goes on to remark: "In general, however, they appear to be completely homotypic (homotop) with the thoracic jointed appendages, and in this respect there could be no reason to call in question their homology with the abdominal appendages of other insects, viz., the Coleoptera and Orthoptera." Finally he concludes that in *Bombyx mori* "the stage of pantopody has only a very ephemeral duration."

In Pieris there are the same relations as in Bombyx, "though the persisting pantopody is more latent." However, he did not perceive any clear traces of the deciduous abdominal legs in Pieris, nor after a reëxamination of his preparations of the primitive streak of Gastropacha did he discover them in that form.

(Fig. 9. Primitive band of *Bombyx mori*, showing the temporary legs on abdominal segments 2–11. After Tichomiroff. *A*. Early stage, in which the abdominal legs al^2–al^{10} appear. *B*. Later stage when they are very faint and all except al^3–al^6 and al^{10} are about to disappear. *C*. The persistent abdominal legs al^3–al^6 and al^{10}, st^2, st^3, the 2d and 3d pair of stigmata.)

As regards the appearance of these structures in the Hymenoptera, Graber states that Buetschli, as is well known, makes the statement that in the primitive streak of the honey bee at a certain stage rudimentary appendages resembling tubercles arise on all the abdominal segments; though Grassi could not confirm this observation.* Very recently, moreover, Carrière reports that in the wall bee† at least on the first two segments, after the appearance of the thoracic legs, "small tubercles" become visible, which however are "only of short duration." In Hylotoma Graber found no traces of these deciduous structures.

From the foregoing facts it would seem reasonable to infer that the figures of Kowalevsky are in the main correct and that the statements and figures of Tichomiroff have been substantiated by Graber. Hence we would feel warranted in concluding that these structures appear in the embryos of certain Lepidoptera and Hymenoptera, though much less distinct and more evanescent than in the lower orders of insects.

If it should be eventually discovered that the deciduous append-

* Balfour, in his *Comparative Embryology*, accepts Buetschli's statements without questioning them (i, 338). See also Buetschli's own statement on p. 537 of his essay: "And after close observation of the following abdominal segments we perceived a very faint similar outgrowth on all of them," etc.

† *Chalicodoma muraria*.

ages are not developed in all Hymenoptera and Lepidoptera, and not at all in the Diptera, this would show that the power of inheritance of these ancestral traits had already in the first two of these orders begun to wane; that their evolution had begun on a higher plane than the polypodous one of the Coleoptera, Orthoptera and ametabolous orders, and that the power was on the verge of extinction. Hence their appearance in certain forms and the cessation of their development in others may be accounted for, just as the scattered and sparse distribution of certain animals, and the reduction in the number of individuals is a preliminary step to their entire extinction.

The lack of these structures in dipterous embryos appears to confirm the view that they are the most extremely modified of all insects. It should be borne in mind that such observations are exceedingly difficult to make, the parts are so delicate and faintly developed, and yet when we take into account the fact that so skillful an observer as Kowalevsky detected them, who was the pioneer in these studies, and who probably had no expectation of discovering such structures, and whose mind was free from any theory in the matter, it seems scarcely probable that he would have figured them unless he had actually seen them.

Returning to the Lepidoptera and to Lagoa, with its rudimentary abdominal legs of the second and seventh segments of the hind body, we feel warranted in the present state of the subject in concluding that they may represent a persistent condition of two pairs of these deciduous abdominal legs. They are certainly of some use to the creature, and thus have survived because they, in a partial way to be sure, have been of service. The others have evidently disappeared from disuse. And it would thus seem that the Lepidoptera and Hymenoptera have descended, like other insects, from polypodous ancestors.

If these conclusions are correct, then Lagoa, in respect to its abdominal legs, even if we do not take into account other characters, is a survivor of an ancient and very generalized type, and represents, as no other known caterpillar, the polypodous ancestor of all Lepidoptera.

The other alternative is that, as Graber once claimed, the abdominal legs of caterpillars are not primitive, but secondary and adaptive structures. Of course these questions can only be settled by further researches. And it is possible that the similar abdominal legs of larval Tenthredinidæ and the abdominal tubercles of Diptera, which, as in Chironomus and Ephydra, bear hooks, may, instead of being new, adaptive characters, be the homologues of the jointed appendages of the other regions of the body.

After reading Graber's first paper on polypody in insect embryos, and Wheeler's essay, I took it that I should have to abandon the view I expressed in my note in the *American Naturalist* in 1885, and it occurred to me that the seven pairs of lateral processes on the first seven segments of Lagoa might be so many pairs of pleuropodia. These processes we may now consider.

The External Lateral Abdominal Glandular Processes of Lagoa.

These are present at birth and in all the larval stages and are represented by Figs. 10 to 13, also Figs. 1 and 5.

There are seven pairs of them, a pair to each of the first seven abdominal segments. They are situated near to and directly behind, but a little lower down than the spiracles and above the infraspiracular tubercles. In fact, they occupy the exact position of the evaginable glands of *Hyperchiria io* and *Hemileuca maia*, etc. In shape they are elongated pyriform conical, or digitiform, being slightly contracted at the base, and with two slight contractions towards the free end, and they remind one of the shape of the appendages of insect embryos just when the joints are beginning to appear. The free end is conical, rounded and, so far as I have been able to discover, imperforate. They are not capable of being retracted and appear to be permanently evaginate, since each pair along the side of the abdomen is of the same general length and size, none being wholly or in part retracted.

Fig. 10. *A*, a camera drawing, represents the shape in the third stage, just before molting; *sp.*, spiracle; the process was on the point of being molted and is hollow. *B* represents the process just after evagination, belonging to Stage IV. It is a little longer and larger than before (both figures are drawn to the same scale, × one half inch *A* eyepiece) and filled with granules in the middle, with narrow linear cells (*hy?*) on the outside or cortex which remind one of the linear cells in the pleuropodia of Blatta figured by Wheeler (Pl. i, Figs. 3, 4). It is to be observed that the spiracle in this stage (*sp.*[1]) is nearly twice as large as in Stage III (*A. sp.*).

In the later stages these processes are concealed by the hairs. They are invariably pale, whitish, the cuticle is smooth and naked, not bearing any setæ or hairs, differing in this respect from the fleshy digitiform processes or soft tubercles of the larva of Attacus and of certain Papilionidæ.

To examine the structure of these processes transverse sections of the larvæ of Stage I were made, and also blocks of the integument of the full-fed larva bearing two of the processes were cut with the microtome. Fig. 11 represents a transverse section of the body of the larva before the first molt, involving the lateral grandular processes on each side of an abdominal segment; *int.*, intestine, with the epithelial or mucous layer enclosing vacuoles, and *m.*, the outer or muscular layer; *mp.*, section of four of the Malphigian or urinary tubes; *n.g.*, the ganglia; *ht.*, the heart; *f.*, cells of the fatty body; *sc.*, thickened portion of the hypodermis (*hy.*) lying under the tubercles and modified into the setigenous cells; *l.*, the abdominal legs; *m.*, muscles; m^1., a pair of muscles inserted near the base of the lateral glandular processes; *cut.*, cuticle. The lateral grandular processes (*l g p*) are seen to be inserted a little below the middle of the segment, and that they are permanently evaginated is seen by the nature of the cuticle, which is rough and subspinulated on the basal third. The process is filled with elongated gland-cells.

Fig. 12. represents different sections, 1^a–1^d through the process of one segment, and 2, 2^a, 2^b through another, the lettering as before.

Longitudinal (A, B, C) and a transverse section (D) through these processes in the fully fed larva are represented by Fig. 13. At A the lumen (*l*) is a deep narrow cavity, with the secretion (*secr.*) collected at the mouth of the cavity composed of a thin mucous-like coagulated fluid, containing granules of varying degrees of fineness which take the stain readily. Outside of these are collected fine *nuclei* (*b*, *c*), stained dark and enveloped in a slight transparent pale protoplasmic envelope, which may be blood-corpuscles. The glandular cells themselves are simply modified hypodermal cells, as seen at *C;* those at the free end of the process are very much elongated, the nucleus however situated near the periphery of the process. In some of the nuclei, indistinct nucleoli are seen, and deeply stained granules, especially around the periphery of the nuclei. The specimens had been in alcohol for at least three years, so that the exact histological structure of the nuclei could not be clearly brought out, but in the general appearance of these grandular cells, there is a general and suggestive resemblance to those filling the pleuropodia, figured and described by Wm. M. Wheeler.* At *B* is represented a section on one side of the middle, but still showing the spacious lumen. In the section represented by *C* the knife passed through the process still nearer the outer edge and near the base; at C^1 three of the glandular cells with their large deeply stained nuclei are drawn. A transverse section at *D* shows the large lumen or cavity (*l*) (in all the preparations the hypodermis and other cellular tissues have shrunk and separated widely from the cuticle).

As to the function and homologies of these structures it is difficult to decide. I have never noticed that they give off any odor, though they may prove to be repugnatorial; they are not visible in the living insect, being concealed by the long dense hairs clothing the body; they are not spraying organs as they are imperforate at the end, not ending as the lateral eversible glands of *Hyperchiria io*, etc., in a crateriform orifice.

There are three views which might be taken as to their homologies.

1. They may be merely fleshy papillæ like the short or long tubercles of the larvæ of Attacinæ and of certain Papilionidæ.

2. They may be permanently everted glands, or osmateria, which have by disuse lost their power of retraction, and their crateriform opening, as well as the power of secreting a malodorous fluid.

3. If it should ultimately be fully proved that Lepidoptera have temporary abdominal appendages, and that the proplegs or so-called abdominal legs, with crotchets, are merely secondary, adaptive structures, then these may be pleuropodia, or homologues of the temporary embryonic abdominal legs of the lower insects.

The first view is unlikely because in the larva of Attacus each lateral long horn-like process arises *in front* of the spiracle, on the prothoracic and second abdominal segments, and there are no such processes in a corresponding position on the other abdominal segments. Moreover the elongated fleshy or soft, flexi-

* Appendages of the first abdominal segment, etc., 1890.

ble tubercles in the larvæ in question are of the same color as the skin and are armed with fine hairs or setæ.

The third view is one which is incapable at present of proof, so that we are driven to provisionally regard these processes as persistently evaginate repugnatorial, or at least scent glands or osmateria which have possibly lost their power of ejecting a poisonous or disagreeable spray or fluid, owing to the fact that by a change or transfer of function the spine-like setæ are poisonous, thus functionally replacing a set of organs originally actively repugnatorial.

It is also to be observed that the fact that in the Hemileucidæ these eversible glands are restricted to but two of the abdominal segments, shows that in the ancestral forms these structures may have been developed on all, or at least nearly all the abdominal segments.

Lagoa, as Regards its Larval, Pupal and Imaginal Characters, a Generalized Type.

We have already seen that in respect to its general appearance the larva of Lagoa is in some respects intermediate between the Cochliopodidæ and Liparidæ. It resembles the former group in the short thick body; in the head being concealed by the prothoracic hood, and in the venomous spines.

On the other hand it resembles the Liparidæ in the hairy body, the hairs being finely plumose, a peculiarity of more common occurrence in the Liparidæ than in the Cochliopodidæ.

As regards the cocoon, this is intermediate in form and texture between that of Orgyia, etc., and the Cochliopodidæ, but it more closely approaches that of the latter; it varies somewhat in density in different species, being usually quite firm and dense like parchment, nearly as much so as in those of the Cochliopodids, and also approaching them in shape, being oblong-cylindrical, oval, contracted at the anterior end, and with a separately spun lid, closing the anterior end. As Dr. Lintner has shown with many interesting details: "The lid is woven by the caterpillar separately from the rest of the cocoon, and is not a section cut from it after its completion" (p. 142).

The pupa is much like that of Limacodes, etc., the integument or cast cuticle being remarkably thin, and after the exit of the moth the antennæ and legs, as well as the wings, are free from the body;

while the latter is split both down the back and along the under side to the end of the thorax. Moreover when the moth escapes from the pupa-skin, the latter is left with the head and thorax projecting out of the end of the cocoon.

As regards its imaginal or adult characters it is also intermediate between the two families mentioned. In the short stout body and short broad wings it has the habit of a Limacodes, rather than of such Liparid genera as *Porthesia*, etc.

In the shape of the antennæ and palpi it is about as near the Liparidæ as the Cochliopodidæ.

In respect to the denuded head, Lagoa is much more like Euclea than the Liparidæ. The clypeus is rather long and narrow, similar in shape to that of Euclea, though rather narrower, and is thus more like that of the Cochliopodidæ than that of the Liparidæ, represented by Orgyia and the European *Porthesia chrysorrhœa,* whose denuded heads I have examined. The epicranium and occiput taken together (on the median line of the body) are about one-third as long as the entire clypeus.

As regards the venation, Lagoa is decidedly nearer Euclea and other Cochliopodids than the Liparidæ (I have examined the venation of Orgyia and Parorgyia). Lagoa has the same wide costal region of the fore wings as in Euclea, that of the Liparidæ being very narrow; the five branches of the subcostal vein are thrown off in nearly the same manner as those of Euclea and Limacodes. The discal veins and origin of the independent (sixth subcostal) are almost precisely as in Euclea, and the four branches of the median vein are also similar in their mode of origin, and unlike those of Orgyia and Parorgyia.

In the hind wings, as in the Cochliopodidæ, there are ten veins, in the Liparidæ only nine; there are but two branches of the subcostal vein; the third branch being detached, so that there are two independent veins, one arising from the anterior, and the other from the posterior discal vein. In the Liparidæ mentioned there is no independent vein at all. The four median veinlets have the same peculiarities in their mode of origin as in Cochliopodids and the same differences from the Liparidæ.

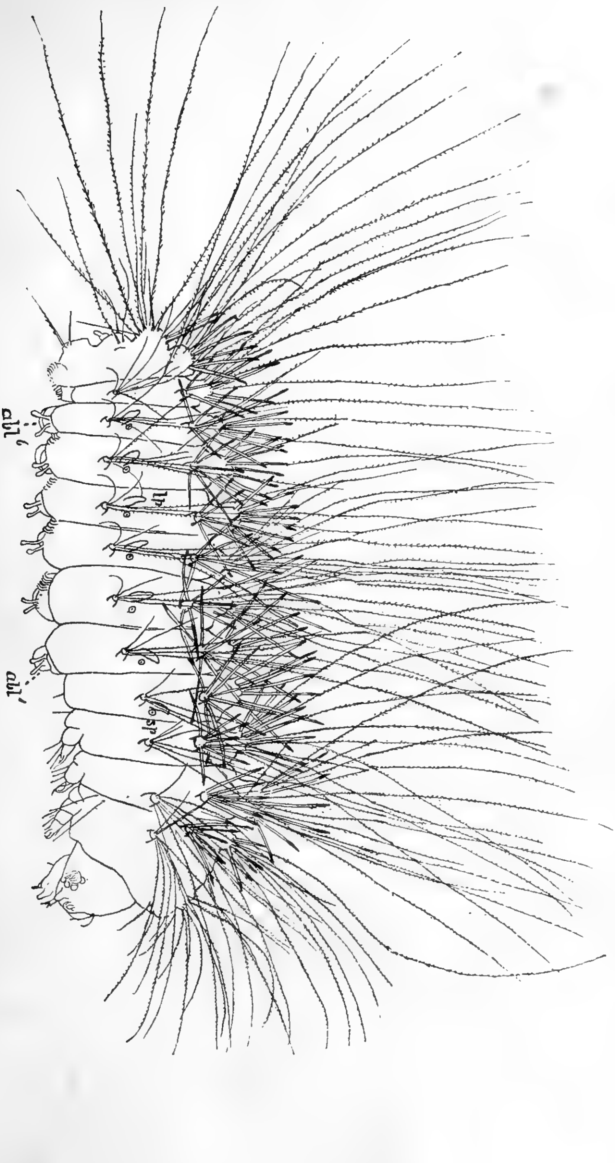
To sum up: in the superficial characters, of the imago, and in having in the larva abdominal legs, Lagoa resembles the Liparidæ, but in all its essential characters, those of the egg, larva, pupa and imago, it belongs with the Cochliopodidæ, except in the matter of the presence of abdominal legs in the larva. On this account it seems fairly entitled to be regarded as the type of an independent group. We may either regard it as a generalized, ancient group of Cochliopodidæ, and refer it to a subfamily *Lagoinæ*, or we may boldly remove it altogether from either of the two families mentioned and consider the genus as the representative of a distinct family and designate the group by the name of *Lagoidæ*. This on the whole seems to us to be perhaps the most judicious course to pursue. At all events the insect is plainly enough an ancient, ancestral, or generalized form. It is, so to speak, a primitive Cochliopodid with larval abdominal legs. It lays eggs like those of Limacodes, etc.; its head in the larval state is concealed from above by the prothoracic hood; its larval armature is more of the Cochliopodid type than Liparid; so are the pupal characters and the nature of the cocoon; and the shape of the important parts of the head and the essential features of the venation are overwhelmingly Cochliopodid. Under these circumstances we feel justified in regarding Lagoa as a most interesting ancestral form, and as affording arguments for considering the Bombyces as a whole as a generalized and ancestral group, and epitomizing the other higher Lepidopterous families somewhat as Marsupials do the placental orders of mammals.

The genus is peculiar to North and South America, and may rank with such forms as the colossal sloths, and certain American vertebrate survivors of middle Tertiary times. In some respects it is intermediate between the Saturniidæ, especially the higher Attacinæ, and the Cochliopodidæ; its clypeus, and the larva, approach in some respects those of the Attacinæ.

[NOTE. I find since this paper was read to the Society that, according to Berg (*Miscellanea Lepidopterologica*, 1883), Megalopyge of Hübner preoccupies Lagoa. Berg also founded the family *Megalopygidæ*, of which Lagoidæ is a synonym.]

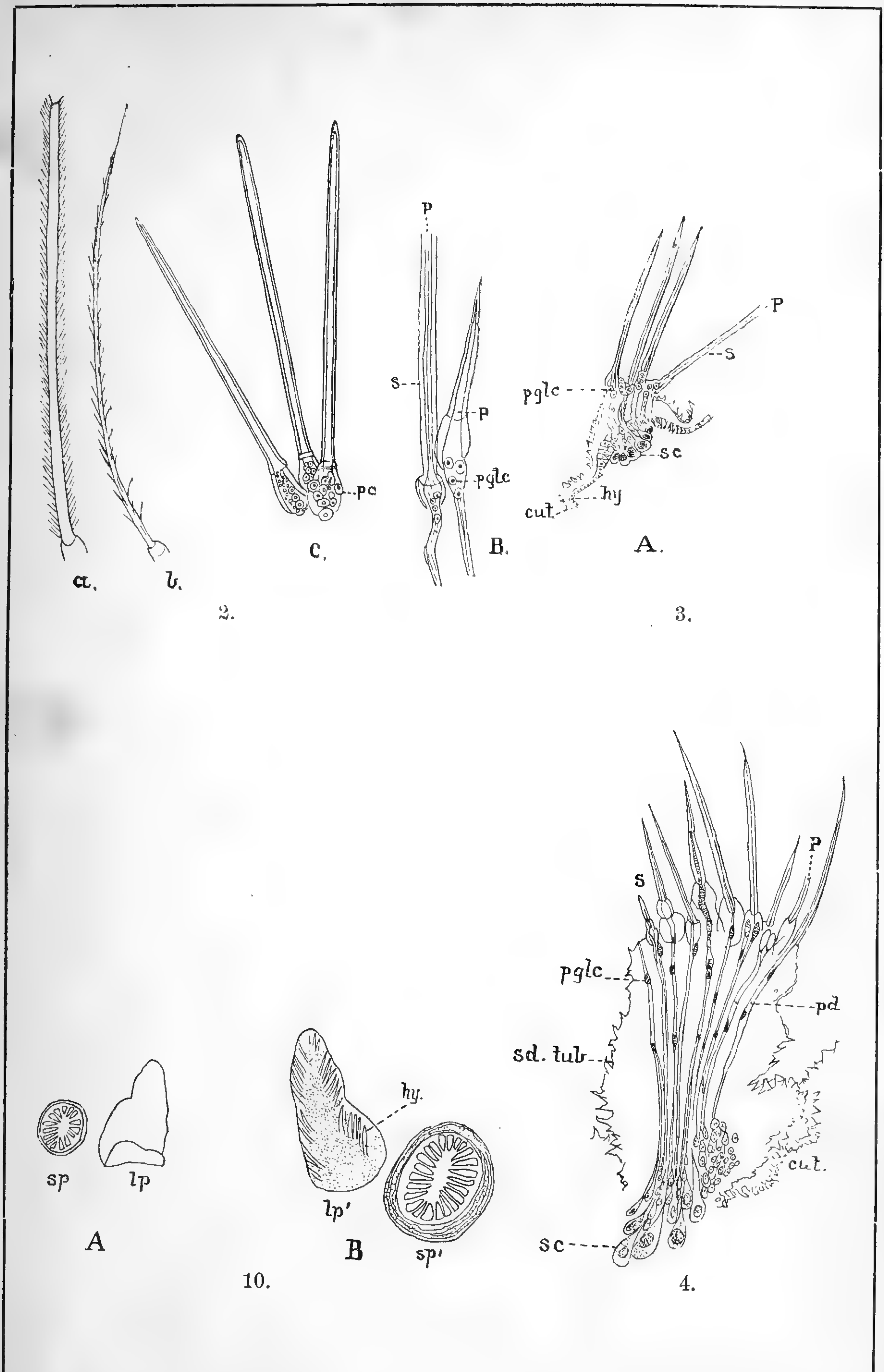
Packard del.

1.



Larva of Lagoa crispata, Stage I, much enlarged.

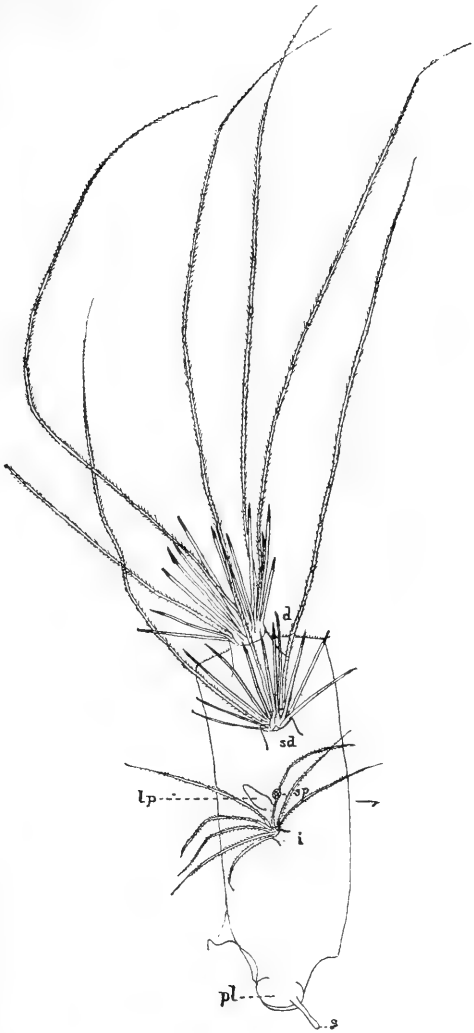
Plate I (Packard).



Packard del.

Armature, etc., of Lagoa.

Plate II (Packard).

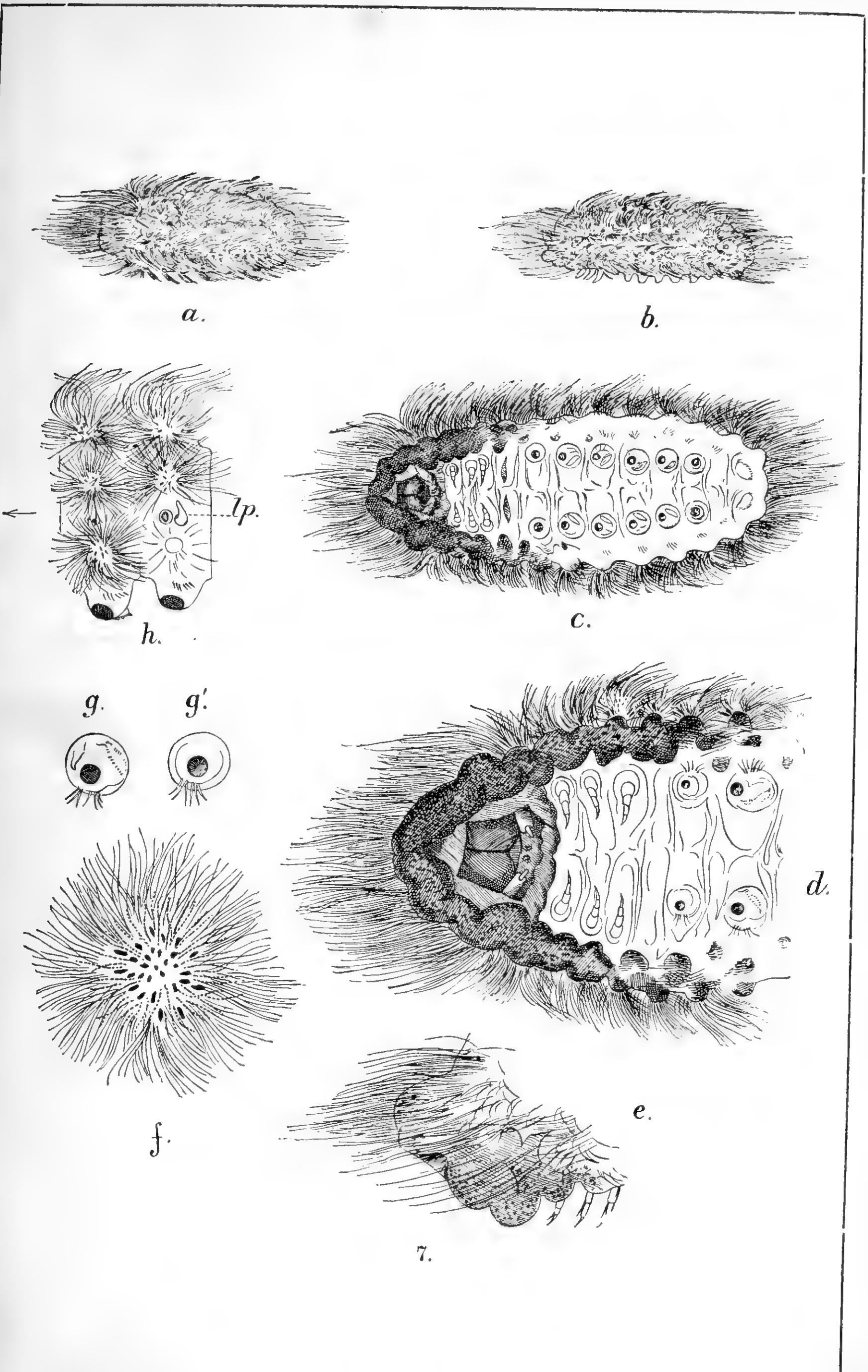


6.

Packard del.

View from Side of Seventh Abdominal Segment of Lagoa, Stage II.

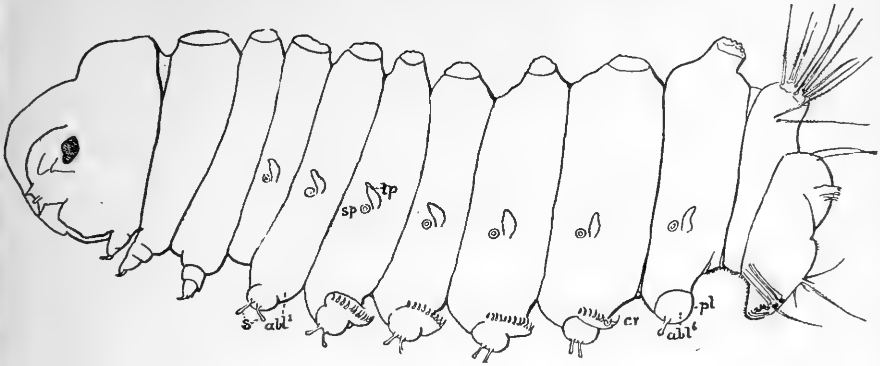
Plate III (Packard).



J. Bridgham del.

Later Larval Stages of Lagoa crispata.

Plate IV (Packard).



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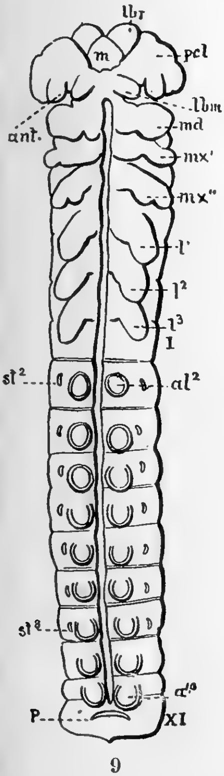

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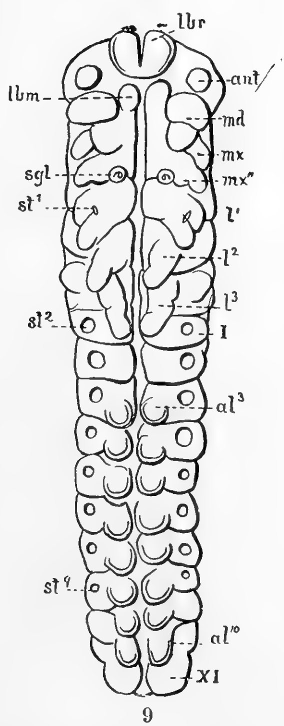
B



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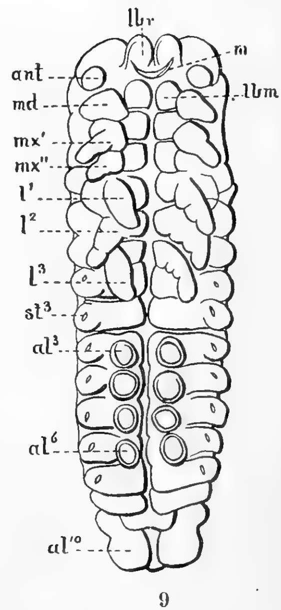
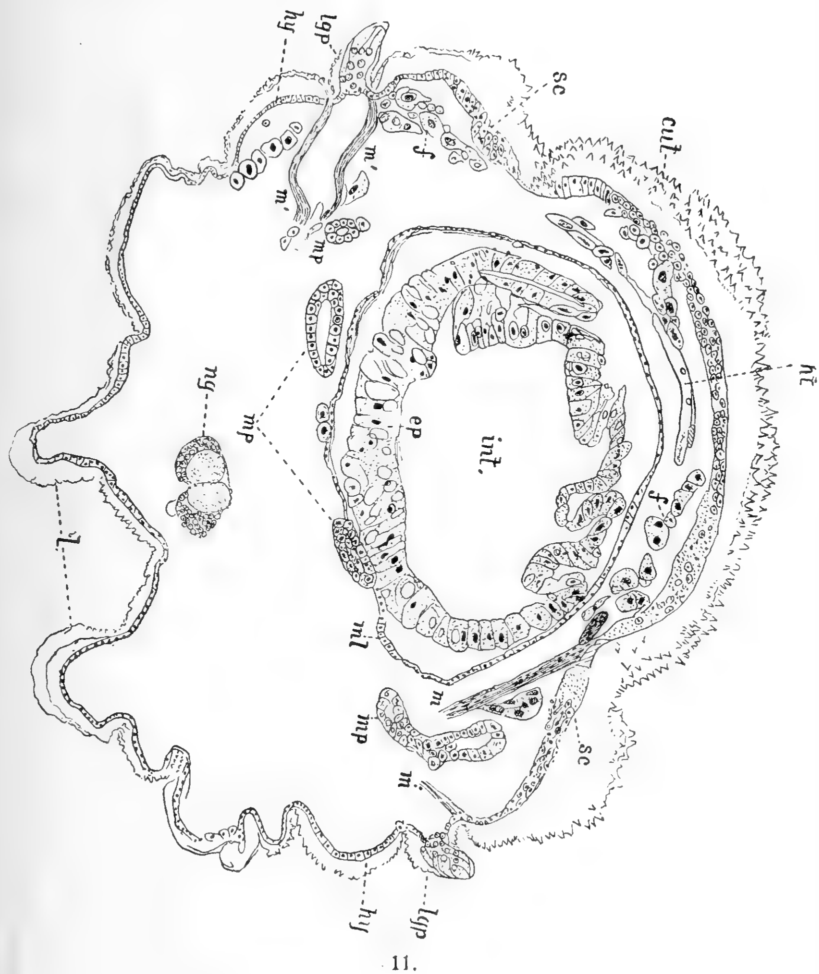
C.



9

Larva, Stage II, and Embryo of Bombyx mori.

Plate V (Packard).

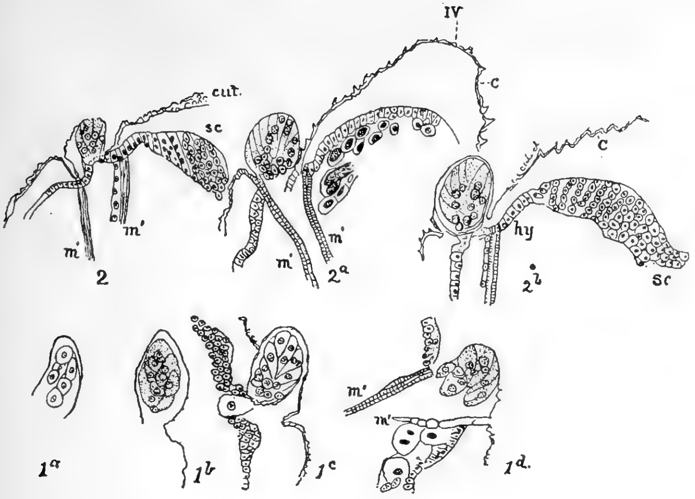


11.

Section through an Abdominal Segment of a Larva of Lagoa in Stage I.

(Packard del.)

Plate VI (Packard).



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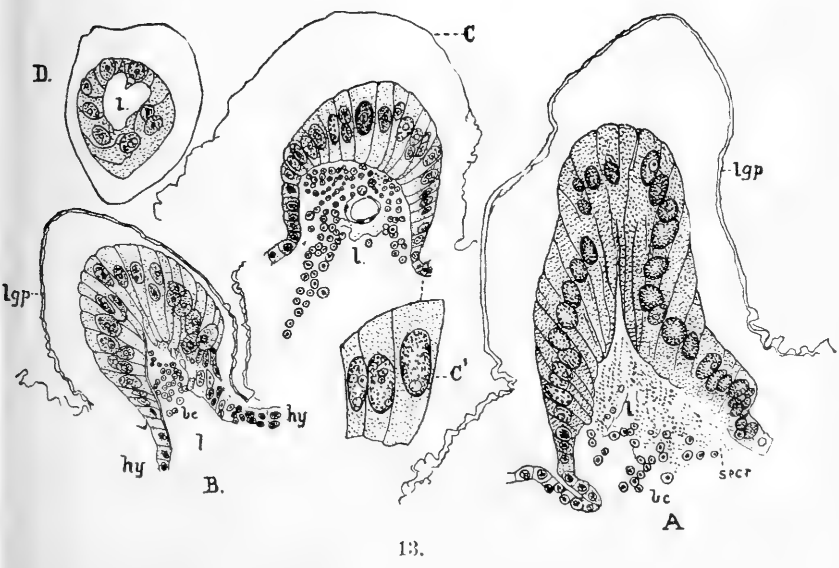

13.

(*Packard del.*)

Sections through the lateral Glandular Processes of Lagoa.

Plate VII (Packard).

Wie Mohammed Köprülü Vezier geworden.

Ein Guslarenlied der slavischen Mohammedaner im Herzogtum.

Aufgezeichnet, verdeutscht and erläutert, von Dr. Friedrich S. Krauss, in Wien.

Unter den 190,000 Versen bosnischer, herzögischer und dalmatischer Volkepen meiner noch ungedruckten Sammlung, besitze ich auch sechs grössere Epen im Umfange von mehr als 6000 Versen, die die Eroberung des Ungarlandes bis hart an Niederösterreich durch die Türken zum Vorwurf der Behandlung haben und ausschliesslich die Kämpfe und Heldentaten des Reorganisators der damals dem Zerfall nahen Türkei, Mohammed Köprülüs schildern.

Wie den Freunden meiner wissenschaftlichen, ethnographischen Arbeiten bekannt ist, werden solche Epen von Leuten aus dem Volke zu einer Geige, die *Guslen* (plur.) heisst, vorgetragen, wonach die Sänger Guslaren (Fiedelleute, Geiger) benannt werden. Es sind dies in den allerseltensten Fällen und nur ausnahmweise selbstständige Dichter, sondern einzig und allein Recitatoren von Epen, die sich durch mündliche Ueberlieferung seit Jahrhunderten im Volke bis auf unsere Tage erhalten haben.

Bosnier und Herzogländer haben unter der Fahne des Islam an der Niederwerfung Ungarn teilgenommen. Die Blüte der slavischen Jugend war in den Reihen der Janičaren vertreten. Vor dreihundert Jahren mochte es eine Zeitlang scheinen, dass halb Westeuropa bis vor die Tore von Wien der Serbisirung unterliegen werde. Wären jene kriegerischen Bewegungen während zweier Jahrhunderte von einer intensiveren kulturellen Strömung des Slaventums begleitet gewesen, wie dies nicht der Fall war, so hätte wahrscheinlich ein Teil Europas ein politish ganz anderes Aussehen.

Eingeleitet ward die Bewegung von einem der bedeutendsten türkischen Staatsmänner aller Zeiten, von dem greisen Mohammed Köprülü. Sein Auftreten war für Jahrhunderte folgenschwer, und es ist kein Wunder, dass die Nachkommen jener Krieger, die unter seiner Führung gekämpft, von jenen für sie glücklichen Tagen noch immer singen und sagen.

Es ist bewunderungwürdig, mit welcher Treue das Gedächtniss des Volkes ohne schriftliche Behelfe den Gang der Ereignisse jener Zeiten im Grossen und Ganzen festgehalten hat. Zum Vergleiche gebe ich im Commentar die zuverlässigen Berichte zeitgenössischer osmanischer und abendländischchristlicher Historiographen nach Hammer-Purgstall und Salamon, bzw. dem Siebenbürger Kraus.

Wann ich in der Lage sein werde, mein grosses Werk über Köprülü zu ediren, weiss ich noch nicht. Wass ich hier darbiete, ist bloss ein Probestück, das ich eigens zur 150jährigen Jubelfeier der "American Philosophical Society," deren Mitglied ich zu sein die Ehre habe, übersetzte. Die Publikation des slavischen Textes, die ohne eingehenden philologischen Apparat nicht angezeigt wäre, behalte ich mir für mein Buch vor. Bemerken muss ich jedoch, um jeder Missdeutung vorzubeugen, dass sich die Verdeutschung *wörtlich* an das Original anschliesst.

Lehrreich ist unser Lied als ein Beispiel, wie sich grosse Ereignisse in der Vorstellung eines auf tiefer Culturstufe befindlichen Volkes widerspiegeln und als authentisches Zeugniss für volktümliche Sitten und Gebräuche, Meinungen und Anschauungen. In dieser Hinsicht sind die südslavischen Guslarenlieder für den Ethnographen nicht minder wertvoll als die altassyrischen, altgriechischen, malayischen, finnischen und turkotatarischen Volkepen. Unserem Liede wohnt zum Ueberflusse auch ein nicht geringer poetischer Gehalt inne, weshalb ich der Hoffnung Raum gebe, es werde als bescheidene Festgabe eines Vereingenossen aus weiter Ferne, dem es zu seinem lebhaften Bedauern nicht möglich ist bei den Feierlichkeiten persönlich anwesend zu sein, eine freundliche Aufnahme finden.

Von Köprülü, dem Vali in Travnik.

In Krankheit fiel der Sultan Suleimân
in seiner weissen Herrscherstadt Istambol
auf seinem Throne wohl in seinem Reiche
am dritten Tag des Monats Rāmazân,
wohl auf dem Schoosse Ibrahîms des Sohnes.
Er kränkelte den ganzen Rāmazân.
Am Abend vor des Bajramfestes Anbruch,
da sprach zu ihm der Sultan Ibrahîm:
—"O hör', mein Vater Sultan Suleimân!
du kränkelst nun den ganzen Rāmazân;

heut Abends vor des Bajramfestes Anbruch,
was meinst du nun, wirst du die Krankheit meistern?
wie? oder meinst du, dass der Tod dir naht?"
Darauf bemerkte ihm Sultan Suleimân:
—"Mein lieber Sohn, o Sultan Ibrahîm!
bei Gott, die Krankheit übersteh' ich nimmer,
im Augenblicke werd' ich dir versterben!"
Da spricht zu ihm der Sultan Ibrahîm:
—"O liebster Vater, Sultan Suleimân!
was schafft dir soviel Leid in deinem Sterben?
hat Leid dein Herz um diesen Ort des Heiles?
tut leid dir deine ganze Kaiserherrschaft?
tut leid dir um die Lalen und Ridžalen,
um deine Stellvertreter, die Veziere?
oder um deine neun erwählten Frauen?
oder um mich den Sohn, den zarten Jüngling?"
Da sagt zu ihm der Sultan Suleimân:
—"O du mein Sohn, o Sultan Ibrahîm!
ich trag' kein Leid um diesen Ort des Heiles,
und kenn' kein Leid um meine Kaiserherrschaft
und hab' kein Leid um Lalen und Ridžalen
noch um Veziere, meine Stellvertreter,
noch um die neun erwählten Sultaninnen,
auch nicht um dich, mein Sohn, den zarten Jüngling!
Doch mir, o Sohn, am meisten liegt am Herzen:
drei beste Städte sind zurückgeblieben
in Kafirhänden, aber nicht in meinen;
die eine Erlau und die and're Ofen,
dazu Seméndra tieferwärts von Belgrad.—
Auch tut's mir leid um Köprülü den Edlen!
Das war ein alter Diener seines Herrn!
Verräter hatten ihn bei mir verläumdet,
ich hab' ihn dann geschickt in die Verbannung
weit über's Meer an hundert Lagerrasten;
zwölf Jahre sind seit damals schon verflossen,
und darum werd' ich nun zu früh versterben!
Doch horch der Rede, Ibrahîm, mein Sohn!
Sobald ich hier auf deinem Schooss' entschlumm're,
erscheinen hier die Hodžen und die Hadži,
die Mollah auch, es sammeln sich die Kadi;

ausstatten wird man mich, o Söhnchen Ibro,
forttragen wird man mich, o Sohn, zum Grabmal,
zum Denkmal auf dem Grab des heil'gen Ali,
zum Inschriftstein der heiligen Tatîm,
und dort, mein Sohn, dort wird man mich begraben,
und auch ein Grabmal wird man auf mich setzen.
Du aber flieh davon von meinem Grabmal!—
Und wie du kommst zum Thron und Reichpalaste
verschliess dich in den festen Käfig, Sohn!
Bald kommen nach die Hodžen und die Hadži
und rufen dich,—du öffne ihnen nicht!
Dann kommen nach die Mollah und die Kadi
und rufen dich,—du öffne ihnen nicht!
Dann kommen nach die Lalen und Ridžalen
und rufen dich,—du öffne ihnen nicht!
Dann, Sohn, dann kommen alle die Veziere,
die hier mir Dienst geleistet in Istambol,
und rufen dich,—du öffne ihnen nicht!
Letzt kommen auch die Janičarenbaschen;
und rufen dich die Janičarenbaschen:
"O Sultan Ibrahîm, Prophetensprössling!
Magst du selbst *uns* die Thüre nicht eröffnen?"
Dann endlich riegele auf des Käfigs Thüre;
dich nehmen drauf die Janičarenbaschen
und hüllen dich in des Propheten Mantel,
und stülpen dir aufs Haupt die goldene Mütze
und setzen dich auf meinen Platz hinauf!
Traun! sie erheben dich zum neuen Kaiser!
Es werden alle Lalen und Ridžalen
und die Veziere und die Stellvertreter,
geführt vom Sigelhüter, hier erscheinen,
an seiner Seite Pascha Seïdi.
Das wird wohl gut drei weisse Tage währen,
und Wunder nimmt's die Lalen und Ridžalen,
was wohl der neue Kaiser wird verordnen,
was für Erlässe nun er wird verkünden.
Aufjammernd wird der Sigelhüter fragen:
—"O Gnade, Kaiser, o Prophetensprössling!
was spannst du uns drei weisse Tag' auf Folter!
gewähr uns hier Bescheid nach Lust und Liebe!"

Dann, Kaiser, sprich mit leiser Stimme also:
"Wer unter Euch ist Köprülü der Vezier?"
Zur Antwort gibt dir wohl der Sigelhüter:
"Hier weilt dir nicht Herr Köprülü der Vezier;
der Vezier ist schon hoch betagt bei Jahren,
der Vezier weilt auf seinem Meierhofe."
Darauf entgegne du dem Sigelhüter:
"Den Vezier her, sonst hau' ich dir das Haupt ab!"
Der Siegelhüter wird darob erschrecken,
er wird betroffen, fassunglos verstummen;
nun wird dir sagen Pascha Seïdi:
—"O Gnade, Kaiser, o Prophetensprössling!
o weh, dein Vater selbst hat ihn verbannt,
ach! über's Meer an hundert Lagerrasten;
zwölf Jahre sind seitdem schon hingeflossen.
Gewähr uns einen Ferman mit dem Namen,
gewähr uns auch die Frist von vierzig Tagen,
wir schaffen dir den Vezier her zur Stelle!"
O Sohn, erteil den Ferman mit dem Namen,
sie werden dir den Hodža her verschaffen.
Und wann dir anlangt Köprülü der Vezier,
sprich so zu ihm, mein Söhnchen Ibrahîm:
"O alter Lala meines teu'ren Vaters!
mein Vater tauschte diese Welt mit jener,
doch liess bei mir er einen Gruss für dich.
Gehört mir auch das ganze Kaiserreich,
ist die Verwaltung, Köprülü, doch dein!
Lass Erlau uns erobern und auch Ofen,
dazu Seméndra tieferwärts von Belgrad!
erfüllen wir des Vaters Wunsch und Willen!"
Da tauschte früh' er diese Welt mit jener.
O weh! so sprach der Sultan Suleimân;
o weh! er starb auf seines Sohnes Schoosse,
und jammernd schluchzte Sultan Ibrahîm.

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Es sammeln sich sie Hodžen und die Hadži,
es kommen an die Mollah und die Kadi,
sie statten aus den wackersten der Kaiser
und tragen fort den Kaiser hin zum Grabmal,

ja wohl, zum Grabesmal des heil'gen Ali,
zum Säulenstein der heiligen Fatim.
Sie bargen Sultan Suleimân ins Grab
und stellten über ihm ein Grabmal auf.
Da floh davon der Sultan Ibrahîm
und schloss sich ein in seinem festen Käfig.
Nun kommen her die Hodžen und die Hadži
und rufen ihn, er soll die Thür' eröffnen,
doch mag er ihnen nicht die Thür eröffnen.
Dann rufen ihn die Mollah und die Kadi,
eröffnen mag er ihnen nicht die Thür.
Drauf rufen ihn die Lalen und Ridžalen,
selbst ihnen riegelt er nicht auf die Thür.
Es nah'n die Stellvertreter, die Veziere,
eröffnen mag er ihnen nicht die Thür.
Letzt rufen ihn die Janičarenbaschen:
—" O Sultan Ibrahîm, Prophetensprössling!
magst du selbst *uns* die Thüre nicht eröffnen?"
Nun schloss sich auf der Sultan Ibrahîm;
es nahmen ihn die Janičarenbaschen,
und hüllten ihn in des Propheten Mantel
und stülpten auf sein Haupt die gold'ne Mütze
und trugen ihn zum Thron und Reichpalaste
und setzten ihn wohl auf den Kaiserstuhl,
und, traun, erhoben ihn zum neuen Kaiser!
Zum Divan nah'n die Lalen und Ridžalen
und die Veziere, seine Stellvertreter,
an ihrer Spitze steht der Sigelhüter,
an seiner Seite Pascha Seïdi.
So harrten sie vor ihm drei weisse Tage,
und bald geraten sie in mächtig Wundern:
" Was wird der neue Kaiser uns verordnen?
" was für Erlässe wird er uns verkünden?"
Aufjammernd sprach zuletzt der Sigelhüter:
—" O gib Bescheid uns, Kaiser von Istambol!"
Nun sprach das Wort der Sultan Ibrahîm:
—" Wer ist mir hier Herr Köprülü der Vezier?"
Darauf entgegnet ihm der Sigelhüter:
—" Fürwahr, der Vezier ist schon sehr gealtert,
er weilt auf seinem grossen Meierhofe!"

Darauf zu ihm der Sultan Ibrahîm:
—"Den Vezier her, sonst hau' ich dir das Haupt ab!"
Vor Furcht erbebend steht der Sigelhüter
und schweigt beklommen, spricht kein einzig Wörtchen.
Da nahm das Wort der Pascha Seïdi:
—"O Gnade, Kaiser, o Prophetensprössling!
Dein Vater schickte fort ihn in Verbannung,
weit über's Meer an hundert Lagerrasten,
zwölf Jahre sind seitdem schon hingeflossen.
Gewähr uns einen Ferman mit dem Namen,
gewähr' uns eine Frist von vierzig Tagen,
wir schaffen dir den Vezier her zur Stelle;
dann sitzst du da, dein Vezier steht vor dir!"
Der Kaiser gab den Ferman mit dem Namen
und liess auch eine Frist von vierzig Tagen.

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Es nahm der Pascha Seïdi den Ferman,
nach allerwärts zerstiebt sodann der Divan.
Schnellfüssig rennt der Pascha Seïdi,
er rennt in das Tatarenheim des Kaisers
und fragt nach Idris, nach dem Hof-Tataren,
dem allerflinksten Hofcourrier des Kaisers.
Drauf gibt er ihm den Ferman mit dem Namen,
und küsst und herzt auf beide Wangen ihn:
—"O Idris, sei durch Gott mir wohlverbrüdert!
renn schleunigst, such mir auf den Köprülü
und führ' ihn her vor unsern wackeren Kaiser!
Du hast, o Sohn, die Frist von vierzig Tagen!"
Da hieng sich Idris um die Reisetasche,
verbarg den Ferman wohl in seiner Tasche
und schwang im Nu sich auf das schnelle Ross.
Ei, rennt da hurtig der Tatar des Kaisers
und kommt gerannt zur dicken Flut des Meeres,
am Meergestade steigt er ab vom Rosse.
Ein schnelles Ruderschiff empfieng ihn allda,
drin liess sich der Tatar des Kaisers nieder
und schlug mit Händen auf den jungen Schiffer:
—"Fahr rascher zu, sonst hau' ich dir das Haupt ab!"
Ei, schnell durchfurcht das Schiff des Meeres Wellen!

Sobald als er das dicke Meer verlassen
und auf der trock'nen Erde Fuss gefasst,
so schwang er sich auf's vorbereitet Rösslein
und jagte hin dem kalten Meer entlang.
Frühzeitig war's, noch vor der lieben Sonne,
als seine dunklen Augen dort erschauten,
als sie am Strand des kühlen Meers gewahrten
wohl einen hochbetagten, alten Herrn ;
der Bart so weiss und silvergrau das Haupt
und seinen Körper schmückt ein grüner Rock ;
er schürzt auf seinen Armen auf die Aermel,
um just die türk'sche Waschung vorzunehmen.
Da rief ihm der Tatar den türk'schen Gruss zu.
Der Greis bedankte sich mit Gegengruss
und Thränen perlten über seinen Bart,
so wie von Tannenzweigen Regentropfen.
Darob sich wundert der Tatar des Kaisers
und hält im Lauf sein schnelles Rösslein an :
—" Ehrwürd'ger Greis, so lieb dir beide Welten,
warum soviel vergiesst du grause Thränen ?"
Aufjammernd gab zur Antwort ihm der Greis :
—"Ach weh ! wie sollt' ich keine denn vergiessen !
zwölf Jahre sind schon wohl dahingeflossen,
dass keinen Sultanboten ich erschaut,
noch einen Sultanferman an dem Boten !
Wie viele hab' ich selber ausgefertigt
am Hof des Kaisers Sultan Suleimâns !
Doch sprich, wie weit bemühst du dich, mein Sohn,
und trägst den Ferman, jagst die schnellen Pferde ?"
Da spricht der Mann : " Ich such' den Köprülü !"
Darauf bemerkt der Greis mit leiser Stimme :
—" Der Vezier Köprülü, der bin ich selber !"
Vom Rosse schwang sich der Tatar des Kaisers
und zog heraus den kaiserlichen Ferman
und übergab ihn Vezier Köprülü.
Der Vezier küsste gleich dreimal den Ferman
und liess ihn nieder auf den grünen Rasen.
Dann nahm er vor mit sich die türk'sche Waschung.
Sonach entfaltet er des Kaisers Ferman
und liest ihn und vergiesst darüber Thränen.

Der Ferman mit dem Namen sagt ihm nämlich:
"O Köprülü, du kaiserlicher Kämpe,
"komm schnellstens nach Istambol in die Stadt!"
Es sprang sofort der Vezier auf die Beine
und gieng zum Schiff hinab mit dem Tataren;
sie setzten sich ins schnelle Schiff hinein.
Der Schiffer gab dem Schiff den schnellsten Lauf.
Sie schifften glücklich über's dicke Meer,
und als sie auf das trock'ne Land gelangten,
so schwangen sie sich auf die feisten Pferde.
Es rennt viel schneller der Tatar des Kaisers,
es rennt ihm nach der Vezier Köprülü,
er rennt und rennt und schreit auf den Tataren:
—"Gemach, gemach, o Idris Hof-Tatare!
o meine Knochen sind im Leib zerbrochen,
und meine Kleidung ist mir auch zerschlissen,
den Dienst versagen mir auch meine Hände,
und beide Füsse sind mir abgefallen,
ich kann mich nicht behaupten mehr, o Sohn!"
Darauf entgegnet der Tatar des Kaisers:
—"Ach tummele dich, o Herr, so Gott dir lieb ist!
wofern mir vierzig Tage Frist verstreichen
und du in Stambol in der Stadt nicht anlangst,
so fliegt von meinem Leib das Haupt herab!"
Drauf sagt zu ihm der Vezier Köprülü:
—"Sei ohne Furcht, o Idris Hof-Tatare,
solange mit dir der Vezier Köprülü!
o Tropf, dich säbelt nicht der Kaiser nieder,
o junger Freund Tatar, schon mir zu Liebe,
und bleibst du aus auch volle hundert Tage!"
So sprachen sie und ritten ihre Rosse,
bis sie nach Stambol in die Stadt gelangten.

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Sobald der Vezier vor den Kaiser hinkam,
so flog er zu des Kaisers Rockschooss hin,
der Kaiser aber fieng ihn bei der Hand:
—"Halt ein, halt ein, du mein getreuer Diener,
du brauchst dich meinem Kleide nicht zu nahen!
mein Vater, als er diese Welt vertauschte,
so liess er einen Gruss bei mir für dich.

Wohl mein ist insgesammt das Kaiserreich,
doch dein ist die Verwaltung in Istambol!
Erobern müssen Erlau wir und Ofen,
dazu Seméndra tieferwärts von Belgrad!
"O Jammer, Herr, drei kaiserliche Städte,
und alle drei in Kafirhand verblieben!"
Drauf tauschte früh' er diese Welt mit jener.
Lass uns des Kaisers Städte drei erobern,
erfüllen wir's aus Liebe für den Toten!"
Der Kaiser zieht heraus das Kaisersigel,
reicht dar das Sigel Köprülü dem Vezier,
dass ihm der Vezier Sigelhüter sei.
Es schlägt das Sigel aus Herr Köprülü;
denn schon dreimal besass er's Kaisersigel,
und hatt' es auch dreimal zurückgestellt.
—"Halt ein, halt ein, o liebster Padischah!
es hält nicht leicht den Blick auf dich zu werfen,
geschweige denn mit dir zu unterreden,
doch heute gilt's ein männlich Wort zu reden.
O Padischah! dein Sigel nehm' ich nimmer,
und nimmer mag ich etwas dir verwalten,
wofern du meinen Willen nicht erfüllst,
den ich, o Kaiser, dir nun sagen werde!"
Darauf zu ihm der Sultan Ibrahîm:
—"O sag's heraus, mein Vezier Köprülü,
nur frisch heraus, was dir am Herzen liegt!"
Da spricht zu ihm Herr Köprülü der Vezier:
—"Willst du Genehmigung mir hier gewähren,
und was du sagst, auch nimmer widerrufen?"
—"So sei's, bei Gott, o Vezier Köprülü,
der Kaiser spricht's,—dem Kaiser ziemt nicht Lüge!"
Da hub der Vezier also an zu sprechen:
—"Gewähr mir freie Hand auf vierzig Tage,
was ich auch tu, dass du's mir nicht verkürzest!"
Er gab ihm freie Hand auf vierzig Tage,
er möge tun, was immer ihm gefalle.

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Nun kehrt zurück der Vezier Köprülü
und ruft herbei den Pascha Seïdi:
—"Wohlan, so führ' mir her der Rufer vier!"

Es kamen hin sogleich der Rufer vier.
Da sagte laut Herr Köprülü zu ihnen:
—" Vier Herolde, so horcht auf meine Worte:
zieht aus und ruft in Stambol in der Stadt:
  " Soviel es immer gibt in Stambol Lalen,
  " soviel als Lalen und soviel Ridžalen,
  " dazu Veziere, Kaiserstellvertreter,
  " vor allen doch der alte Achmedaga,
  " das Oberhaupt von allen den Vezieren,
  " das Alterhaupt von allen den Ridžalen,
  " der höher steht denn alle and'ren Lalen,—
  " in die Moschee des Kaisers, in die alte,
  " in die Moschee, die alte, solt Ihr kommen!
  " Es traf der Kaiser solcher Art Verfügung;
  " denn einen Kriegzug will der Kaiser führen,
  " hier muss er Gold verteilen unter Euch!"
Vier Herolde nun liefen fort behende,
drei weisse Tage lang erscholl ihr Rufen,
sie kamen dann zum Vezier Köprülü:
—" O Köprülü, du alter Kaiserdiener,
in der Moschee, der alten, sind sie alle!"
  Da sprang er auf, der Vezier Köprülü,
und rief zusammen dreissig Henkerknechte
und obenan den Henkerbascha Ibro.
Zu ihm nun sprach der Vezier Köprülü:
—" O Henkeroberhaupt von dreissig Henkern,
so lass uns geh'n zu der Moschee, der alten;
wir bleiben steh'n vor der Moschee, der alten;
wer auch drin weilt in der Moschee, der alten;
und heil aus der Moschee herauskommt, Ibro,
und heil sein Haupt auf seinen Schultern fortträgt,
dann wird dein Haupt dir abgesäbelt, Ibro!
Drum übergeh' in Schonung Niemands Haupt!"
  Sie stiegen zur Moschee, zur alten, nieder.
Aufstellung nahmen dort die dreissig Henker,
an ihrer Spitze Henkerbascha Ibro,
und ihm zur Seite Vezier Köprülü.
  Zur Thüre sandten sie nun einen Herold,
der Herold rief vor der Moschee, der alten:
—" O kommt heraus aus der Moschee, der alten!

Der Kaiser ruft euch aufs Gestade tauïg!"
Es drängten sich die Lalen und Ridžalen
und die Veziere, Kaiserstellvertreter;
Trat wer heraus aus der Moschee, der alten,
flugs stand nicht mehr sein Haupt auf seinen Schultern.
Verlassen hatten alle die Moschee,
nur einer fehlt, der Lala Achmedaga,
der Obristlala aller der Ridžalen,
das Alterhaupt von allen den Vezieren.
Da schrie laut auf der Vezier Köprülü:
—" So geh' hinein denn, Henkerbascha Ibro,
geh' mal hinein in die Moschee, die alte,
heraus mir führ' den Lala Achmedaga!"
Man hört den Lala Achmedaga wimmern:
—" O Henkerhauptmann, sei durch Gott mein Sohn!
o raub mir von den Schultern nicht das Haupt,
dann geh' ich schon vor die Moschee, die alte!"
Darauf entgegnet Henkerhauptmann Ibro:
—" Geh' frohen Mut's, o alter Achmedaga!"
Es schlich heraus der alte Achmedaga,
sein Bart ist weiss und silbergrau sein Haupt,
kein Zahn ist mehr in seinem Mund vorhanden,
auf seinem Kopf ein alter weisser Turban.
Den Säbel schwang der Henkerbascha Ibro,
er schwang den Säbel, schlug ihm ab das Haupt;
es fiel sein Haupt in's grüne Gras hinab
und von dem Haupte fiel herab der Turban.
Am Haupte sieh! die Kreuze und Marien,
Dazu am Haupte Kreuze in Quadraten!
Dem Vezier Köprülü entstürtzten Thränen
und Achmedagas Haupt vom Boden hob er auf:
—" Gedankt sei Gott, der heut'ge Tag gepriesen,
ich sah das Haupt des alten Achmedaga!
Der da, der hat gemacht mich zum Verbannten
durch Ränke bei dem Sultan Suleimân,
weit über's Meer an hundert Lagerrasten,
zwölf Jahre sind seitdem schon hingeflossen!
Der Sultan Suleimân, der ist verschieden,
und hinterblieben Sultan Ibrahîm.
Der Sultan Ibrahîm, der liess mich kommen;

ich werde seinem Vater Dienste leisten,
dem Toten werd' ich eine Lieb' erweisen!"

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Dann lief er hin zum wackersten der Kaiser,
das tote Haupt, das trug er in den Händen
und warf es hin vor Sultan Ibrahîm;
es kollerte ganz nah zum Knie des Kaisers:
—"Hier, Kaiser, schau dir deinen Erzverräter!
dass, Kaiser, ist dir mein geschwor'ner Feind!
Der wehrt uns ab von Erlau und von Ofen
und von Seméndra tieferwärts von Belgrad!
Er war's der mich geschickt in die Verbannung.
So wollt' es Gott, er musst' sein Haupt verlieren!
Nun werd' ich dir mit meinem Rate dienen
und deinem Vater eine Lieb' erweisen.
Schreib', Kaiser, einen Ferman mit dem Namen!"
Da schrieb der Kaiser einen Namenferman.
Noch spricht zu ihm der Vezier Köprülü:
—"O send' ihn ab ins lehm'ge Land der Bosna
nach Sarajevo in die weisse Stadt,
zu Handen Rustanbegs des Glaubenstreiters,
ausheb' er Mann und Ross im Bosnaland!
Und leg's in deinem Ferman ihm ans Herz,
den einz'gen Sohn der Mutter nicht zu nehmen,
ins kaiserliche Heer ihn nicht zu pressen;
auch jenen, der sich kürzlich erst beweibt,
er soll auch solchen Mann in Ruh' belassen;
denn jammerklagend bleiben sonst die Mütter,
und junge Edelfrau'n verbleiben weinend
und fluchen *dir*, o Sultan Ibrahîm
und jenem Mann, der solches angeordnet;
du hast's befohlen, angeordnet ich.
Ein schlimmer Segen könnte heim uns suchen!
Er soll das ganze Bosnaland erheben,
von jedem Dorf je zwei bewehrte Mannen,
von jedem Markt je sieben reis'ge Kämpen.
Dann soll das machtgewalt'ge Heer, o Kaiser,
auszieh'n, o Sultan, unter Temešvar,
dort wo die Save in die Donau mündet

und unterhalb der weissen Stadt von Ofen;
vor allem wollen Ofen wir erobern.
Jetzt aber schreib noch einen andren Ferman,
und lass ihn abgeh'n in das Land des Herzogs
zu Handen Ljubovičs des edlen Begs.
Er soll das ganze Herzogland erheben,
nur nehm' er nicht den einz'gen Sohn der Mutter,
noch jenen, der sich kürzlich erst beweibt;
sonst jammern alle Mütter ach und wehe,
und junge Frauen brechen aus in Thränen
und fluchen dir, dem Kaiser von Istambol,
und jenem Mann, der solches angeordnet;
von dir ist der Befehl, von mir die Weisung;
ein schlimmer Segen könnte heim uns suchen!
Wann er das ganze Herzogland erhebt,
von jedem Dorfe nehm' er je zwei Mannen,
von jedem Markt je sieben reis'ge Kämpen."
Der Kaiser machte nun den Ferman fertig.
Da nahm das Wort der Vezier Köprülü:
—"Geduld ein wenig, Sultan Ibrahîm!
bis ich die zwei Fermane abgesendet,
den einen g'radenwegs ins lehm'ge Bosna
nach Sarajevo in die weisse Stadt,
den and'ren aber in das Herzogland."
Es eilt in das Tatarenheim des Kaisers
der Vezier, rüstet junge zwei Tataren
und sendet ab des Kaisers zwei Fermane.

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Es zogen fort die schnellen zwei Fermane.
Der eine stieg hinab nach Stadt Sarajevo
zu Handen Rustanbegs des Glaubenstreiters.
Er schreibt das Aufgebot ins Bosna Kotland,
doch heischt er nicht nach dem Geheiss des Fermans
von jedem Dorf nur je zwei reis'ge Mannen,
von jedem Markt je sieben reis'ge Kämpen;
er heischt vielmehr nach eigenem Belieben,
von jedem Dorf je sieben reis'ge Mannen,
dazu von jedem Markt je sieben Fähnlein.
Auch bot er auf den einz'gen Sohn der Mutter
und auch den Mann, der jüngst sich erst beweibt.

Der zweite stieg hinab ins Land des Herzogs.
Es bietet auf das Heer Beg Ljubović
und hält sich auch nicht ans Geheiss des Fermans;
er schreibt vielmehr nach eigenem Belieben
und heischt vom Dorf je sieben reis'ge Mannen,
dazu von jedem Markt je sieben Fähnlein.
So bot er auf den einz'gen Sohn der Mutter
und auch den Mann, der kürzlich sich beweibt.

* * *

Dann sprach das Wort der Vezier Köprülü:
—" O hör' mich, Kaiser, hör' mich Padischah, an!
im Bosnaland, ist immerdar ein Notstand
und die Bošnjaken sind bedürft'ge Helden.
Ach, tätst du, Kaiser, meinen Rat befolgen,
entsenden Geld für sie zur Reisezehrung,
dass jeder folgen könnt' im Heereszuge!"
Gleich macht der Kaiser bares Geld bereit,
Maultiere lässt er, Freund, damit beladen
und schickt sie in die Stadt nach Sarajevo
gerad zu Rustanbeg, dem Glaubenstreiter,
dass jeden Helden er damit beteile,
auf dass es jedem möglich sei zu folgen.
Es zogen fort aus Stambol aus der Stadt
nach Sarajevo all' die Maultierlasten.

* * *

An einem Freitag war's. Der Glaubenstreiter
Beg Rustan war in der Moschee und eben
verliess nach dem Gebet er die Moschee,
als zur Moschee die Maultierlasten kamen.
Am ersten hängt die Meldung, fein geschrieben.
Was mag ihm wohl die feine Meldung sagen?
ein Maultier schnaubt das andre Maultier an;
wie's erste vor die Hauptmoschee gelangte,
am End' der Čemaluša stand das letzte.
Es trieb sie fort der Glaubenstreiter Rustan;
dort auf dem Abhang lud er ab die Schätze
und teilte auf dem Abhang aus die Schätze,
beteiligte den letzen gleich dem besten,
doch jeden recht, als wie den eig'nen Bruder.

Dann sprach das Wort der Vezier Köprülü:
—"So lass das Heer uns aus Istambol schicken!"
Fort zog das Heer aus Istambol aus der Stadt
und liess sich nieder unter Temešvar,
dort wo die Save in die Donau mündet.
Wohl unterhalb der weissen Stadt von Ofen,
dort lagerte das Heer zwei volle Monde.
Bald kam auch Rustanbeg der Glaubenstreiter
und brachte mit das ganze wüste Bosna.
Dann harrten sie wohl einen vollen Monat,
bis Ljubović der Beg hinzugestossen
und hingebracht das ganze Herzogland.
Sie flochten für den Kampf die Schutzgeflechte
und pflantzten auf die Räder Feldkartaunen
und schlugen ein den Weg zum weissen Ofen.
Vier Monde lang sie Ofen bombardierten
über die Save und den Donaustrom
und waren nicht im Stand, der Stadt zu schaden,
nicht Kalk, nicht Stein der Mauer abzuschlagen,
geschweige denn den Mauerwall zu brechen,
und wissen gar nicht, wo das Festungtor.
Da sprach Herr Rustanbeg, der Glaubenstreiter:
—"So lasst uns eine Weile hier verweilen
und lasst uns einen Meldungbrief entsenden
nach Stambol in die weissgetünchte Stadt
zu uns'res Kaisers glückumstrahlten Throne,
zu Handen uns'res Sultans Ibrahîm
und seines Grossveziers, des Köprülü!"
Sie folgten Rustanbeg, dem Glaubenstreiter,
und stellten ein der Kriegkanonen Donnern.
Der Beg verfasst den feinen Meldungbrief
und ruft herbei den flinksten der Tataren:
—"Aufs Pferd hinauf, da nimm den Meldungbrief
und trag ihn fort nach Stambol in die Stadt
zum glückumstrahlten kaiserlichen Throne!
Und irr' dich etwa nicht, mein guter Junge,
und überreich' ihn keinem and'ren Manne
als nur allein dem Kaiser in Istambol,
falls nicht zur Hand der Vezier Köprülü;
du wirst schon sehen, was das Briefchen sagt."

Aufs Ross sich schwang der schnelle Feldtatar
und nahm den feinen Meldungbrief entgegen
und floh davon aus Temešvars Gemarkung.
Er jagt den Schlachtenzelter wild und wütig
und jagt mit ihm nach Stambol in die Stadt
zum glückumstrahlten kaiserlichen Throne.
Er steigt vom Pferd herab und nimmt den Brief,
rennt grad zum Throne hin und Reichpalaste,
wo Sultan Ibrahîm im Glanze thront.
Bemerkt hat ihn der Vezier Köprülü,
der eben in des Kaisers Nähe weilte;
der Vezier sprang vom Bolster auf die Beine
und hielt des Kaisers Feldtataren auf:
—"So wart, Tatar, du sollst den Kopf verlieren,
bis ich den wack'ren Kaiser erst befragt,
ob's dir gestattet wird, vor ihn zu treten!
Es wär' doch schad, du stürbst so jung an Jahren!"
Da blieb der Feldtatar des Kaisers stehen.
Dann fragt ihn noch Herr Köprülü der Vezier:
—"Woher des Wegs? aus welchem Orte bist du?"
Und der Tatar, der stand ihm Red' und Antwort:
—"Aus weiter Ferne, unter Temešvar,
allwo die Save in die Donau mündet,
allwo des Kaisers ganzes Heer gelagert
und obenan der Glaubenstreiter Rustan.
Ich bring' da einen feinen Meldungbrief."
Drauf sprach das Wort Herr Köprülü der Vezier:
—"Gib her den feinen Meldungbrief, Tatare!"
Doch spricht zu ihm der schlanke Feldtatare:
—"Mir aus dem Weg, du kaiserlicher Schranze!
dir geb' ich nicht den feinen Meldungbrief,
dem Kaiser nur allein zu eig'nen Handen;
wo nicht, nur einem sicher'n Köprülü!"
Es lachte satt sich Vezier Köprülü,
nahm an der weissen Hand den Feldtataren
und führt' ihn vor den wack'ren Kaiser hin.
Da nimmt den Meldungbrief der Feldtatare
und überreicht ihn Sultan Ibrahîm
und rennt im Saal zurück zur Eingangtüre.
Darauf hub an der Sultan Ibrahîm:

—"O Köprülü, o du mein alter Lala!
so lies mir vor den feinen Meldungbrief!"
Der Vezier Köprülü den Brief betrachtet,
an seiner Seite Kaiser Ibrahîm.
—"Die Unterschrift: 'Beg Rustan Glaubenstreiter,'
er sandte diesen Brief zur Hand des Kaisers.
Das, Kaiser, ist ein feiner Meldungbrief!
"Du wirst die Stadt von Ofen nie erobern.
"Gar nichts vermögen wir der Stadt zu schaden,
"auch wissen wir nicht wo das Stadttor ist,
"das gen die Save führt und gen die Donau."—
Darauf bemerkt der Vezier Köprülü:
—"O hör mich an, du Kaiser von Istambol!
nun muss auch ich mich auf die Wander machen,
auch du, mein Kaiser, musst nun Stambol lassen.
Wir müssen wandern hin nach Temešvar,
damit wir seh'n was unser Heer verrichtet,
ob *wir* im Stande sind, was auszurichten.
Wir müssen, Kaiser, Ofen uns erobern,
und, Kaiser, einen Liebedienst erweisen,
wohl deinem Vater Sultan Suleimân!"
Darauf bemerkt der Sultan Ibrahîm:
—"Wie's immer dir beliebt, so handle, Vezier!
hab' ich's dir nicht schon lang vordem gesagt:
das Kaiserreich ist mein, o guter Freund,
doch die Verwaltung Vezier Köprülüs!
dass Erlau wir erobern und auch Ofen,
dazu Seméndra tieferwärts von Belgrad!"
Da sprang der Vezier hurtig auf die Beine
und rüstete sich in der Stadt Istambol
an seiner Seite Sultan Ibrahîm.
Sie hinterliessen Seïdi, den Pascha,
als Stellvertreter eines wack'ren Kaisers,
und zogen fort von Stambol aus der Stadt.

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So zog des Wegs der Vezier Köprülü
und neben ihm der Sultan Ibrahîm.
Sie stiegen nieder unter Temešvar,
allwo die Save in die Donau mündet,

allwo das türk'sche Heer im Lager stand,
an seiner Spitze Rustan, Glaubenstreiter,
aus Sarajevo aus der weissen Stadt,
als Unterfeldherr Ljubović der Beg,
der mitten aus dem Herzoglande stammt.
Und Heerschau hält der Kaiser von Istambol;
vier Lager bildete die ganze Heermacht.
Da stellt die Frage Sultan Ibrahîm:
—"O Köprülü, du mein getreuer Diener,
aus welchem Land ist jedes einz'lne Heer?"
Bescheid erteilt ihm Köprülü der Vezier.
Es spricht zu ihm der Sultan Ibrahîm:
—"Aus welchem Land ist jenes mächt'ge Heer,
dess' Volk mit Silber und mit Gold beladen,
dess' Rosse reich mit Goldgeschmeid beladen?"
Darauf bemerkt der Vezier Köprülü:
—"Das ist das Aufgebot des eb'nen Bosna,
dort sind allein dir alle die Bošnjaken."
Da sagt ein Wort der Sultan Ibrahîm:
—"O Köprülü, du mein getreuer Lala,
wohl steht nicht alles so, wie du mir's darstellst!"
Darauf betroffen Köprülü der Vezier:
—"Was meinst du, Kaiser, sprich, so lieb dir Gott ist!"
—"Du schilderst mir das Bosnaland als lehmig
und die Bošnjaken als bedürft'ge Helden;
nun schau, die sind mit Goldgeschmeid beladen,
und schau die Rosse, silberreich beladen!"
Darauf bemerkt der Vezier Köprülü:
—"O hör' mich, Kaiser, an, was ich nun sage!
das ist ein leid'ger Brauch im Bosnavolk.
Wo einer was besass, er hat's verschachert
und gleich mit Gold und Silber sich behangen
und unterm Leib ein Ross sich angeschafft,
damit er, wann es gilt, ins Heer zu rücken,
wenn's Not tut deine Ehre hoch zu halten,
gleich ausgerüstet seinen Mann die Stelle.
Stiegst du hinab ins ebne Bosnaland,
wo ihre Mütter sie zurückgelassen,
der seine Mutter, *der* die junge Schwester,
und mancher, Kaiser, sein getreues Eh'lieb;

da sähst du erst wie ihre Häuser ausschau'n !
Mit Zaunwerk sind sie ringsherum umflochten
und obenauf mit Stroh bedeckt ein wenig;
da fehlt's an Kupfer—und an Holzgeschirr,
man isst vielmehr aus irdenen Gefässen !"
Darauf bemerkt der Sultan Ibrahîm:
—"Was fangen wir nun an mit unserm Leben?
wie werden wir die Ofner Stadt bestürmen?"
Darauf erwidert Köprülü der Vezier:
—"So wart' ein wenig, Kaiser von Istambol !"
Nun sucht er auf zwei junge Heeresrufer,
sie rufen aus nach allen Himmelstrichen:
—"Wer wird als Held im Heere sich bewähren,
wer kann die Donau und die Sau durchschwimmen,
um bis zur Ofner Festung hinzukommen,
und wo der Festung Tor ist, zu erkunden?"
So riefen aus die beiden jungen Rufer;
ihr Rufen hallte zwei geschlag'ne Stunden,
doch mochte Niemand zum Bescheid sich melden.
Da sprach ein Wort Herr Ljubović der Beg,
der nach dem Herzoglande sich benennt:
—"O Köprülü, o teuerster Gebieter !
ich will die Donau und die Sau durchschwimmen
und unserm Kaiser einen Dienst erweisen,
und kehrt' ich nun und nimmermehr zurück !"
Schon wirft er ab von seinem Leib die Kleidung.
Er stürzt sich in den dicken Savestrom,
durchschwimmt die Save, lenkt zur Donau ein.
Just war er in des Savestromes Mitte,
als ihm gar Wundersames dort begegnet:
ein seltsam Mädchen sass im Savewasser,
die Save abwärts streckt' sie ihre Beine,
sie hält auf ihrem Schooss ein Stickgestelle,
darüber hat sie aufgespannt ein Linnen.
Und sie erschaute Ljubović den Beg,
erschaut' ihn wohl und sprach zu ihm das Wort:
—"Wohin des Weges, Ljubović, o Beg?
hat dich der Kaiser gar geschickt nach Ofen,
wohl um das Ofner Burgtor auszukunden?
So kehr' nur um, du sollst den Kopf verlieren !

den Savestrom, den kannst du nicht durchschwimmen,
den raschen Savestrom, die breite Donau!
Kehr ruhig wieder um zum wack'ren Kaiser,
bei ihm verweilt der Vezier Köprülü.
Bring meinen Gruss dem Vezier Köprülü;
verbringt die liebe Nacht auf freiem Felde
und seid gerüstet früh beim Morgenanbruch.
Darauf berate Köprülü den Vezier,
er soll's gesammte Kaiserheer erheben,
ein jeder nehm' die türk'sche Waschung vor,
vor allen ander'n Sultan Ibrahîm
und gleich nach ihm der Vezier Köprülü;
verrichtet Morgens früh die Morgenbeugung.
Und nach dem Frühgebet der Morgenbeugung
aufs weisse Ofen richtet eu'ren Blick,
da werdet Ihr das Ofner Tor erschauen,
und leichter Müh' die Ofner Stadt erobern!"
Beg Ljubović, der schaut die Maid verwundert,
aus Gold die Hände bis zum Ellenbogen,
und goldig wallt das Haar herab den Nacken.
Im Nu verschwand auch schon das holde Mädchen!
Der Beg geriet gar mächtig in Verwundrung,
auf was für Wunder er da aufgestossen,
und machte Umkehr auf der eb'nen Save.
Als er herauskam unter Temešvar,
was spricht zu ihm der Vezier Köprülü?
—"Schon dort gewesen, Ljubović, o Beg?
hast gar so schnell die Save durchgeschwommen?"
Da nun erzählt der Beg sein Abenteuer,
welch wundersam Gebild er angetroffen.

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So blieb denn hier zu Nacht das Heer gewaltig
und war schon auf den Beinen früh am Morgen.
Sogleich erhob sich Vezier Köprülü.
Das türk'sche Heer, das nahm die Waschung vor,
Allen voran der Sultan Ibrahîm,
und gleich nach ihm der Vezier Köprülü,
und alle beugten sich zur Morgenandacht.
Nachdem die Beugung sie verrichtet hatten,

da schaut hinüber Vezier Köprülü
und er erschaut das Tor der Ofner Festung,
die beiden Flügel angelweit geöffnet!
Da ruft nun aus der Vezier Köprülü:
—"Dort, Kaiser, schau dir an die Ofner Tore!"
Losstürmte nun das allgewalt'ge Heer
und nahm sofort die Ofnerstadt des Kaisers.

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Drauf setzten sie die Heermacht in Bewegung,
zwölf Stunden führt der Weg zum eb'nen Erlau.
Die Türken stürmten los nunmehr auf Erlau.
Bei Gott, das Christenheer empfieng sie warm!
Allhier entspann sich bald ein blutig Ringen,
und sieben Stunden währt das Schlachtgemetzel.
Es klang in einem fort der krumme Säbel,
die langen Täler füllten sich mit Blut!
Als letzt die Türken Erlau eingenommen,
da hatten sie auch Leichen viel gelassen!
Von hier erhob sich dann das Heer der Türken
und stieg hernieder tieferwärts von Belgrad.
Sie griffen an die alte Stadt Seméndra,
—die Christen hatten sie zuletzt erobert,
bevor sie Erlau und auch Ofen hatten,
und sie mit bestem Mauerwall umgeben.—
Sie wehren sich von vier bewehrten Seiten,
und von Seméndra dröhnen die Kanonen.
Daselbst erfuhr das Heer ein wenig Schaden;
vier Tage lang auch dauerte das Kämpfen.
Hier ward verwundet Ljubović der Beg,
Man trug zu Grabe alle Türkenleichen,
und auch Seméndra nahmen ein die Türken.
Von hier erhob sich dann das Heer der Türken,
voraus als Führer Sultan Ibrahîm
und hinter ihm der Vezier Köprülü,
ihm folgt Herr Rustanbeg der Glaubenstreiter,
in gleicher Reih' mit ihm Beg Ljubović.
So stiegen sie hinab zum eb'nen Stambol,
zum Thron des Kaisers und zum Reichpalast.
Daselbst verweilten sie wohl einen Monat,

entliessen allwärts hin das Heer der Türken,
bezeigten ihre Lieb dem toten Kaiser,
dem toten Kaiser Sultan Suleimân.

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Dann spricht das Wort der Sultan Ibrahîm:
—"O Ljubović aus meinem Herzoglande!
da nimm das ganze Herzogland entgegen;
ich werde nichts von dir an Steuer nehmen,
nicht einen weissen Heller noch Denar,
nur kurze Zeit hindurch, zwölf volle Jahre!"
Darauf zu Rustanbeg, dem Glaubenstreiter:
—"O Glaubenshort vom eb'nen Sarajevo!
zieh' heimwärts, Aermster, in die Stadt Sarajevo;
du hast ein neues Gotteshaus erbaut,
doch ich bezahle, was du ausgegeben.
Soviel als in Sarajevo Gotteshäuser,
dir sei die Oberaufsicht über jedes,
vom Kirchengut der Stadt von Sarajevo,
dass keine Steuern du entrichten magst
wohl nach Istambol in die weisse Stadt,
so lang in Türkenhand das Bosnaland!"

Und spricht zu Vezier Köprülü gewendet:
—"Ja, Vezier, o du mein getreuer Lala,
mit was für Gabe soll ich dich bedenken?"
Darauf erwidert Vezier Köprülü:
—"Was willst du, liebster Sultan Ibrahîm?"
Darauf entgegnet Sultan Ibrahîm:
—"Zieh g'raden Wegs ins lehm'ge Bosnaland
und in die weissgetünchte Stadt von Travnik,
dort sei im Bosnaland mein Landesvogt!"
Zum weissen Travnik wandert hin der Vezier,
der Glaubenstreiter in die Stadt Sarajevo
und heim ins Herzogland Beg Ljubović;
in seinem Reichpalast der Kaiser blieb.

Erläuterungen.

Zu V. 1. Die Volküberlieferung knüpft auch hier, wie sonst öfter, an den ruhmreichen Namen Suleimân II. an (1520–1566), unter dessen Regierung die türkische Machtentwicklung ihren Höhepunkt erreicht hatte. Sultan Ibrahîms Vorgänger auf dem Throne war Murad IV. und Nachfolger Mohammed IV.

V. 23. *Lalen und Ridžalen.*—*Lala* türk. Diener. Als Lehnwort auch bei den Bulgaren, Polen und Russen. Im serbischen nur für "Kaiserliche Diener," so z. B. (der Sultan spricht):

lalo moja, muhur sahibija,
što mi zemlje i gradove čuvaš!

O du mein Diener, du mein Sigelwahrer,
der du mein Stadt und Land mir wohl behütest!

oder:

Divan čini care u Stambola
za tri petka i tri ponediljka;
sva gospadu sebi pokupio,
okupio paše i vezire:
—Lale moje, paše i veziri!

Divân beruft der Kaiser ein in Stambol
dreimal je Freitags und dreimal je Montags;
berief zu sich die Herren allzumal,
berief die Paschen und Vezieren ein:
—O meine Lalen, Paschen und Veziere!

Ridžal arab. türk. Reisiger, übertrager: hoher Würdenträger zum *redžal;* albanesisch: *ridžal,* Advokat, griech. *rhitzali.*

V. 25 u. 33. *Neun erwählte Frauen.*—"Von den Frauen des Sultans Ibrahîm führten sieben den Titel Chasseki, d. i. der innigsten Günstlinginnen, bis zuletzt die achte, die berühmte Telli, d. i. die Drahtige, ihm gar als Gemahlin vor allen angetraut ward. Eine andere hiess Ssadschbaghli, d. i. die mit den aufgebundenen Haaren. Jede dieser sieben innigsten Günstlinginnen hatte ihren Hofstaat, ihre Kiaja, die Einkünfte eines Sandschalks als Pantoffelgeld, jede hatte einen vergoldeten, mit Edelsteinen besetzten Wagen, Nachen und Reitzeug. Ausser den Sultaninnen Günstlinginnen hatte er Sklavinnen Günstlinginnen, deren zwei berühmteste die Schekerpara, d. i. Zuckerstück und Schekerbuli, d. i. Zuckerbulle hiess; jene ward verheiratet, diese aber stand zu hoch in der Gunst, um je verheiratet zu werden. Die Sultaninnen Günstlingnnen erhielten Statthalterschaften zu ihrem Pantoffelgeld, die

Schützlinginnen Sklavinnen hatten sich die höchsten Staatämter vorbehalten." I. von Hammer-Purgstall, *Geschichte des Osmanischen Reiches*, Pressburg, 1835, V, S. 255f.

Zu V. 37. *Kafirhänden.* Im Texte: u Kaurina, türk. *gjaur, gjavir*, aus dem arab. *ci Kafir*, pers. *gebr*, der Ungläubige.

V. 38–39. Die Nennung dieser drei Städtenamen, sowie späterhin Temešvars hier eine dichterische Freiheit. Die Eroberung von Erlau (Egra) und Kanísza bilden Glanzpunkte der Regierung Mohammed III. (verstorben 22. Dezember 1603). Ueber Erlau vergl. Franz Salamon, *Ungarn im Zeitalter der Türkenherrschaft* (deutsch v. Gustav Turány), Leipzig, 1887, S. 125f. u. besonders S. 138ff.—Die Einnahme Ofens erfolgte im J. 1541. Soliman, der 1526 Ofen nicht besetzten wollte, nimmt es 1541 endgiltig in seine Hand. Im J. 1543 setzte er seine Eroberungen fort. Der Sultan nahm zuerst die Burgen Valpó, Siklós und Fünfkirchen, darauf Stuhlweissenburg und Gran. Bis 1547 gehörte den Türken Peterwardein, Požega, Valpó, Essegg, Fünfkirchen, Siklós, Szegszárd, Ofen, Pest, Stuhlweissenburg, Simontonnya, Višegrad, Gran, Waitzen, Neograd und Hatvan; jenseits der Theiss nur das einzige Szegedin, das sich im Winter 1542 freiwillig ergeben und als türkischer Besitz isolirt dastand.—Semendria (Szendrö) versuchten die Türken im J. 1437 einzunehmen, um sich den wichtigen an der Donau gelegenen Schlüsel des Morava-Tales zu sichern, aber das ungarische Heer unter Pongraz Szentmiklósi errang einen glänzenden Sieg über sie. Als sich 1459 die Festung Semendria an Mohammed II. ergab, gelangten zugleich zahlreichere kleinere Festungen in seine Gewalt. Serbien wurde zum Sandžak, und der Türke siedelte an Stelle der massenhaft in die Sklaverei geschleppten Einwohner, Osmanen in die Städte und führte daselbst seine Verwaltung ein. 1466 als König Mathias beschäftigt war in Oberungarn einige Aufrührer zur Ruhe zu bringen, lässt ein türkischer Pascha seine Truppen in Serbien einrücken und nimmt durch Ueberrumpelung die Festung Semendria. Vergl. Dr. Wilhelm Fraknói, *Mathias Corvinus, König von Ungarn*, Freib. i. Br., 1891, S. 70ff.

Zu V. 59. "*Verschliess dich in den festen Käfig.*"—"Als nach Murads Verscheiden der Hofbedienten Schaar mit Freudengeschrei an die Thüre des Käfigs, d. i. des Prinzengemaches drang, um den neuen Herrn glückwünschend auf den Thron zu ziehen, verrammelte Ibrahîm die Thür, aus Furcht, dass dies nur List des noch atmenden Tyrannen Murad sei, um ihn, den einzigen überlebenden

Bruder so sicher ins Grab voraus zu schicken. Mit ehrfurchtvoller Gewalt wurde die Thür erbrochen, und noch immer weigerte sich Ibrahîm der Freudenkunde Glauben beizumessen, bis die Sultanin-Mutter Kösem (eine Griechin) selber ihn von des Sultans Tod versicherte und ihre Versicherung durch den vor die Thür des Käfigs gebrachten Leichnam bestätigte. Da begab sich erst Ibrahîm aus dem Käfig in den Thronsal, empfieng die Huldigung der Veziere, Reichsäulen, Ulema und Aga, trug dann mit den Vezieren des Bruders Leiche selber bis ans Tor des Serai und ward hierauf nach altem Herkommen osmanischer Thronbesitznahme zu Ejub feierlich umgürtet." Bei J. v. Hammer, a. a. O., V, S. 215f., unter Berufung auf Rycauts *Continuation of Knolles II*, p. 50. Die neu eröffnete otomanische Pforte t. 458.

Zu V. 75ff. Am neunten Tage nach der Thronbesteigung fand die Umgürtung des Säbels in der Moschee Ejub in den durch das Gesetzbuch des Ceremoniels vorgeschriebenen Formen des Aufzuges und der Feierlichkeiten statt. Mit Sonnenaufgang versammelten sich alle Klassen der Staatbeamten im ersten Hofe des Serai. Die ausführliche Schilderung siehe bei Hammer, a. a. O., IV², S. 499–450.

Zu V. 76. "*Goldne Mütze.*"—Im Texte *tadža.* Sultan Bajezid I. (gestorb. 1403) trug als Turban weder die Goldhaube (uskuf) der ersten sechs Sultane, noch den vom siebenten angenommenen runden Kopfbund der Ulema (urf), sondern nahm den hohen, cylinderförmigen, mit Musselin umwundenen an, der sofort unter dem Namen Mudževese (tadža) der Hof- und Staatturban geblieben.

Zu V. 80f. Die ersten Säulen des Reiches und Stützen des Divans sind die Veziere, d. h. die Lastträger. Es gab ihrer unter Ibrahîm schon vier. Die Vierzahl gibt als eine dem Morgenländer beliebte und heilige Grundzahl den Teilunggrund der ersten Staatämter ab. Vier Säulen stüzen das Zelt, vier Engel sind nach dem Koran die Träger des Thrones, vier Winde regieren die Regionen der Luft nach den vier Kardinalpunkten des Himmels, u.s.w. Aus diesem Grunde setzte Sultan Mohammed der Eroberer, vier Säulen oder Stützen des Reiches (erkiani devlet) fest in den Vezieren, in den Kadiaskeren, in den Defterdaren und in den Nišandži, die zugleich die vier Säulen des Divans, d. h. des Staatrates sind. Anfangs war nur ein Vezier, dann zwei, dann drei unter den ersten Sultanen; der Eroberer erhob ihre Zahl auf vier, deren erster und allen überigen an Macht und Rang bei weitem vorhergehende, der Grossvezier wurde, der unumschränkte Bevollmächtigte, das sichtbare Ebenbild des Sultans, sein vollgewaltiger Stellvertreter, der oberste Vorsteher aller Zweige der Staatverwaltung, der Mittelpunkt und der Hebel der ganzen Regierung.

Zu V. 81. "*Sigelhüter*" (muhur sahibija). — Der Kanun des Sigels (nach Sultan Mohammed II.) überträgt dem Grossvezier darüber die Obhut, als das Symbol der höchsten Vollmacht; in der Ueberreichung des Sigels liegt auch die Verleihung der höchsten Würde des Reiches. Der Grossvezier darf sich (abgesehen von der Versigelung der Schatzkammer, die, beiläufig bemerkt, nur in Gegenwart der Defterdare geöffnet werden kann) dieses Sigels nur zur Besiglung der Vorträge bedienen, und da alle Vorträge durch die Hand des Grossveziers gehen müssen, und Niemand als er das Recht hat, an den Sultan schriftlich zu berichten, so sieht der Letztere kein anderes Sigel als sein eigenes oder etwa das der fremden Monarchen, wenn deren Gesandte ihre Beglaubigungschreiben in feierlicher Audienz überreichen.

Zu V. 82. "*Pascha Seidi.*"—Ueber Achmed Sidi, Köprülüs Schwager, die Geissel Siebenbürgens, Pascha von Neuhäusel, vergl. Hammer, a. a. O., VI, S. 272. Wird in den Epen moslimischer Guslaren häufig auch als ein Heiliger genannt und gerühmt. In einem Guslarenliede heisst es:

efendija muhur sahibija
sa svojijem pašom Seidijom,
što je paša na četeres paša.

[Erschienen war] Efendi Sigelhüter
zugleich mit ihm sein Pascha Seïdi,
der Obrist Pascha über vierzig Paschen.

Zu V. 93ff. Im J. 1696 war Mohammed mit dem wunden Halse Grossvezier.

"Am 10. September 1696 fand ein Divan statt. Der Sultan sagte zum Grossvezier: 'Ich will selbst in den Krieg ziehen, du musst durchaus für die nötige Rüstung sorgen!' Der hilflose Greis faltete die Hände, als ob er die ganze Versammlung um Hilfe anflehte und sagte: 'Glorreichster, gnädigster Padischah, Gott gebe euch langes Leben und lange Regierung! bei der herrschenden Verwirrung und dem Mangel an Kriegszucht ist es schwer, Krieg zu führen; zur Möglichkeit der nötigen Rüstungen ist von Seite des Reichsschatzes eine Hilfe von zwanzig tausendB euteln notwendig!' Der Sultan schwieg zornig und hob die Versammlung auf." Hammer, V, 461.

"Schon bei der ersten Unzufriedenheit nach der Einnahme von Tenedos und Lemnos hatten der Chasnedar der Walide, Ssolak Mohammed, der Lehrer des Serai, Mohammed Efendi, der vorige Reis Efendi Schamisade und der Baumeister Kasim, welcher schon ein paarmal den alten Köprüli zum Grossvezier in Vorschlag gebracht, sich insgeheim verbündet, diesem das Reichssigel zu verschaffen. Der Grossvezier hatte ihn auf seiner Reise von Syrien nach Konstantinopel zu Eskischehr wohl empfangen und nach Konstantinopel mitgenommen, wo er dermalen sich ruhig verhielt; sobald er aber durch den Silihdar des Sultans Wind von dem Vorschlage erhalten, ernannte er den Köprüli zum Pascha von Tripolis, und befahl ihm sogleich aufzubrechen. Der Kiaja, ins Vertrauen der Freunde Köprülis gezogen, suchte vergebens den Reisebefehl zu verzögern. Da die Sache noch nicht reif zum Schlag war, brachten die Freunde Köprülis durch die Walide sehr geschickt die Ernennung des Silihdars zum Statthalter von Damaskus und die Einberufung des dortigen Wesiers Chasseki Mohammed zuwegen, wodurch das allgemeine Gerede entstand, dass dieser zum Grossvezier bestimmt sei, und die Aufmerksamkeit des Grossveziers von Köprüli abgelenkt ward. Der Silihdar, der Patron des Grossveziers beim Sultan, war entfernt, aber noch stand den Freunden Köprülis ein anderer mächtiger Feind desselben, der Janičarenaga im Wege. Sobald derselbe abgesetzt und an seine Stelle der Stallmeister Sohrab, ein Freund der Freunde Köprülis ernannt war, erklärte sich dieser gegen dieselben, dass er einige Punkte der Walide vorzutragen, nach deren Zusage er die Last der Regierung auf seine Schultern zu nehmen bereit sei. Noch am selben Nachmittage wurde Köprüli heimlich vom Kislaraga zur Walide eingeführt, und antwortete auf ihre Frage, ob er dem ihm bestimmten Dienst als Grossvezier zu versehen sich nicht fürchte, mit dem Begehren folgender vier Punkte: erstens, dass jeder seiner Vorschläge genehmigt werde; zweitens, dass er in der Verleihung der Aemter freie Hand und auf die Fürbitte von Niemand zu achten habe: die Schwächen entständen aus Fürsprechen; drittens, dass kein Vezier und kein Grosser, kein Vertrauter, sei es durch Einfluss von Geldmacht oder geschenktem Vertrauen, seinem Ansehen eingreife; viertens, dass keine

Verschwärzung seiner Person angehört werde; würden diese vier Punkte zugesagt, werde er mit Gottes Hilfe und dem Segen der Walide die Wesirschaft übernehmen. Die Walide war zufrieden und beschwur ihre Zusage dreimal mit: 'Bei Gott dem Allerhöchsten!' Am folgenden Tage (15. September 1656), zwei Stunden vor dem Freitagsgebete, wurden der Grossvezier und Köprüli ins Serai geladen. Dem Grossvezier wurde nach einigen Vorwürfen über den Mangel seiner Verwaltung das Sigel abgenommen und er dem Boslandžibaschi zur Haft überlassen, dann Köprüli in den Thronsal berufen. Der Sultan wiederholte die vier versprochenen Punkte, einen nach dem andern und sagte: 'Unter diesen Bedingnissen mache ich dich zu meinem unumschränkten Vezier; ich werde sehen, wie du dienst; meine besten Wünsche sind mit dir!' Köprüli küsste die Erde und dankte; grosse Thränen rollten den Silberbart herunter; der Hofastronom hatte als den glücklichsten Zeitpunkt der Verleihung das Mittagsgebet vom Freitage bestimmt, eben ertönte von den Minareten der Ausruf: 'Gott ist gross!'" Hammer, a. a. O., V, S. 462, 2te Aufl.

Zu V. 170. Dem abgesetzten Grossvezier Mohammed mit dem wunden Halse, dem neunzigjährigen Greise, wurde nach Einziehung seiner Güter, dass nach dem Ausspruche des Sultans verwirkte Leben auf Köprülüs Fürbitte geschenkt und ihm zur Fristung des schwachen Restes seines Lebens die Statthalterschaft von Kanisza verliehen. Hammer, V, S. 467.

Zu V. 360ff. Ganz erfunden ist diese Episode nicht. Hammer berichtet B. V, S. 467ff.:

"Acht Tage nachdem Köprüli das Reichsigel erhalten, Freitag den 22. September 1656, versammelten sich in der Moschee S. Mohammeds die fanatischen Anhänger Kasisades, die strengen Orthodoxen, welche unter dem alten Köprüli, den sie für einen ohnmächtigen Greis hielten, ihrer Verfolgungswut wider die Ssoffi und Derwische, Walzer- und Flötenspieler, um so freieren Lauf zu geben hofften. Sie beratschlagten in der Moschee und fassten den Entschluss, alle Klöster der Derwische mit fliegenden Haaren und kronenförmigen Kopfbinden von Grund aus zu zerstören, sie zur Erneuerung des Glaubensbekenntnisses zu zwingen, die sich dess weigerten zu töten, u.s.w. In der Nacht war die ganze Stadt in Bewegung; die Studenten der verschiedenen Collegien, welchen orthodoxe Rectoren und Professoren vorstanden, bewaffneten sich mit Prügeln und Messern und fiengen schon an die Gegner zu bedrohen. Sobald der Grossvezier hievon Kunde erhalten, sandte er an die Prediger Scheiche, welche die Anstifter der Unruhen zur Ruhe bewegen sollten; da aber dies nicht fruchtete, erstattete er Vortrag an den Sultan über die Notwendigkeit ihrer Vernichtung. Die sogleich dem vortraggemässe allerhöchste Entschliessung des Todesurteils wurde von Köprüli in Varbannung gemildert."

Zu V. 371. "*Der alte Achmedaga.*"—In der türkischen Geschichte heisst er Achmedpascha Heberpascha, d. h. der in tausend Stücke Zerrissene (Hammer, III, S. 930). Nach Hammer, B. III, S. 930, fiel tatsächlich ein Grossvezier des Namens Achmedpascha durch Henkershand am Vorabende der Thronstürzung Sultan Ibrahîms. Es war am Abend des 7. August 1648. Kaum hatte der abgesetzte Grossvezier Ahmedpascha einzuschlafen versucht, als er mit der Botschaft geweckt ward, er möge sich aufmachen, die aufrührischen Truppen verlangten ihn und er, der Grossvezier möge als Mittler versöhnend dazwischen treten. Als er die Stiege hinunter gekommen, griff ihm jemand unter die Arme. Er sah sich um, wer es sei und sah vor sich Kara Ali, den Henker, den er so oft gebraucht. "Ei, ungläubiger Hurensohn!" redete er ihn an. "Ei, gnädiger Herr!" erwiderte der Henker, ihm lächelnd die Brust küssend; unter die Linke Ahmedpaschas griff Hamal Ali, des Henkers Gehilfe. Sie führten ihn zum Stadttor, dort zog der Henker seine rote Haube vom Kopfe und steckte sie in seinen Gürtel, nahm dem Ahmedpascha seinen Kopfbund ab, warf ihm den Strick um den Hals und zog denselben mit seinem Gehilfen zusammen, ohne dass der Unglückliche etwas anderes als: "Ei, du Hurensohn!" vorbringen konnte. Der ausgezogene Leichnam wurde auf ein Pferd geladen und auf des neuen Grossveziers Sofi Mohammed Befehl auf den Hippodrom geworfen.

Zu V. 392. "*Kreuze und Marien.*"—Im Texte Križi i maiži. Kreuzchen und Marienmedaillen, wie solche im Haare von Christen jener Zeit getragen wurden. Eine anschauliche Beschreibung gibt uns eine Stelle in einem noch ungedruckten Guslarenliede meiner Sammlung. Halil, der Falke, ist entschlossen, an einem Wettrennen im christlichen Gebiete teilzunehmen, um den ausgesetzten Preis, ein Mädchen von gefeierter Schönheit, davonzutragen. Seine Schwägerin, Mustapha Hasenschartes Gemahlin, hilft ihm bei der Verkleidung zu einem christlichen Ritter, wie folgt:

ondar mu je sa glave fesić oborila
i rasturi mu turu ot perčina
i prepati češalj ot fildiša
te mu raščešlja turu ot perčina
a oplete sedam pletenica
a uplete mu sedam medunjica
a uplete mu križe i maiže
a uplete mu krste četvrtake
a šavku mu podiže na glavu
a pokovata grošom i tal'jeron
a potkićena zolotom bijelom.

Vom Haupte sie warf ihm das Fezlein herab
und löste den Bund des Zopfes ihm auf
und griff nach dem Kamm aus Elfenbein
und kämmte den Bund des Zopfes ihm auf
und flocht ihm sieben Flechten das Haar
und flocht ihm sieben Medaillen hinein
Und flocht ihm Kreuze hinein und Marien
und flocht ihm hinein quadratige Kreuze
und stülpte den Helm ihm auf das Haupt,
der beschlagen mit Groschen und Talerstücken,
der geschmückt mit weissen Münzen.

So wie hier Halil als Christ auftritt, so ist der als Moslim verkappte Christ eine stehende Figur des Guslarenliedes. Christ und Moslim sind in der angenommenen Rolle einander wert und würdig.

Zu V. 447. Ljubović, der berühmteste moslimische Held des Herzogtums, eine stehende Figur der Guslarenlieder beider Confessionen. Mustapha Hasenscharte schreibt einmal ein Aufgebot aus. Der Brief zu Handen des Freundes Šarić:

O turćine Šarić Mahmudaga!
Eto tebi Knjige našarane!
Pokupi mi od Mostara turke,
ne ostavi bega Ljubovića
sa široka polja Nevesinja,
jer brež njega vojevanja nejma.
O [Bruder] Türke Šarić Mahmudaga!

Da kommt zu dir ein Schreiben zierlich fein!
Von Mostar biet mir auf die Türkenmannen,
lass nicht zurück den Beg, den Ljubović,
vom weitgestreckten Nevesinjgefilde;
denn ohne seiner gibt es keinen Feldzug.

Als Jüngling meldete sich Beg Ljubović einmal bei Sil Osmanbeg, dem Pascha von Essegg, als freiwilliger Kundschafter, um durchs feindliche Belagerungheer durchzudringen und dem Pascha von Ofen Nachricht von der Bedrängnis der Stadt Essegg zu überbringen. Sil Osmanbeg umarmt und küsst ihn und schlägt ihm mit der flachen Hand auf die Schulter:

Haj aferim beže Ljuboviću!
vuk od vuka, hajduk od hajduka
a vazda je soko ot sokola;
vazda su se sokolovi legli
u odžaku bega Ljubovića!

Hei traun, fürwahr, mein Beg, du Ljubović!
Vom Wolf ein Wolf, vom Räuber stammt ein Räuber,
doch stets entspross ein Falke nur dem Falken;
und immer fand sich vor die Falkenbrut
am heimischen Herd des Ljubović, des Beg!

Zu V. 678. Die Schilderung naturgetreu. Auf meinen Reisen zog ich es mitunter vor in eine Rossdecke eingehüllt unterm freien Himmel selbst zu Winterzeit zu übernachten, als im Schmutz und Ungeziefer und Gestank einer bosnischen Bauernhütte. Auch meine Aufzeichnungen machte ich meist im Freien im Hofraume oder an der Strasse sitzend. Ich fragte den Bauer Mujo Šeferović aus Šepak, einen recht tüchtigen Guslaren, ob er wohl ein eigenes Heim besitze. Darauf er: imam nešto malo Kuće, Krovnjak (ich besitze ein klein Stückchen Haus, eine Bedachung). Neugierig, wie ich schon bin, gieng ich zu ihm ins Gebirge hinauf, um mir seine Behausung anzuschauen, eigentlich in der Hoffnung, bei ihm meinen Hunger zu stillen. Ein hohes, mit verfaultem Stroh bedecktes Dach, und statt der Wände aus Stein oder Ziegeln ein mit Lehm beschmiertes Reisergeflechte! Brod und Fleisch fehlte im lieblichen Heime. Durch meinen Besuch fühlte er und seine

Familie sich aufs Aeusserste geehrt und geschmeichelt. Die Hausfrau, die nicht zum Vorschein kam, sandte mir mit ihrem Söhnchen einen Bohnenkäse und eingesäuerte Paprika hinaus. Als Getränk Kaffeeabsud und Honigwasser.

Zu V. 707ff. Das seltsame Mädchen ist als die Sreča, d. h. fortuna Köprülüs aufzufassen. Vergl. meine Studie, *Sreća. Glück und Schicksal im Volkglauben der Südslaven,* Wien, 1887.

Zu V. 821. Zwei Köprülü waren Veziere (Vali) zu Bosnien: Köprülüzade Numan, der Sohn des Grossveziers 1126 (1714) und Köprülüzade Hadži Mehmed 1161 (1748); zum zweitenmale derselbe 1179 (1765). Der erste Köprülü war natürlich nie bosnischer Gouverneur, nur der Guslar erhebt ihn zu diesem nach seinen bäuerlichen Begriffen ausserordentlichen Ehren- und Würdenstellung.

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*Gshicht fun dä al'tä tsai'tä in Pensilfâni.**

By W. J. Hoffman, M.D.

Di num'mer fun men'sha in Pensilfâni das fun dä ärsh'tä dai'tshä ai[n] sīd'lär här shtam'mä, tsē'lä aläwail' kshwi'shä acht hun'rt dau'send un a[n] milyân', a'wer wī fīl fun den'nä wis'sä was fer tsai'tä das di al'tä lait als kat hen, wi si arsht a[n] kum'mä sin in dem landt far sich en hē'met tsä mach'ä. Far en fol'li gshicht tse shrai'wä dēts me[n] plats uf nem'mä das mer nem'mä därf an so'erä tsait, wī mīr aläwail' un'ser hun'rt un fuf'tsichsht yōres'fesht fai'ärä und wū noch fīl an'ärä â eb'bäs tsä sâ'ghä hen.

Mer wis'sa tsim'lich al das di arsh'tä wai'sä lait in dem shtâdt di Shwē'dä wâ'rä. Dī hen sich shun gset'l'd kat uf der Del'awer im yōr 1638, un wâ'rä därt bis 1655, wi di Hō'lender si raus gedri'wä hen, un dī sin sel'wer raus gepush't war'rä nain yōr shpē'ter, bai dä Eñg'lisha. Wi der Penn kum'ma is in 1682, wâ'rä shun Dai'tshä dabai', un di mensh'ta fun den'na hen sich ni'dter gset'l'd am a plats wu Gär'mendaun [Germantown] nau is.

'Snēksht yōr sin pâr mē[n] Dai'tsha rai[n] kum'ma, un so wid'der yē'der yōr bis 1708, und fun sel'ärä tsait â[n] bis 1720, sin si baim dau'send kum'ma. Di mensh'tä wâ'rä aus der Pfalts, wail un'ich dä

* Sketch of the olden times in Pennsylvania.

i'werich'ä wâ'rä dēl aus Bâ'dä [Baden], Sak'sä [Sachsen], un a'närä fun da glē'na Dait'sha shtâ'ta.

'S landt ab tsä klō'rä und tsä set'lä is lañg'som gañ'gä, und di ä'räwet wâr shwēr. Di hai'ser wâ'rä net so nēksht bai nan'ner das mer laicht psuch'ä kan, od'ter far hilf tsä shpriñg'ä wan eb'bäs wich'-tiches gshē'na is. Do hen di lait sich als sel'wer hel'fä mus'sä wan's krank'ä ge'wa hot, un yē'deri al'ti frâ hot als ir glē'na sek fol gegrai'der kat, far tē â^n tsä bri'a od'ter en blash'ter tsä mach'a. Dēl fun den'na retsep'tä hen si draus mit rai^n gabrocht', un del hen si dohin aus gfun'na dar'ich arfär'uñg. Nō war a'wer noch en set men'sha das gebraucht' hen, un al'lä sar'tä karyō'sä sach'ä gedūn', das wī's blūt shtop'pa; gaish'ter aus drai'wa; fai'er lesh'a, kshtōlänä sach'ä tsä fin'na; hek'sä tsä ben'ichä, und so wai'der. Fīl fun den'na âw'erglâ'wa hen aläwail', noch ân heñ'gär.

Di lait hen als ir duch un kle'der sel'wer mach'a mis'sa, un fer wol tsä fä'räwä hen si del karyō'sä sach'ä gebraucht'.

Flaks brech'ä, hâi'et, ärndt, di sōt, un's dresh'a, wâ'rä als tsai'tä das ä'räwet gemacht' hen, un oft'mōls hen di bau'erä nan'ner kol'fä. An so tsai'ta hots als gshpas ge'wä un'ich den yuñ'gä lait.

Am wel'shkarn bash'tä, dep'pich kwil'tä, un latwär'ik rīr'rä hots als mē^n nar'haitä ge'wa und do hen si alsamōl' der dai^{n}he^{n}k'er kshpīlt.

Alsämōl' hen si in de^n fel'der 's welsh'kärn gebasht', un wan ēns fun da bū'wa en rō'ter kol'wä kfun'nä hot, hot er ēn'ich ēns fun da mēt gebost' das är fañg'ä hot ken'na, od'ter das är gegli'chä hot. Wan a'wer ēns fun da mēt en rō'ter kol'wa gfun'nä hot, nō hot där was es ärsht gsē'na hot si gebost'. Wan's bash'tä fär'tich war, hen si en dans kat, alsämōl' im feldt, a'wer mersh'tens in der shai'er.

Wan als di yuñg'ä men'ner gañg'ä sin tsä shpär'iyä, sin si shīr al'fart garit'tä. Nō wan si ir gail nēksht am haus a^n gebun'nä hen, hen si glai aus'finna kenna eb si wil'kum wâ'rä o'der net; wail, wan di mēt si net gewelt' hen, hen si ir gail shtē^n los'sä, un wan di bū'wa wil'kum wâ'rä hot e'bar di gail glai im shtal kat.

Samsh'dâk ō'wets war shpär'iyä tsait, und bai del fun dä bush lait war's bund'la's gebrauch', so das di kärls als fun samsh'dâks bis mōndâks bai da mēt wâ'rä. Sun'dâks sin si als an di kä'rich gañg'a, un dan hot mer oft rō'ta blak'kä uf da mēt ī'ra hels sē'na ken'na wu di bū'wa si tsu hart gebost' hen—oder ferlaicht' a bis'sel gebis'sä.

'S kan sai^n das in da âl'tä tsai'ta fershi'denä sach'a kol'fa hen's bund'la a'rik gebraich'lich tsä mach'ä. Di lait hen hart gshaft un sin no frī ins bed; lich'ter wâ'rä râr und dai'er, und di bū'wa hen oft wait tsä gē^{n} kat. Oft mols wâr yusht ē^{n} shlōf shtub im haus, und so hen di âl'tä und di yuñg'ä sich hī^{n} gelēkt' tsä blau'derä o'der tsä shpär'iyä.

Des bund'lä wâr â^{n}na tswa'i'w'l fum aus'landt rai^{n} gebrocht', un si hen's â in Nai Yar'ik gedū^{n}' sowōl' als in Pensilfâni. Aläwail' dū'na si noch in Centre County, hi^{n} un dō, a bis'sel bund'lä, a'wer's nemt nim'mi lañg bis di lait se^{n}'na wi shandbar'lich so en gebrauch is.

Ēns fun dä karyōsh'dä sach'ä das mer aläwail' noch findt, is der wēk wi dēl fun den'na brauch'a dok'tär dū'na. Ē'ner das ich shun fīl yōr ken is gans hend'ich am ras''lshlañg'a fañg'a. Des dut ar mit em a^{n} said'-enä shnupduch das ar gē'ghä di shlañg hēpt. Di tsēn in der shlañg sin wen'ich tsärik'tsus gebō'ghä, so wan si sich in di hē shtrekt 's shnupduch tsä bai'sa, hen'ka di tsē^{n} fesht wi hō'ka; sel'awēk dut dar dok'tär di shlañg nō in di hē hē'wa, so das ar mit der an'ärä hand si hin'na am kop nemt. No wâ'rä di tsē^{n} raus geropt' das si en net bai'sa kan.

Dēl sâ'ghä das mer en shlañg fañg'ä kent un das si em â net bai'sa kent, wam mer di war'tä sâkt:

"Wi Moses di shlañg in der wil'dernes in di hē kō'wa hot, so hēb ich dich uf. Im nâ'ma dem Fa'der, Sâ^{n} un Hai'lich Gaisht solsht du ken gewalt' ha'wä mich tsä bai'sa."

D'no kam mer di shlañg â^{n}'na gfōr uf hē'wa.

Wan awer di shlañg ēns baist, no wärt en mit'tel gebraucht' das die lait i'werâl sâ'ghä, dēt nī'mols fē'lä. Der ēn'sichsht wēk aus tsä fin'na eb 's gut is o'der net, is fär, e'bär's shtoft re'ghelmē'sich tsä brauch'ä wi 's gebraucht' sai^{n} sot. Des is en blants das si mēsh'ter wart'sel hēsa. Der recht nâ'mä is *Sanicula marylandica* L. Wen'ich fun der wart'sel wärt ferklopt' und in mil'ich gekocht', und no gedruñg'ka; di sēm tsait wärt a fun der ferklop'ta wart'sel in was'ser ksōkt und uf di wund gelēkt'.

Dēl fun da âl'tä â'warglâ'wishä lait sâ'ghä mer sot en hin'kel in der mit dar'ich shnai'tä, und ē^{n} helft uf en shlañga bis lē'ghä; des, sâ'ghä si, tsīkt's gift aus der wundt so das es hin'kel gans grī^{n} wärt. A'närä sâ'ghä das mer'm'a hin'kel sai^{n} bärt'zel uf di wundt lē'ghä sot, un das es gift so raus getso'gha wärt.

Der alt dok'tär sâkt â das är di ras''lshlañg'a tsē^{n} ferkâ'fä dēt tsu dä yuñ'gä men'ner, so'ichä wu di mēt si lī'wä mach'ä wod'tä. Der kärl das en mēt''l lībt das net fil fun īm denkt, dut di shlañg'ä tsē^{n}

in sai^n hen′shiñg, und wan ’s mēt′′l nō sai^n hand nemt kan si sich nim′mi mē^n hel′fä; si mus’n lī′wa eb si wil o′der net.

Wan en ras′′lshlañg ab′getso′ghä is, heñg′ka sī si uf in di sun, so das’s ēl o′der fet, ab′dropst. Des wärt no gebraucht′ far in di ō′ra tsä drop′sä wam′mer hart′härich wärt.

Shlañg′a bis wä′rä â fershī′denä wē′ghä gekiūrt′ in fershi′denä plets. Dēl lait fershtam′pa ’n tswī′w’l un mik′sä ’s uf mit sals, und lē′ghä ’s blashder uf di wund.

In Lecha County hen si als shwart′si shlañg′a wart′sel fai^n gemasht′ un in was′ser gekocht′, un d’r no dafun′ in′nerlich ge′wä un uf di wund gelēkt′. Di sēm tsait hot des, was gebraucht′ hot, dī war′tä gshproch′a:

> “Gott hot al′les arshaf′fa, und al′les war gūt,
> Als du allē^n, shlañg, bisht ferflucht′.
> Ferflucht′ solsht du sai^n un dai^n gift!
>
> † † †
> Tsiñg Tsiñg Tsiñg.”

Yēd′ermol das es wärt tsiñg aus′gshprochä war, hot der braich′er, mit em fiñger, en kraits i′wer di wund gemacht. Des wart shaint das wan es fum wart tsiñgla hai′shtamma dēt; awer dō kam er net shur sai^n, net mē^n das in der brauch′a glâ′wä sel′wer.

Des is ä^{n}na tsai′w’l en alt Daitsh sâ′ghäs, wail mer es shun im a buch find das in Red′in [Reading] getrukt′ war in 1812 oder 1813, wu es so shtedt:

> “Gott hatte Alles erschaffen, und Alles war gut;
> Als du allein, Schlange, seiest verflucht;
> Verflucht sollst du sein und dein Gift.
>
> † † †
> Zing, Zing, Zing!”

Fīl lait sâ′ghä â das was en ras′′lshlañg′ en shwar′tsi baist, das di shwarts grât fart genkt un dēt sich shwart′si shlañg′a wart′sel such′a und det dafun′ fres′sa, so das es gift ken shâ′dä dēt.

Wam′mer di ras′′l fun′era shlañg in a glē^n sek′ilchiä bind und am a kind sai^n hals henkt, grikt’s ken gich′tera wan’s tsânt.

Wan di ra′s’l im hut getrâ′ghä wärt, grikt mer ken kop′wē. Lañ′ga tsai′ta tsärik′ hens si als haut, fun e^{n}nicha sar′tä shlañg′a, um den â′räm gebun′nä far ru′matis tsä farhī′ta. Des war shīr gâr uf der sēm plân das wi di bū′wa als ō′la haut um’s bē^n, o′der um en â'räm, gebun'nä hen far kramp tsä farhī'ta wan si im was'ser wâ'rä far tsä shwim'mä.

Far shtich fun wesh'pä, har'nēsel, hum''la und ī'ma, hen dēl lait als nas'ser lēⁿma uf di wund gelēkt'.

A'närä hen en shtik sil'wer uf der shtich kō'wa. Dēl hen ksât si ken'tä wesh'pä ban'nä, und's sâ'ghä dafōr' wâr:

"Wish'bli, wesh'bli, shtech mich nicht,
Bis der Dai'w'l di sē'ghä shpricht."

Wam'mer sō getsif'fer uf hē'wä wil âⁿna gshtoch'a tsä saiⁿ, mus mer dī wai'tä sâ'ghä:

"Weshp [oder was es saiⁿ mâk], dū hosht net mēⁿ gewâlt' far mich tsä shtec'hä, das der Dai'w'l sē'lichkait hot far mich fum dōt tsä wek'kä."

En al'ter hex'a dok'tär hot mer ksât das er ē'nicher hund ba'nä kent das er net blaf'fä kent. Wan er der hund sēⁿ'na dēt, dēt ar en shtik hols, o'der, noch bes'ser, en fen'sä shtâ'kä, in grund rum dre'ä, und di wart'ä sâ'ghä:

"Hund'li hald daiⁿ mund'li,
Bis där shtâ'kä wid'der recht
Kumt im grund'li."

Wan ar no wid'der tsarik' gēt drēt ar den shtâ'kä, o'rder's shtik hols, rum, we's dafōr' war.

Des laut a'rik fīl das wan es fun ēm aⁿ âl'tä buch genum'mä wär [getruk't beim Hō'hman in Reading abaut 1812–'13], wū's shtēt:

"Hund, halt deinen Mund auf die Erden; mich hat Gott erschaffen; dich hat er lassen werden.

† † †

"Dies machst du nach der Gegend hin, wo ungefahr der Hund ist; den du musst die Kreuze machen nach dem Hunde zu, und er darf dich vorher nicht erst sehen, und du musst auch erst den Spruch sagen."

Der sēm brauch'a dok'tär sâkt â das er rōt'lâfä shtop'pä kent wan er di hand drei mōl i'wer der wē plats raibt, und yē'dermol di wai'tä sâkt:

"Der rōt'lâfa un drach fârt i'wer 's dâch:
Der rōt'lâfa fargiⁿgt', un der drach fershwint'."

Far en shnit tsä hē'lä, shnait mer drai kart'sä shtek', elchiär fun ep''l hols. Nō nemt mer si gshwish'a di fiñ'gär und hēbt di en′ner ēns noch em a′närä, wed′der den shnit, wik′′lt si ai^n in babīr′ o′der lum′pa und henkt si in der sharn′shte^n. Wi no di shtek′-elchair uf drik′lä wärt di wund druk′kä und hēlt.

Far wârt′sä tsä färdai′wä, raibt mer yē′deri wârts drai mōl und sâkt:

"Der hin′nersicht und der fär′sichsht;
Der hin′nersicht und der fär′sichsht;
Der hin′nersicht und der fär′sichsht."

Des kan a′wer yusht glik′lich gadu^n′ sai^n wa mer tswē men′ner uf em gaul sēnt.

Noch en wēk far en wârts tsä fardra′iwa is wa mer′n bend′′l drum bindt und no grât ab nem′ma und wek henk′ka un′ich ′s dach. Wi der bend′′l färfault so gēt di wârts wek.

′S dut färlaicht′ ken shâ′dä wa mer a wen′ich e′bäs mē^n sâkt fun da hai′ser un ′s hēm′lewä. Di eld′shtä hai′ser wâ′rä natī′rlich fun blek, a′wer si hen e′wä glai â a^n′fañgä shtē^n′nä tsä bau′a.

Mer wis′sa shīr al, das di shai′erä gawē′^{n}netlich grē′ser un bes′ser gebaut wâ′rä wīdi hai′ser. Shīr al′les das im haus gebraucht′ wâr, wâr hēm′gemacht. Dish, shtīl, bed′lâdä, lich′ter-shtek un fet′-lichter, kär′äpet und dep′pich, sowōl wi di klē′der un shū, wâ′rä bai ens o′der′m a′närä in der noch′barshâft gemacht′.

Di waib′slait hen der flaks gshpun′na, un di kär′äpet lum′pa tsam′ma ganēt′, wail di men′ner′s duch un der kä′räpet gewō′wa hen. Di waib′slait hen a di shtrimp und hendshiñg gshtrikt.

We′ghä wâ′rä shpâr, un dī was es net ärfor′da hen ken′na en weg′′lchia tsä hal′ta hen lâ′fä mis′sa far uf psuch o′der an di kär′ich tsä gē^n.

Di menshta sin gâ rit′ta, wail di wēghä e′wa net i′weral gūt wâ′rä, un debai′ hot mer so fīl bes′ser rum gekent′. Hoch′tsich part′is sin tsum pâ′rä gerit′tä, un sel′amōls hot di pâ′räsfrâ di hoch′tsich kuch′a und a′ner es′säs gfun′nä. Al′samōls hot der pâ′rä gâr niks grikt far sai^n dinsht.

Ō′wets hot als shīr al′lä famil′iä gekoch′ter mush kat. Der wâr i′närä grō′sä shi′s′l mit mil′ich, in der nut fum dish, und do hot sich no yē′ders sel′wer kol′fä.

Wan si mitdâks flēsh kat hen, mit grē′wi—dun′kes hen si ′s kē′sa—no hot yē′ders sai^n brōd in glē′na shtik′ker farbroc′hä und mit′erä ga′w′l in di shis′sel gedunkt′. Do hots alsamōl′ shtrait gewa wan ens sai^n dun′kes âl ges′sä kat hot, und hot no saim noch′bar sains shtē′la wel′la. Sauer kraut hen als del lait mit da fīs nun′ner gedrē'ta, wail si 's net mit em shtemp''l färdä'wä hen wol'la. Bâi, un shnits un knep, hen si â als fīl mēⁿ ges'sä wī hait'sedâks. Ōbsht wâr als gedärt', und fīl hen si â aiⁿ gemacht far im win'ter tsä es'sä.

Lạd'wärik par'tis hen si als im shpōt'yor kat, wan di ep''l tsaitich wâ'rä un der sai'där wâr shun gemacht'. Dō hen si als dergân'sä dâk ep''l gshēlt un im sai'dar gekocht', un wi es no shīr fär'tich war, gē'ghä ō'wets, sin di bū'wa kum'ma tsä hel'fa, und wan al'les fär'tich wâr hen si en dants kat.

Alsämōl' hen si a'rik gemacht', mit nan'ner rum nar'rä; und si hen als ksât dâs dro'wä in Le'châ coun'ti 'n par'ti mōl di kats sō geyâkt' hen das si 's letsht in der kes'sel getshumt' is. Nō, 'wi ens gfrōkt hot was si a'wer nau mit em lad'wärik duⁿ ken'ta, hot di alt ksât, "Ai, mer shik'ka 'n e'wa noch Mach Tshonk'" [Mauch Chunk]. Si sâ'ghä dart hait noch, wan e'pas net gut is, das mer's noch Mach Tshonk shik'ka sot.

Di rēl'wē'ghä un di eñg'lisha shū'la mach'a en gros'ser un'nershit un'ich dâ lait, so das mer nim'mi so fīl Daitsh härt wi drais'ich yōr tsärik'; un was noch bes'ser is, is das di âl'ta âw'erglâ'wa shtar'ik aus gē'na. Di kin'ner lar'nä was recht und nōt'wennich is, un hal'ta sich uf mit der tsait.

Phonetics.

a as in father.
ä as in hat.
â as in law.
e as e in bet.
ē as a in ale.
i as i in it.
ī as e in feel.
o as u in hut.
ō as o in pole.
u as oo in foot.
ū as oo in fool.
ai as in aisle.
âi as oy in boy.
tsh as ch in chip.
gh as soft g, approaching the sound of ch in ach, or Arabic χ.
ñg as in sing.
' apostrophe indicates the elision of a sound.
' added to accented syllables.
ⁿ the superior *n* indicates that the preceding vowel is to be nasalized.

Note.

Other papers by the present writer, relating to the Pennsylvania Germans, were published in the *Proceedings* of this Society, Vol. xxvi, 1888, as follows: "Grammatic Notes and Vocabulary," pp. 187–285; "Folk-Medicine," *ibid.*, pp. 329–352. Also in the *Journal of American Folk-Lore*, Boston and New York, Vol. i, 1888, as follows: "Folk-Lore," pp. 125–135; Vol. ii, 1889, "Folk-Lore," pp. 23–35; and *ibid.*, "Tales and Proverbs," pp. 191–202.

On the Growth of the Forestry Idea in Pennsylvania.

By Dr. J. T. Rothrock, Secretary of the Pennsylvania Forestry Association; and Member of the Pennsylvania Forestry Commission.

An occasion like the present, when this Society celebrates its century and a half of useful activity, might also mark a fitting period for the State to inaugurate a change from a period of wasteful extravagance in its forests to one of jealous care for their perpetuity. We may, at least, record the fact, that the first serious attempt on the part of the Commonwealth to adopt protective forest laws dates from the spring of 1893.

It is quite true that Penn had stipulated, with those whom he styles adventurers, in his newly acquired domain, that they should retain one acre in six in trees; especially that the oak and the mulberry should be preserved, the one for ships and the other for silk. How these healthful restrictions came to be abrogated, or set aside, is unknown to the writer.

The following letter is of interest, not because it indicates any real forestry ideas, for it does not, but because it is so strikingly appropriate yet.

"Passy, December 24, 1782.

"I thank you for your ingenious paper in favor of the trees. I own I wish we had two rows of them in every one of our streets. The comfortable shelter they would afford us in walking, from our burning summer suns, and the greater coolness of our walls and pavements, would, I conceive, in the improved health of the inhabitants, amply compensate the loss of a house now and then by fire, if such should be the consequence; but a tree is soon felled, and as axes are at hand in every neighborhood, may be down before the engines arrive."—Dr. Benjamin Franklin to John Hopkinson.

Marshall's *Arbustum*, published in 1785 in Philadelphia, was not only a notable contribution to the forest literature of its time, but is now of increasing interest in view of important changes in nomenclature which are pending.

The earliest settlers on the New England coast did, here and there, farm out timber privileges and grant special wood rights under certain circumstances. It was not to be expected that they could at once come to consider trees as of no value. Education and experience both forbade this.

It was otherwise with the first generation born here. In their eyes the forest was simply illimitable; and without it the soil was of greater value than with it. Two centuries have matured the tree-destroying tendency into an instinct; and in regard to the proper use and conservation of our forest resources, we, as a people, are in the position of France, for example, four centuries ago. To put the proposition in another form, we furnish an illustration of a nation lapsing into the extravagance of barbarism because of the abundance of our supplies, so far at least as our use of the trees is concerned.

April 3, 1872, marked an era in our national forestry legislation, for on that date, Hon. Richard Haldeman, of Pennsylvania, introduced into Congress, by unanimous consent, a bill (21,971) to encourage the planting of trees, and for the preservation of woods on the public domain. Mr. Haldeman, explaining his measure, on April 11, speaks of it as a "subject hitherto unattempted in legislation," by which, of course, he meant in this country. On the 17th, he further explained that his bill was only to meet a pressing need, without discouraging the rapid settlement of the great West. It is fair to say that, considered as a whole, Mr. Haldeman's address on the subject has not been improved upon, to this day. April 30, the measure was further discussed, and was defeated by a small majority. The agitation, however, was not without result; for in 1873, the American Association for the Advancement of Science urged an examination into the subject. The President made the recommendation the basis of a special message, out of which grew "a bill for the appointment of a commission for inquiry into the destruction of forests and into the measures necessary for the preservation of timber." March 17, Mr. Dunnell, from the Committee on Public Lands, submitted a report upon the cultivation of timber and the preservation of forests. It is a matter of some pride that a Pennsylvanian, a member of this Society, was Chairman of the Committee on Public Lands, which reported favorably upon the request for a commission of inquiry; and he was largely instrumental in aiding the passage of the bill, authorizing it, through the lower House. I refer to the Honorable Washington Townsend, of West Chester. The years 1877, 1878, 1879 and 1882, witnessed the publication by the late F. B. Hough of his reports upon forestry, through the Department of Agriculture in Washington. With all their defects they are to this day landmarks in our forest literature.

With these preliminary statements, we may now turn to our immediate subject, The Growth of the Forestry Idea in Pennsylvania.

In 1877, the State Board of Agriculture began an active advocacy of forest restoration in this State; no less than five papers dealing with the different aspects of the problem were printed in its report for that year. In 1878, there were two brief papers. The current was started, and from that time on to the present, each year has witnessed a more or less extended presentation of the subject in the agricultural reports of Pennsylvania.

Among the contributors are Prof. Meehan, Josiah Hoopes, Franklin B. Hough, Thomas J. Edge, Prof. William A. Buckhout, Dr. John P. Edge, Dr. W. S. Roland, and the writer. The report of Dr. Roland is, up to this time, the most painstaking and satisfactory that has been produced on the trees of Pennsylvania. It serves, however, to illustrate how much the State is in need of a full, reliable report bearing on every aspect of the subject. Nothing better than the report of Dr. Roland could have been produced at the time and under the circumstances. In 1885, the Senate resolved and the House concurred in a resolution requesting the Governor to appoint one day each year as "Arbor Day." This resolution received the Governor's signature: but for some reason, a similar resolution was passed at the next session of the Legislature, 1887, which resolution, however, originated this time in the House. What the ultimate outcome of the day may be here, it is impossible to predict; though the promise is not encouraging. It was natural enough that Arbor day should have been eagerly adopted in treeless States. The case is wholly different in a Commonwealth ranking as the second lumber-producing State in the Union. There was not only indifference, but actual hostility, in some quarters, to any agitation of the forestry problem. Until within a brief period even the lumbermen recognized neither utility nor sense in it.

The year 1877, however, produced another active force in moulding public opinion in favor of forest conservation and restoration. The legacy of F. Andre Michaux (commonly here called The Younger Michaux), a member of this Society, became available as a fund which could be legitimately devoted to the support of a course of forestry lectures.

It would be clearly improper to fail to record the fact that the earliest funds available in this country for instruction in a science which every other civilized government had come to recognize as worthy of State support reached us as a legacy from a *foreign savant.*

Michaux had traveled extensively in this country, alone and also in company with his father. While he recognized the crude condition of much of what he saw, indeed of what we were proud, and criticised it freely, he, nevertheless, retained a feeling of respect and affection for the young Republic where he was hospitably received and of which he evidently entertained great hopes.

His will provided that, after the death of his wife, his property should be divided between the Agricultural Society of Massachusetts and the American Philosophical Society of Philadelphia. It was specified that the money so received was to be utilized in the interest of agriculture and forestry.

It also befits the time that the part taken by another member of this Society in the institution of the Michaux lectures should be recorded.

It was to the late Eli K. Price that the idea of commemorating Michaux, the testator, in this manner seems first to have occurred. He was not led from the plain conditions of the bequest into any illusions which the will neither contemplated nor allowed. The money was clearly devoted to the most practical of sciences, and it is creditable to this Society that it has been conscientiously so expended.

We may fairly measure the value of the work done in moulding public sentiment into healthy form, when it is remembered that it was in these Michaux lectures the following points were first suggested as representing a healthful public policy for Pennsylvania.

1. That the individual forest owner is under moral obligations not to recklessly despoil the State by waste of timber resources; and that it is equally the duty of the State to see that he does not impair the future prosperity of the Commonwealth by any willful extravagance. This follows from the simple proposition that the first duty of a State is to provide for its own perpetuity. It is for this reason that we submit to legal control; for without perpetuity the strong inducement to thrift, in the interest of our children, is lacking.

2. That so long as any owner of timber land allowed his timber to stand, he receiving no benefit therefrom, he was entitled to an exemption from taxes because the chief value of trees under such conditions was to hoard water for a community at a distant point.

In other words, the owner paid the taxes, and another party received the benefit.

3. That it would be a wise policy for the State to pay the taxes on poor water sheds from which the timber has been removed (when these were sold by the sheriff), and then either hold them itself, as permanent forest preserves, or to turn them over to the counties, under certain restrictions, as a sort of communal property to be kept in timber, allowing only removal of that which is matured.

4. That whilst it is true that trees are more important to the State than to the individual land owner, it would be "un-American" to deprive him even under this pressure of the right to do as he wishes with his own; but that it is in order for the land owner to ask what aid does the State propose to offer in production and protection of the trees which are of such vast importance to it?

Mr. Price may well have been called a seer. His vision has since often proved to have been prophetic. His relation to the great questions of the day was so close that no history of Pennsylvania can well be written without reference to his name, and it is but justice to say, that he was about the year 1877, the most active and powerful friend of forestry in the State. His memory extended back clearly for three-fourths of a century. He could recognize the extremity to which we were coming. Vast areas of timber had been removed and the ground rendered unproductive to the Commonwealth. Of all this he was an eye-witness. It is therefore not strange that he became so positive in his views.

The times were ripe for this new movement. The general Government, though its measures were but half-hearted, had given an impetus to the States. Especially were the Western ones concerned in forestry. Their mechanical and agricultural industries clearly must languish but for the timber; and the water which the woodlands retained. In most instances it was quite clear that there was not enough for immediate wants; and the question naturally arose as to the future.

It is doubtful whether any of the Eastern States has been more active in bringing about the forestry revival than Pennsylvania. Certainly none had larger interests at stake. The census statistics for 1880 showed that in point of lumber production it stood second; and common observation also revealed the fact that this did not suffice for her own wants, because she *imported* more than she *exported.* Her output for that year reached enormous proportions, and aggregated 1,733,844,000 feet, board measure. The total value of all her forest products, for the same period, was $22,457,359, and the wages paid amounted to $2,918,459.

In the year 1886, some public-spirited ladies in Philadelphia took active measures for the formation of the Pennsylvania Forestry Association. There was but little general interest in the new organization, and as it offered little else than a prolonged struggle with public opinion its active workers were few. They were, however, thoroughly loyal. In spite of neglect, and often of ridicule, the work went quietly on. A modest little journal under title of *Forest Leaves* was published, with occasional illustrations. It should here be noted that but for the zealous volunteer services of Mr. John Birkenbine, as editor, this missionary sheet could not have been continued. Through the liberality of a few members, it was largely circulated, almost regardless of the recipient's relation to the subscription list. Though it was quite clear that the intelligence of the community was crystallizing in regard to the forestry idea, the fact had not impressed itself upon the Pennsylvania Legislature even as late as the session of 1889, for a bill "to establish a forest commission and to define its powers and duties, and for the preservation of forest and timber lands" was buried beneath the negative recommendation of the Committee on Agriculture of the lower House; notwithstanding the fact that the services of the commission involved no other expense than the actual outlay of the members when on duty. It is worth while to record these facts because they illustrate how very near one may be to victory of a principle (as that of 1893), when in the very face of defeat.

Certain concessions had already been made by our Legislature; for example, that of 1879 authorized a remission of taxes for tree planting by the roadside, and it protected the same when planted. It also enacted a law against those who "wantonly and willfully kindle any fire on the land of another;" *if that fire results in any damage.*

The session of 1885 enacted that sales of land made for arrearages of taxes were to be deemed valid, whether said lands were seated or unseated at time of sale. The session of 1887 amended this, so as to allow the owner two years in which to redeem his lands. It was also enacted in 1885 that lands were not to be sold and sales were not to be valid, if at time of assessment there was sufficient personal property on said lands to pay taxes. These sales mostly related to poor timber land.

In 1887, an act was passed for encouragement of forest culture and provided penalties for the injury and destruction of forests. This was amended in session of 1891, and now stands thus on the Statute Book:

An Act

For the encouragement of forest culture, and providing penalties for the injury and destruction of forests.

SECTION 1. *Be it enacted*, etc., That in consideration of the public benefit to be derived from the planting and cultivation of forest or timber trees, the owner or owners of any land in this Commonwealth planted with forest or timber trees in number not less than twelve hundred to the acre, shall, on making due proof thereof, be entitled to receive annually from the commissioners of their respective counties, during the period that the said trees are maintained in sound condition upon the said land, the following sums of money:

For a period of ten years after the land has been so planted, a sum equal to ninety per centum of all the taxes annually assessed and paid upon the said land, or so much of the said ninety per centum as shall not exceed the sum of forty-five cents per acre;

For a second period of ten years, a sum equal to eighty per centum of the said taxes, or so much of the said eighty per centum as shall not exceed the sum of forty cents per acre;

For a third and final period of ten years a sum equal to fifty per centum of the said taxes, or so much of the said fifty per centum as shall not exceed the sum of twenty-five cents per acre;

Provided, That it shall be lawful for the owner or owners of the said land, after the same has been so planted for at least ten years, to thin out and reduce the number of trees growing thereon to not less than six hundred to the acre, so long as no portion of the said lands shall be absolutely cleared of the said trees;

And provided also, That the benefits of this act shall not be extended to nurserymen or others growing trees for sale for future planting.

SEC. 2. The owner or owners of forest or timber land in this Commonwealth, which has been so cleared of merchantable timber, who shall, within one year after the said land has been so cleared, have given notice to the commissioners of their respective counties that the said land is to be maintained in timber, and who shall maintain upon the said land young forest or timber trees in sound condition, in number at least twelve hundred to the acre, shall, on making due proof thereof, be entitled to receive annually from the commissioners of their respective counties the sums of money mentioned in the first section of this act: *Provided*, That the first period of ten years shall be counted from the time that the said land has been cleared of merchantable timber, and that, after the said first period of ten years, the number of trees upon the said land may be reduced as in the said first section is provided.

SEC. 3. Any person or persons who shall willfully or carelessly cut bark from or otherwise cut, burn or injure any tree, plant, shrub or sprout planted, growing or being on any land in this Commonwealth, without the consent of the owner or owners thereof first had and obtained, or who without such consent, shall kindle, or cause to be kindled, a fire on any forest or timber land in this Commonwealth, or who shall carry into or over any forest or timber land any lighted candle, lamp or torch, or other fire, without having the same secured in a lantern or other closed vessel, or who shall discharge or set off fireworks of any kind on said land or among the trees thereon, or who shall willfully or carelessly burn or fire upon his or their own land, or that of others, any tree, brush, stubble or other combustible material whereby fire shall be communicated to the leaves, brush or timber upon any forest or timber lands belonging to other parties, shall be subject to a penalty not exceeding one hundred dollars for each offense committed, with costs of suit; *Provided*, That if the defendant or defendants neglect or refuse to pay at once the penalty imposed and costs, or shall not enter sufficient bail for the payment of the same within ten days, he or they shall be committed to the common jail of said county for a period of not less than one day for each dollar of the penalty imposed; *And provided*, When the penalty imposed is above five dollars, the defendant or defendants may enter into a recognizance, with good security, to answer said complaint on a charge of misdemeanor, before the Court of Quarter Sessions of the peace of the county in which the offense is committed, which court, on conviction of the defendant or defendants of the offense so charged, and failure to pay the penalty imposed by this Act, with costs, shall commit said defendant or defendants to the common jail of the county for a period of not less than one day for each dollar of penalty imposed.

SEC. 4. Any justice of the peace or alderman, upon information or complaint made before him by the affidavit of one or more persons of the violation of this act, by any person or persons, shall issue his warrant, to any constable or police officer, to cause such person or persons to be arrested and brought before the said justice of the peace or alderman, who shall hear and determine the guilt or innocence of the person or persons so charged, who, if convicted of the said offense, shall be sentenced to pay the penalty aforesaid.

SEC. 5. The commissioners of each county shall, within one month after the passage of this act, cause the same to be published, one or more times, in one newspaper of general circulation in their respective counties.

It should be said that the Legislature of 1889, though it killed in Committee the bill for the act to establish a Forest Commission, did have the grace to remunerate those who had drawn the bill for the time and labor bestowed upon the work. The Legislature of 1891 actually went so far as to pay the expenses of the delegates appointed by Governor Beaver to the meeting of the American Forestry Congress which held its session in Philadelphia. In the same year an act was passed which provided "for recovery of damages to trees along public highways, by telegraph, telephone and electric light companies." This, however, can hardly be said to have affirmed any new principle. At most, it rendered the general law a little more specific.

December 12, 1892, Prof. J. T. Rothrock was engaged to devote his whole time to the interests of the Association.

In January, 1893, the Hon. D. Smith Talbot, of Chester county, introduced a measure for the Pennsylvania Forestry Association into the Legislature. "It was entitled An Act Relative to a Forestry Commission and Providing for the Expenses Thereof." The measure as it finally passed, is inserted here in full, as it enjoys the distinction of being the first act passed which recognized that forests were of enough importance to the State to be looked after, even if the oversight must be paid for. It is clearly then a boundary line between old and new methods.*

SECTION 1. *Be it enacted, etc.,* That the Governor be authorized to appoint two persons as a Commission, one of whom is to be a competent engineer, one a botanist, practically acquainted with the forest trees of the Commonwealth, whose duty it shall be to examine and report upon the conditions of the slopes and summits of the important watersheds of the State, for the purpose of determining how far the presence or absence of the forest cover may be influential in producing high and low water stages in the various river basins; and to report how much timber remains standing of such kinds as have special commercial value, how much there is of each kind; as well, also, as to indicate the part or parts of the State where each grows naturally, and what measures, if any, are being taken to secure a supply of timber for the future. It shall, further, be the duty of said Commission to suggest such measures in this connection as have been found of practical service elsewhere in maintaining a proper timber supply, and to ascertain, as nearly as is practicable, what proportion of the State, not now recognized as mineral land, is unfit for remunerative agriculture, and could with advantage be devoted to the growth of trees.

SEC. 2. The said Commission shall also ascertain what wild lands, if any, now belong to the Commonwealth; their extent, character and location, and report the same, together with a statement of what part, or parts of such lands would be suitable for a State Forest Reserve; and further, should the lands belonging to the Commonwealth be insufficient for such purpose, then to ascertain and report what other suitable lands there may be within the State, their extent, character

*This Act was approved by Governor Pattison on the 23d day of May; and on June 8, he further complied with its provisions by appointing Dr. J. T. Rothrock the botanist member and Col. A. Harvey Tyson the engineer member of the Commission. The statistician appointed under the Act was Mr. Frysinger Evans. Col. Tyson was soon succeeded by Mr. William F. Shunk; and Mr. Evans by Mr. Percy McClellan.

and value. The final report of the said Commission shall be presented to the Legislature not later than March 15, 1895.

SEC. 3. The said Commission shall have power to appoint one competent person to act as statistician, whose duties shall be to compile the statistics collected by said Commission, under their direction and supervision, whose salary shall be one thousand dollars per annum, with necessary expenses, to be paid in the same manner as is hereinafter provided for the payment of the Forestry Commission.

SEC. 4. The Commissioners appointed hereunder shall be entitled to receive by quarterly payments a compensation as follows: The Engineer, twenty-five hundred dollars ($2500) per annum; the Botanist, twenty-five hundred dollars ($2500) per annum, with necessary expenses for each; and the sum of twenty thousand dollars ($20,000), or so much as may be necessary, is hereby appropriated out of any money in the treasury, not otherwise appropriated, to be paid by warrant drawn by the Auditor-General.

It should be added that the chief executive officers of the Commonwealth had already recognized the magnitude of the forestry problem. Governors Hartranft, Beaver and Pattison had made urgent allusions to it, in their messages.

Such, in brief, is the history of the forestry idea in Pennsylvania. There remains yet to be given an outline of the conditions existing when a change in public policy seems to be assured for the near future.

The area of Pennsylvania may be stated in round numbers at 46,000 square miles. Of this we may say approximately 64 per cent. is in farms; or under some general oversight, not usually accorded to forests in this country. That is to say, that in a little more than two and a half centuries of civilized occupation, we have swept off about two-thirds of the forest area of the State. When first settled almost its entire area was densely wooded. In doing so we have reached a point where importation of lumber exceeds exportation. Nor is this all. We have practically exterminated the Wild Black Cherry (*Prunus serotina* Ehrh.), the Black Walnut (*Juglans nigra.* L.), and two of our most valuable Hickories (*Carya alba* Nutt. and *Carya porcina* Nutt.) have ceased to be abundant enough for our own special industries. Hemlock (*Tsuga Canadensis* Carr.) is superseding White Pine (*Pinus strobus* L.) because the latter is becoming poor in quality, or high in price; in fact the better qualities of earlier days are no longer to be had except at exorbitant rates. Within five years, extensive Hemlock forests have been cut solely for the bark, the trunks being allowed to remain and rot unutilized, just where they fell. It may be possible that this wasteful lumbering still exists; though it must be uncommon.

As late as 1892 the farmer was obliged by the fence law of 1700 to fence out his neighbor's cattle from his fields. Thus each individual stood in a condition of armed neutrality with his community. The special bearing of the fact, however, lies in this, that to maintain this fence law, which was a relic of barbarism, we were wasting, in the State of Pennsylvania enough of valuable timber to have made a five-rail fence around the globe thirteen times. In other words, there were standing in our State in the year 1893 about 325,000 miles of fences. Nothing more wasteful than this in relation to our timber resource is known to have existed since the pioneer period, when the settler was driven to roll his logs into piles and burn them. It is hardly creditable to the law-making intelligence of the State that a law so false in principle, as this, was allowed to stand unrepealed upon our statute books for one hundred and ninety-two years.

Forest fires are allowed to rage during the drier period of each year, until competent authority has placed the average annual loss of forest property in the State at the enormous sum of between two and three millions of dollars. In fact, under certain conditions, frequently existing, no insurance company will assume risks on such property. Worst of all, the public mind accepts, too often, this state of affairs as inevitable.

In the spring of 1893, there existed in Pennsylvania but one artificially planted forest, which was conducted on business principles and with a prospect of financial return for the capital invested.

The forestry movement indicates a reform in other directions than appears on the surface. It is a recognition of the broad fact that we as a young people have been wasteful in the use of all our resources; but that now we are coming under the inexorable laws of economy which govern older nations. The altered conditions will probably be none the more pleasant because enforced.

To-day we celebrate an anniversary of our Society, and it would appear to be a fitting occasion for a statement of facts concerning the forest regime which is passing away before a new and better one. Especially is this so when it is remembered how conspicuous a part the Society has taken in bringing the change about.

Dust from the Krakatoa Eruption of 1883.

By Joseph Wharton, Philadelphia.

The splendid roseate glows which in the winter of 1883–4 were visible in the western sky after sunset and in the eastern sky before sunrise, gave rise to many conjectures, but apparently to almost no experiments. A few persons believed those glows to be sunlight reflected from the under surface of a stratum of fine solid particles suspended at a great height in the atmosphere; some thought with me that those particles might be volcanic dust which had floated to us from the eruption at Krakatoa, but, as no one offered any proof of this, I attempted on the morning of January 20, 1884, to demonstrate it. Six miles northward from the centre of Philadelphia, where I reside, a light and fine snow was then gently falling in an almost calm atmosphere, presumably from a high altitude. Of that snow, while it was yet falling, I collected about a gallon by skimming it carefully with my hands from a considerable surface in a field a hundred yards to windward of my house and a quarter-mile from the nearest windward building.

This very clean new-fallen snow I melted under cover in the porcelain bowl it was gathered in, and was at first unable to detect any sediment; after maintaining for several minutes a gentle rotatory movement of the bowl in order to bring into its deepest part any solid matter which might be present, I poured off most of the water and evaporated the remainder. A minute quantity of fine dust was then discerned by the tiny vitreous reflections which it gave in the sunlight. My practice in chemical analysis, and therefore in weighing small quantities, affords some justification for the estimate that the total weight of this dust was less than one-hundredth of a grain.

Under the microscope, where it was immediately placed, this dust showed the characteristics of volcanic glass; it consisted in part of irregular, flattish, blobby fragments, mostly transparent and showing no trace of crystalline structure, in part of transparent filaments more or less contorted, sometimes attached together in wisps, and mostly sprinkled with minute glass particles. The filaments of glass had about the same diameter as single filaments of silk placed on the microscope slide for comparison with them.

Having microscopically examined the dust again and again, I ignited it upon platinum to destroy any organic matter which might be present, and thereafter found the filaments, the flat plates, and the amorphous accretions of glass quite unchanged.

No pyroxene, augite, or magnetite, such as have elsewhere been observed in volcanic dust, was present; it may be assumed that, if at first mingled with the glass, those heavier minerals had been dropped during the long voyage of more than ten thousand miles of space and more than four months of time.

The capacity of fine volcanic glass to float in the air to considerable distances being a well-established phenomenon, my examination claims no greater novelty or interest than what may be due to the actual finding of such glass at so great distance from the point of its ejection.

In this case two separate ejections seem to be indicated, for on several evenings I observed a second and fainter glow after the original and stronger glow had entirely disappeared. A higher stratum of finer particles doubtless reflected the sunlight from the greater altitude after the sun had set at the lower elevation of the principal dust stratum.

Early in February, 1884, the ship *J. E. Ridgeway* arrived at Philadelphia from Manila by the Strait of Sunda. On February 12, I visited that ship, and read on her log-book that at 10 P.M., October 27, 1883, in south latitude 7° 57′ and east longitude 100° 54′ (about five hundred miles W. S. W. from Krakatoa), she encountered a vast field of floating pumice, through which she sailed until 7 A.M., October 29. So abundant was this pumice that the ship's speed was reduced from nine knots when she entered it to two knots at 6 P.M., October 28; several hours after that time her speed gradually increased, as the pumice became less dense, from two knots to eight, and finally, when she cleared it, to her normal nine knots. No volcanic ash had fallen upon the ship, as she arrived too late upon the scene.

Some of this pumice I took directly from the hands of the mate and steward, who had collected it from the sea and had kept it in their private lockers. It can scarcely be doubted that this pumice was ejected from Krakatoa.

Now, on placing under the microscope small crumbs of that pumice and filaments picked out from its cavities, I recognized just such transparent flattish scraps and ragged accretions as were among the dust found in the snow-fall of January 20, while the filaments, though less varied and interesting than those then collected, were quite similar in character, even to the tiny glass particles sprinkled upon them.

A minor point of resemblance was that the yellow color of one little vesicular mass in the dust caught January 20 was fairly matched by a slight streak of similar color in the pumice.

In March, 1884, I collected dust from the steel works at South Bethlehem, Pa., and also dust from a blast furnace there, in order to compare them with the dust found in the snow and with the filaments and crumbs of pumice from the ship *J. E. Ridgeway.*

After separating from these dusts the large proportion which was attracted by the magnet, the remnant showed in each case many vitreous particles; that from the iron furnace largely spheroidal or globular, with a few filaments; that from the steel works partly minute rounded particles, but containing many filaments of great tenuity. Neither contained such clear vitreous plates and aggregations as abounded in the snow-dust, while the filaments in both cases were of dark color, and smooth, straight form, distinctly different from the colorless and frequently contorted filaments of the snow-dust.

It is difficult to resist the conclusions (1) that the vitreous dust found in the snow-fall of January 20, 1884, was not derived from iron or steel furnaces, (2) that it was of similar origin to the floating pumice found by the ship *J. E. Ridgeway*, (3) that it was ejected by the huge volcanic explosions of Krakatoa.

Den Forschern.

*Von Dr. Hermann Rollett** (*Baden bei Wien*).

Welch' frischhinwogende Bewegung hast
Du aufgestört, die Alles rings erfasst,
Du Wort *Darwin's*, das längst lag auf den Zungen,
Doch auszusprechen Keinem war gelungen:
Dass sich—nach Luftart, Nahrung, anderm Leben—
Die Organismen "anzupassen" streben;
Dass "Aenderungen" sich dadurch gestalten,
Die durch "Vererbung" fest sich forterhalten;

*Als Gruss aus der Ferne gewidmet zur glorreichen, am 22. bis 26. Mai 1893 stattfindenden Jubiläumsfeier der American Philosophical Society in Philadelphia.

Dass jene Arten *dauern* dann der Wesen,
Die frei im "Kampf um's Dasein" *aus* sich lesen;
Dass mit der "Zuchtwahl" so am Ziel wir wären,
Die "Artenbildung" einfach zu erklären.—

Und spähend folgt das Aug' der Wissenschaft
Dem Wirken der im Stoff gelegnen Kraft,
Dem Uranfang der Wesen, deren Stoff
Aus glüh'ndem Dunst des Weltalls einstens trof,
Durch dessen Schlummer stets die Kräfte wallten,
Die schaffend vor Aeonen Welten ballten,—
Dem Zwange folgend, der in ihnen lag,
Und als "Bewegung" ewig wirken mag.—
Der Eine sieht im Geist—organisch' Leben
Aus unorganischem sich mälig heben,
Und sieht aus kraftbelebten Stoffs Gewalten
Die Zelle "autogonisch" sich gestalten.
Der And're sieht—weil *ewig* ihm das Leben—
Organ'schen Stoff seit je im Weltraum schweben,
Zum "Urschleim" ihn sich bilden früh auf Erden,
D'raus erste Wesen "plasmagonisch" werden.

Und wie's auch sei,—es that's doch ewig nur
Aus unbewusstem Drange die Natur;
Und, ob es mälig oder rasch geschah,—
War nur die Form einmal der *Zelle* da,
So konnten alle Wesen sich gestalten
Durch jene "artenbildenden" Gewalten;—
Die Wissenschaft geht siegreich aus dem Streit,
Weist forschend nach, dass hier in aller Zeit
Die Wesenreihe eine Kette ist,
An der wohl manches Glied noch wird vermisst,
Das ausgestorben längst und so verschwunden—
Wenn nicht vielleicht, bis jetzt nur nicht gefunden;—
Und von der Zelle bis zum Menschen zeigt
Kein Sprung sich ihr; und bildend abgezweigt
Erscheint die neue Form nur von der alten
In der Natur unendlichem Gestalten.

Vom Affen kann der Mensch zwar nimmer stammen,
Doch *einen* Urahn hatten wir zusammen,
Aus dem zwei Formen, die sich strebend fanden,
Durch jene Artenbildung einst entstanden.

Und weiter geht die rüst'ge Wissenschaft—
Natur befreiend aus des Dunkels Haft—
Und sagt: die Bildung neuer Arten werde
Nur dann *besteh'n*, wenn fern, auf *neuem* Herde
Des Bildens, sich die neue Abart findet,
Wenn die Vermischung mit der alten schwindet.
Die *Wanderung* sei dieser Wandlung Grund—
"Migration" benennt's des Forschers Mund.

Und weiter noch führt fort des Wissens Pfad,
Es schallt: Ihr seid der Wahrheit nur *genaht;*—
Die "Zuchtwahl" nicht und "Wand'rung" nicht *allein*
Wirkt artenbildend,—*beide* mögen's sein!

So wird denn mehr und mehr die "Schöpfung" klar,
Das *Weltgeheimniss* leuchtend offenbar;
Und in das dämmernde Gewirr des Lebens
Der Forscher hält die Fackel nicht vergebens.

Die Angstgemüther doch und Finsterlinge,
Die rufen "Weh" nur über diese Dinge;
Sie schreien "Frevel ist's!" in alle Welt,
Dass es der Menschheit in die Ohren gellt.
Sie schnauben: "Hört nur!—nicht von Gott erschaffen
Erklären sie den Menschen, den vom Affen
Sie stammen lassen; und des Menschen *Geist*,
Der sich von *Gott* gegeben doch erweist,
Den nennen sie ein 'Resultat' vermessen—
O hört!—von 'Compensations-Processen!'
Da endet der Begriff von Bös und Gut,
Von Recht und Tugend! Allen Lebensmuth
Verliert der Mensch da, dem die tolle Zeit
Den Glauben raubt an die Unsterblichkeit!

Im 'Kampf um's Dasein' wird der Vortheil nur
Die Menschheit leiten; wie der *Thier*-Natur
Wird sinnliches Geniessen nur allein
Das Ziel gewissenloser Wesen sein!
Die Erde, die der Weg zum Himmel ist,
Sie wird ein ekler Sumpf zu dieser Frist;
Und statt, dass Seligkeit der Menschheit winkt,
Verzweifelnd sie in Barbarei versinkt!"—

So jammern sie. Und in des Morgens Flimmen
Da rufen noch die besten von den Stimmen:
"*Versöhnung*—an dem Abgrund, der uns droht,—
Von *Wissen* und von *Glauben* thut uns noth!"
Und zuruft manch' Verfechter uns des Alten—
Der *Schule* Philosoph—" doch Mass zu halten,
Das ew'ge *Unbedingte* 'Gott' zu nennen,
Das vom *bedingt* Besteh'nden sei zu trennen;"—
Indess doch unbedingt ist *alles* Sein
Dem *Wesen* nach,—die *Form* bedingt allein,
Die ohne vorbedachten Zweck entsteht,
Aus innerem Gesetz hervor nur geht,
Das von der strengen Regel *ab* nur weicht,
Wird fest dadurch ein *höher* Ziel erreicht.—

Ihr Forscher! muthig fort nur auf der Bahn,
Die lichtvoll führt aus altem Trug und Wahn.
Und wie sie lärmen auch und wie sie toben,
Die selbstisch Grund und Sinn des Seins verschoben,
Die einen "vorbedachten Zweck" verlangen,
Weil ihrer *Herrschaft* Fesseln daran hangen,
Die einen Zweck, der *ausser* uns ist, setzen
Und so für's "Diesseits" zur *Entsagung* hetzen,
Die demuthsvoll den *Glauben* da begehren,
Wo wir des Lichts des *Wissens* noch entbehren,
Das wir doch leuchtend hell hervor seh'n blitzen
Aus der Verhüllung schon weitoffnen Ritzen.

Nur fort, ihr Forscher! lichtet alles Dunkel!
Macht frei der *Wahrheit* strahlendes Gefunkel!

Enthüllt die hehre, leuchtende Gestalt,
Die lange lag in finsterer Gewalt!
Verkündet aller Dinge Sinn und Grund
Und gebt der Welt zugleich die Mahnung kund:
Dass Keiner seine Würde je vergisst,
Weil er ja Glied der Menschheitskette ist,
Und weil als solches Jedes seine *Pflicht*
Und auch sein *Recht* hat; da flieht Tugend nicht,
Und nimmermehr wird jener Schreckruf wahr,
Dass alles Edle, Hohe in Gefahr;—
Und wahre Sittlichkeit hebt dann die Brust
Und bringt ihr Lebensfreude, Lebenslust,
Und macht—indem sie für den Sturm der Welt
Den Menschen fest auf *eig'ne* Füsse stellt,—
Dass er dem armen kurzen Erdentag
Ein wenig doch des Glücks entringen mag,
Und dass wir wirken froh, durch That und Wort,
Und *ewig* leben in der *Menschheit* fort!

Phylogeny of an Acquired Characteristic.

By Alpheus Hyatt.

Preface.

This memoir was first given as a short address before the American Philosophical Society of Philadelphia, at the celebration of the one hundred and fiftieth anniversary of the foundation of that illustrious body. A short preliminary abstract was subsequently published in their *Proceedings* and in the *American Naturalist* for October, 1893, with one diagrammatic plate. The statements made in these two preliminary papers before all the facts were brought together and correlated were true, in the main, but necessarily defective and have been put into more correct shape in the following pages.

Introduction.

The nature of the evidence afforded by fossil shells is even at the present time very little understood. They have been so often spoken of slightingly, as a sort of jacket, an unimportant part, etc., that all conclusions arrived at by their study alone are considered as peculiarly liable to error.

A shell, to begin with, ranks as a primary, essential part arising in an early stage of development from the shell gland common to the embryos of all forms of Mollusca. Subsequently, by its mode of growth it becomes a model of the external form, and at the same time a mould of the outlines of the internal soft parts to an extent which has not been fully appreciated. The shell is often, also, a permanent record of the series of changes which the form has undergone, from the time it first began to enclose the embryo until the death of the soft parts, since it retains the young shell and all the later stages of growth. Among Nautiloids and Ammonoids, it also contains the calcareous tube or so-called siphuncle, which exhibits remarkable and significant changes of structure and position following upon the development of the animal. This siphuncle connects the septa or horizontal partitions, which with their sutures vary with the age of the animal constituting a third record of changes and structural modifications.

All these parts, the shell proper, the siphuncle, the septa and the sutures are in correlation with each other and together make an index to the life history of the individual, which is unequaled in some respects among other existing or extinct animals.

A single shell, either from a living or fossil form, may present accurately the general history of the development of the young, the stages of the adult and old age. The results of heredity and of the action of endemic or traumatic diseases may also be detected, if one knows how to study and compare the remarkable and distinct series of metamorphoses displayed by this external or protective skeleton with those of congeneric forms. This can be done even when the young is not visible externally by breaking down or dissecting a well-preserved fossil and thus following the history of the shell backwards through all of its stages to the embryo.

The researches of Beecher, Schuchert and Clarke among Brachiopoda have demonstrated that the shell and the internal brachial armature of these forms possesses similar life histories to those here described for the external and internal skeletons of the Cephalopoda. Jackson has demonstrated similar phenomena among Pelecypoda and Beecher among corals.

The vertebrate skeleton has long been considered a standard, and the evidence afforded by its fossil remains is very important and convincing. The series made in the case of the horses found by Marsh and Cope and those described by Gaudry are universally quoted as the strongest proofs of evolution. This evidence is considered complete, because naturalists understand and have thoroughly studied the skeleton, and because it is internal and has been assumed to be more invariable than the shell. All of these arguments have their due weight, but there are no examples of greater invariability than exist between the shells of the Nautilus now existing and those of Barrandeoceras (Nautilus) of the Cambrian, or the Triassic and Silurian Orthoceras, or of the Prodissoconch stage in the young of Pelecypoda as demonstrated by Jackson, or of the Protegulum among Brachiopoda as shown by Beecher. The Prodissoconch and Protegulum are embryonic shells that have persisted from the earliest horizons of geologic time and are still to be found in living shells attached to their apices.

The conclusions arrived at by the study of the vertebrate skeleton are reliable, but they are neither more conclusive nor important in theoretical meaning than any other series of equally well-understood hard parts in any other branch of the animal kingdom found as fossils when traced out in the same thorough and careful manner.

How unreasonable it would seem to a student of fossil Mammalia, if he were requested to do what it would be appropriate to require from a student of the fossil Cephalopoda, viz., to describe from the investigation of a single perfect fossil skeleton of an adult, not only the characteristics of the skeleton at the stage of growth at which the animal died, but the developmental stages of this same skeleton, and in case it were the remains of an old, outgrown animal, also, the retrograde metamorphoses through which it had passed during its last stages of decline. It might require a life time to make out the stages of a single species of mammal satisfactorily from the isolated specimens which would be found and the attempt would be hopeless for all the youngest stages of growth, while the bones were still cartilaginous.

This kind of evidence, however, is readily obtainable among fossil Cephalopods with relation to the shell and other hard parts as among living animals, and it can be obtained in good collections everywhere, whether "in situ" or in museums. Thus it is possible to study the relations of these fossil forms very minutely and with a certainty of possessing a clue to their true relations, which is rarely obtainable even among existing animals. For among these we have only the embryos and young of contemporaneous forms and necessarily lose all relations of succession in time, unless the investigation embraces a prolonged series of experiments or is more or less historical, and even then the facts cannot have a very wide chronological range.

The class of Cephalopoda has two subclasses, Tetrabranchiata and Dibranchiata. These were established by Richard Owen as orders—a purely technical difference, which does not change in any way the value of the structural distinctions as given by this eminent naturalist. The Tetrabranchiata are shell-covered; and they are represented by the modern Nautilus, the only existing genus. The Dibranchiata are descendants of the former, but enclosed the shell, and resorbed it in many forms, so that they appear as naked animals. The cuttlefishes, squid, devil-fishes, etc., are existing types. In studying these types, the author has been led to adopt a new method of characterizing the divisions, and besides the old structural distinctions, which are still available, to apply the correlations of habit and structure to the elucidation of some of the ordinal characters.

The classification adopted is as follows:

Class Cephalopoda.
Subclass I, Tetrabranchiata.
Order, Nautiloidea.
" Ammonoidea.
Subclass II, Dibranchiata.
Order, Belemnoidea.
" Sepioidea.

These four orders converge to one type by intermediate forms, by embryology and development of the shells and internal hard parts, by their morphology and by the possession of a similar embryonic shell, the protoconch, or the cicatrix which is a remnant of the aperture of this stage on the apex of the true shell or conch.

The class is composed of exclusively aquatic and marine animals, and consequently they breathe with gills. The structures of the orders mentioned coincide with the distinct habitats they respectively occupy.

The animal of the Nautilus has a large mantle or fleshy sac enclosing the internal organs, which can be opened around the margin, or closed, at the will of the animal. Admitting the water around the margin they fill their mantle cavity with fluid, and then constricting the margin and compressing the mantle-sac, force it out with violence through a fleshy pipe, which is exclusively used for that purpose, and always situated on the ventral side. The reaction of the stream is sufficiently powerful to drive the body of the animal with varying degrees of swiftness backwards. The fleshy pipe is therefore an ambulatory pipe or *hyponome;* and it is advantageous to replace the old and confusing terms by this name.

The Dibranchiata change the external shell, which they inherit from the Nautiloids, into an internal organ, and by suitable modifications of shape and also taking advantage of the powerful hydraulic apparatus, which they also inherit, and increasing its efficiency, become exclusively swimmers.

The hyponome of the Nautilus causes a corresponding depression or sinus to occur in the aperture of the shell on the same side, and its effect is also to be seen in the striæ of growth on this side; so that we know, from these indications in any fossil, what was the comparative size of the pipe, and whether the animal was more or less powerful as a swimmer.

Other indications, such as the openness or contracted form of the various apertures of different genera, exhibit with equal clearness what they could do in the way of crawling. The wide-open apertures indicate powerful arms, capable of carrying and easily balancing the large spire of the shell above; the narrow contracted aperture shows that the arms were small, and that the animal could not so efficiently balance or carry the shell in an upright position, and was therefore, according to the amount and style of the contraction, more or less inefficient as a crawler.

In studying the different types of the Tetrabranchiata, we find that there are two orders as first defined by Prof. Louis Agassiz—the Nautiloidea and the Ammonoidea—and, further, that these divisions coincide with differences in the outlines of the ambulatory sinuses which indicate distinctions of habit general in the normal forms of each order.

The extinct Nautiloidea had large ambulatory sinuses, and were evidently capable, like the modern Nautilus, of rising to the surface, and swimming with a jerky motion ; though their open apertures, as a rule, show their normal condition to have been reptant, or bottom-crawling. The exceptional shells, which depart from the typical form in the sinus and apertures, exhibit their peculiarities in the adults, but not, as a rule, in the young, except in cases

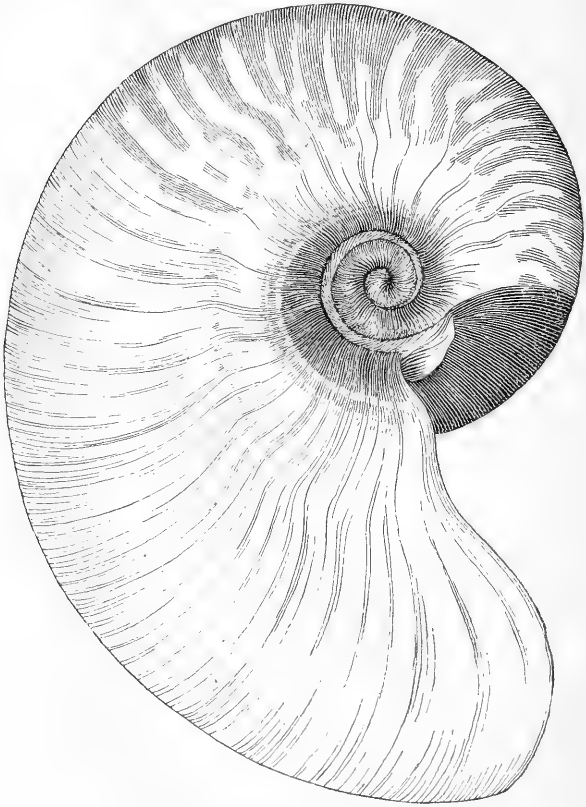

FIG. 1.—*Nautilus umbilicatus.*

where direct inheritance has occasioned the exception, and these are, in fact, the most conclusive proofs of the power of the habitat to produce permanent changes in the apertures.

The orthoceratitic shells of this order are straight cones, with internal septa dividing them into air-chambers, connected by a tube passing through all the air-chambers, and opening into the body of the animal itself, which occupied a large terminal chamber, which however was a small part only of the whole length of the cone. This is the simplest form: and others are, the bent or arcuate, cyrtoceratitic; the loosely coiled, but with whorls not in contact, gyroceratitic; the closely coiled, with whorls in contact, nautilian; and the still more closely coiled or involute shells, the involute nautilian, in which the outer whorls may simply overlap the inner, or entirely conceal them by their excessive growth, as in *Nautilus pompilius*.

The Ammonoidea in the earlier forms, the Goniatitinæ of the Silurian,* had apertures with well-marked ambulatory sinuses sufficient to show that they must have had considerable powers of rising or leaping in the water, if not swimming, like the Nautilus. In the later forms of the same suborder and in the Ceratitinæ, Ammonitinæ and Lytoceratinæ the ambulatory sinus is absent; and in its place a projecting crest or rostrum was developed indicating reduction in size and disuse of the hyponome. This and the generally open apertures enable us to see that they were more exclusively bottom-crawlers than the Nautiloidea.

The most interesting of the facts in this order lies among the exceptional shells, some of which must have been sedentary, and could neither have crawled nor moved about with any ease; but none of these, so far as we know, seems to have exhibited a type of aperture which indicated transition to an exclusively swimming habit. These shells appear in our subsequent remarks among phylogerontic and pathologic types.

The Belemnoidea of the Jura had a solid cylindrical body, called the guard, attached to the cone-like internal shell, and partly enclosing it. Aulacoceras of the Trias, as described by Branco, is a transitional form with an imperfect guard, which frequently contains fragments of other shells and foreign matter. This demonstrates that this guard could only have been built by some external flap or inclosing sac, independent of the true mantle. This false mantle must have inclosed both the shell and the guard, and must have been at the same time open, so as to admit the foreign materials which Branco found built into the substance of the guard. One of the straight shells of the Silurian Nautiloidea, *Orthoceratites truncatus*, regularly breaks off the cone of its shell, and then mends the mutilated apex with a plug. This plug, we are able to

* See Plate ii.

say, is the precise homologue, in position and in structure, of the guard of the Belemnite.

Barrande endeavored to show this plug to have been secreted by external organs, as he supposed—two arms stretching back from the aperture like those of Argonauta, and reaching beyond the broken apex. The dorsal fold of Nautilus is, however, a secreting organ stretching back over the shell; and, as the probable homologue of the plug-secreting organ of the Orthoceratites and the guard-building organ of the Belemnoidea, it enables us at once to explain how the Belemnoidea arose from the Orthoceratites, and why Aulacoceras had an imperfect mantle. This fold, which was far larger among the ancient Orthoceratites, would have been necessarily open on the ventral side, then more but not completely closed in Aulacoceras, and finally completely closed in the later Belemnoidea, and able to construct a guard as perfect as that which they carry.

The solid guard of these animals, a compact cylindrical body such as they were known to possess, could have been only a heavy burden to a swimming animal. The Belemnoidea, therefore, were not purely natatory; but for these and other reasons, which we cannot here discuss, they were evidently ground-swimmers, probably boring into the mud for shelter, or as a means of concealing themselves while lying in wait for their prey.

The old view, that the guard could have been in any sense a "guard" against collisions with rocks, etc., in their wild leaps backwards, is inadmissible for many reasons. The most obvious are its position as an internal organ, its solid structure, and its weight. I think it more reasonable to suppose that it might have increased the liability to injury from collisions. In tracing the Belemnoidea to the Orthoceratites I have simply continued the labors and carried out more fully the sagacious inferences of Quenstedt and Von Ihering.

The modern Sepioidea are known to be almost exclusively swimmers; and the more ancient, normal, flattened forms, and their descendants, the cuttle fishes, have very light, flattened, internal shells, in which the striæ of growth are remarkable for their forward inflection on the dorsal aspect, due to the immense comparative length of this side of the aperture.

The enclosure and suppression of the shell was predicted, with a sagacity which commands our highest admiration, by Lankester, from studies of the embryo of Loligo; and these facts carry out his conclusions, substituting, however, the hood for the two mantle-flaps which were imagined by him as the organs which inclosed the shell and formed the shell-sac.

Most paleontologists have considered the Sepioidea and Belemnoidea as more closely allied; but they appear to us as two orders, certainly as distinct as, and perhaps even more widely divergent than, the Nautiloidea and Ammonoidea.

Among these two orders we recognize many exceptional forms—

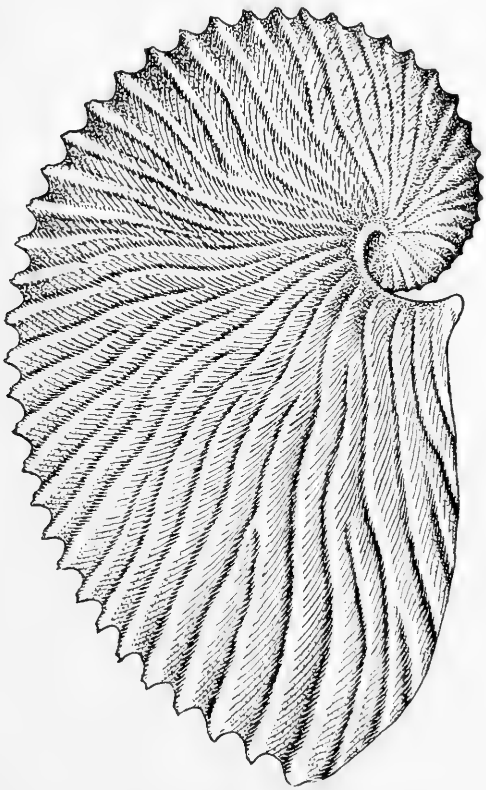

FIG. 2.—*Argonauta sp.?*

such as the Spirula among Belemnoidea, and among Sepioidea the octopods; and we think they all prove our position, that the habitat so closely accords with the structural changes of the type that its purely physical agency must be regarded as the efficient and direct cause of the correlated changes of structure which distinguish the different orders and suborders, and often of the exceptional genera and species.

We will mention but one of these exceptional cases, in some respects the most pertinent—the existing Argonauta, or paper nautilus (Fig. 2, p. 357). Here a thin shell secreted by the mantle, by the edge of the mantle, and by the two pairs of long dorsal arms, encloses completely the animal of the female alone, the male being naked. As a sexual organ for the protection of the eggs; as an adolescent and adult structure, originating at a late stage in the life of the individual, and not in the shell gland of the embryo; and in its microscopical structure—it is not a true shell, or similar to any true shell among Cephalopoda. Still, in form and position, and as built in part by the mantle, it is analogous to a true shell, and has in part also the functions of a true external shell, and ought therefore to support or refute the hypothesis maintained above. It belongs to a swimming animal, and should therefore have the hyponomic sinus in the aperture and striæ of growth as in Nautiloidea; and these it certainly has. Compare the side view of *Nautilus umbilicatus* (p. 354, Fig. 1), with the Argonauta and it will be seen that the lines of growth agree in both and that both possess the hyponomic sinus on the outer side. One can appeal to this example as a most convincing exception to prove the rule that the shell is a true index of the most remarkable adaptive structures, and, among the fossils, can give us exact information of important similarities or differences in structure and habits.

The *efforts* of the Orthoceratite to adapt itself fully to the requirements of a mixed habitat of swimming and crawling gave rise to the Nautiloidea; the *efforts* of the same type to become completely a littoral crawler evolved the Ammonoidea. The successive forms of the Belemnoidea arose in the same way. But here the ground-swimming habitat and complete fitness for that was the object. The Sepioidea, on the other hand, represent the highest aims as well as the highest attainments of the Cephalopods in their evolution into surface-swimming and rapacious forms. We cannot seriously imagine these changes to have resulted from intelligent effort; but we can with Lamarck and Cope picture them as due to efforts on the part of the animal to take up new quarters in its environment and thus acquire habits and structures suitable to the changed physical requirements of its surroundings and this position is better supported by facts than any other hypothesis.

Confining the discussion to the Tetrabranchiata, which are the most favorable for the present purposes, the next problem presenting itself is whether the two orders, Nautiloidea and Ammonoidea, have had a common origin, or whether they bear internal evidence of having sprung from different ancestors.

The embryo of all Ammonoidea, as shown by the author in his *Embryology of the Fossil Cephalopods of the Museum of Comparative Zoölogy*, and since confirmed by the more extensive researches of Dr. Branco, is the little bag-like shell first discovered by Saemann. This is attached to the apex of the secondary shell. The embryonic bag has been called the *protoconch* by Owen; and the secondary or true shell, the *conch*.

There is no protoconch in most Nautiloidea, as first shown by Saemann, then by Barrande, and subsequently by the author and Branco; but where it ought to have been attached on the apex of the conch, there is a scar, first demonstrated by Barrande. The view brought forward by the author, that this scar indicated the former existence of a protoconch in the Nautiloidea, has been opposed by Barrande, Branco, and several authors, on the ground that the cicatrix demonstrated the existence of a distinct embryonic form. Therefore, according to Barrande, the Nautiloidea were not similar to the Ammonoidea in their earliest stages of growth, and must have been equally distinct in origin.

I have found the protoconch in several forms of Orthoceratites, the figures being reproduced here, Figs. 3-7, and, further, it can probably be found on the apex of all of the so-called perfect shells, which have no scar or cicatrix. These, when described by DeKoninck, were supposed by him, in his "Calcaire carbonifere" (*Ann. du mus. roy. de Belgique*), to be fatal to this conclusion. Having no scar, they could not possibly, according to DeKoninck, have had a protoconch. When the so-called perfect apex is broken off, the observer will probably find that this apex was the shriveled remains of a protoconch which concealed the cicatrix underneath, as in Fig. 4.

There is therefore no essential difference between the embryos of the Ammonoidea and those of the Nautiloidea. There are some of minor importance which we cannot discuss here. These, however, do not interfere with the facts of general agreement; and there is great ;probability that the shell-covered forms of all kinds which have the protoconch—namely, the ancient and modern Gastropoda, Tentaculites, and the ancient Pteropoda, and all the radical

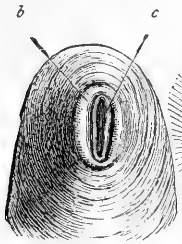

FIG. 3.

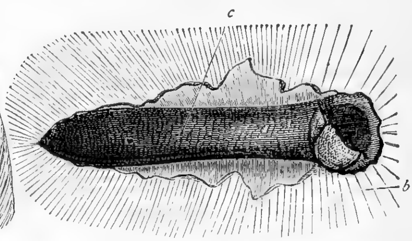

FIG. 4.

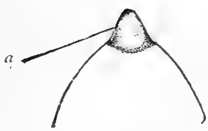

FIG. 5.

FIG. 6.

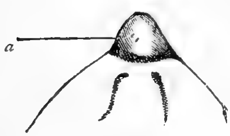

FIG. 8.

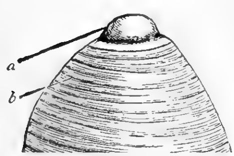

FIG. 9.

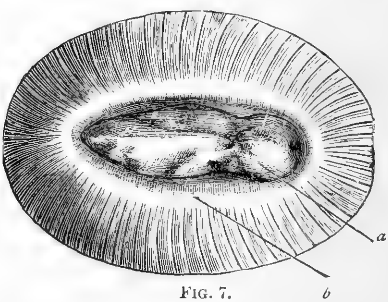

FIG. 7.

Fig. 3.—Aspect of the apex of the conch in *Orth. unguis* Phill., after the protoconch has been shed in the usual manner. *b*, conch or shell of the apex; *c*, cicatrix.

Fig. 4.—Aspect of the apex, after the protoconch has been accidentally broken off, fracturing the outer shell, and exposing the cicatrix. *b c*, as before.

Figs. 5–7.—Apex and protoconch of *Orth. elegans* Munst. from the front, side and above. *a*, protoconch; *b*, shell of apex.

Figs. 8, 9.—Another individual, said to be of the same species, less magnified. *a b*, as before. The author has also, in *Spy. crotalum*, traced the striæ of the outer shell on the protoconch itself, showing the continuity of the shell over this part (*a*), and completing the evidence that it must have been the shell which enclosed the embryo, and could not have been a mere plug, as asserted by Barrande (*Syst. sil.*, pl. 488). (See Figs. 10 and 11, p. 361).

forms of Cephalopoda—had a common origin, probably in some chamberless and septaless form similar to the protoconch.

Clarke has recently shown that a straight, Orthoceras-like shell may have a complete egg-shaped protoconch like that of Bactrites.* His form certainly has the characters of an Orthoceras, but the protoconch is large and like that of the Ammonoidea. The shell may be transitional from Orthoceras to Bactrites, but is probably not a typical form of Orthoceras.

The young of the simplest and earliest of Ammonoidea, the Nautilinidæ, have in varieties of two species, as shown by Barrande, a straight apex, like the adult shell of such forms as Bactrites † and that described by Clarke. I have already claimed that this fact was sufficient to prove the high probability of a common origin from a straight shell like Orthoceras for both of the orders. *Mimoceras compressum*, sp. Beyrich (Figs. 1–6, 20, Pl. ii), is a shell which differs from all other Ammonoidea in an essential and highly important character. The septa have no inner lobe. The V-shaped annular lobe, which occurs in all the Ammonoidea except the Nautilinidæ, is also absent in this species. What is more to the point, some species have the sutures of a true nautiloid, since they have

* "The Protoconch of Orthoceras," *Am. Geol.*, xii, Aug., 1893. See also Figs. 28, 29, Pl. ii.

† A straight form of Goniatitinæ (see Figs. 30, 31, Pl. ii).

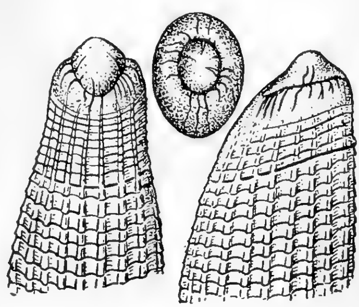

FIG. 10. FIG. 11.

FIGS. 10–12, SPYROCERAS CROTALUM.

* Prof. Hall, in his *Paleontology of New York*, described a young specimen of *Spyroceras* (Orthoceras) *crotalum*, sp. Hall, which he subsequently loaned me for further study. Upon developing the specimen, I found the beautifully preserved apex shown in Figs. 10–12. This shows the shriveled protoconch with striations passing on to its surface from the conch, which are made somewhat more prominent in the figures than in nature, in order to demonstrate this connection. The ananepionic substage is smooth and distinctly marked off from the succeeding, probably metanepionic substage, which shows both longitudinal ridges and transverse bands of growth. The metanepionic substage is marked off below by a more prominent band of growth, probably indicating the aperture of this substage. The paranepionic substage below this changes in the form of the cone and in the character of the ridges and bands of growth. The absence of a hyponomic sinus in the young, of straight as well as of nautilian shells, shows that they were not active swimmers in these earlier nepionic substages, and that the hyponome was acquired or at any rate large and functionally active only at a comparatively late age of the ontogeny.

dorsal saddles in place of dorsal lobes, as in the sutures of their nearest allies among the Nautilini and all of the remaining Ammonoidea. *Mimoceras ambigena* Barr., of the Silurian (Figs. 7, 8, Pl. ii), is a close ally of this Devonian species, and with *Mimoceras* (Gon.) *lituum* (sp. Barr.) Hyatt (Figs. 40–42, Pl. viii), are the only ammonoids which are not involute nautilian in form. The whorls are in contact; but there is no impressed zone, and no sutural lobes on the dorsum, as in true nautilian shells. On the contrary, they are purely gyroceran forms, with rounded dorsum and sutural saddles on this side in place of lobes. All of the Nautilinidæ also have the septa concave, as in the Nautiloidea, in place of the invariably convex character of the septa in later Ammonoidea, as shown in Pl. x. As doubts may disturb the mind as to whether *M. compressum* is an ammonoid, we recommend a comparison of this shell with the young of an undoubted species of Goniatitinæ, *Agoniatites fecundus* of Barrande, which is a miniature copy made by heredity (Figs. 9–11, Pl. ii).

Bactrites is a perfectly straight form, similar to the members of the Goniatitinæ in all important characteristics, especially the siphuncle and septa, and it also has, like the young shell described by Clarke and all the coiled Ammonoidea, a comparatively large protoconch, as demonstrated by Branco, whose figure has been reproduced on Pl. 2 of this paper. This same genus includes straight cones like *Bactrites* (Orthoceras) *pleurotomus* Bar. (*Syst. sil.*, Pl. 296), which are undeniably transitions to true Orthoceras in their striæ of growth and position of siphuncle. There is, therefore, convincing evidence in the structures of these Silurian shells that the Ammonoidea, with their distinct embryos, arose from the orthoceran stock, and passed through a series of forms, in times, perhaps, preceding the Silurian, which were parallel to those characteristic of a number of genetic series among Nautiloidea, viz., straight, arcuate, gyroceran, and nautilian.

In *Science* (Vol. iii, No. 52, February, 1884, p. 127), an article written by the author closed with the following words: "The study of the tetrabranchs teaches us that, when we first meet with reliable records of their existence, they are already a highly organized and very varied type, with many genera, and that there was a protozoic period; and the tetrabranchs, like their successors, certainly must have had ancestors which preceded and generated them in this period, but of which we are at present necessarily ignorant. Whatever the future may have in store for us we cannot now predict; but at present the search for the actual ancestral form, though necessary, is nevertheless not hopeful. We can, however, rely upon the facts of embryology, and predict without fear of failure that, when our knowledge makes this prototypical form known, it will have a decided resemblance in structure and in aspect to the earlier stages of the shell as observed in the fossil cephalopods."

At the time this was written I had in my possession two fossils which I had collected myself in the lowest Calciferous of Newfound-

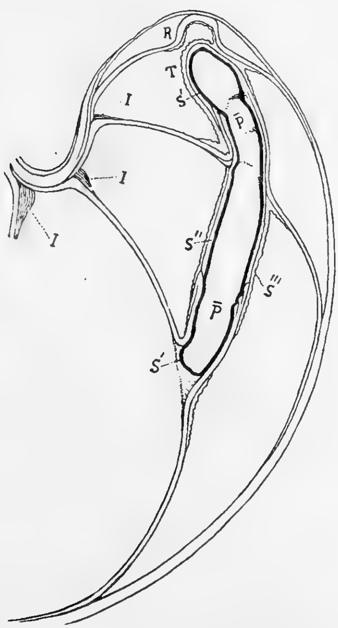

FIG. 13.—*Nautilus pompilius.*
[Contributed by Henry Brooks.]

land. I was aware that they presented peculiar and apparently septate siphuncles, but in the field had supposed this to be due to an accident that not infrequently happens, viz., the intrusion of Orthoceratites of small size into the open upper parts of the large siphuncles of the Endoceras. When an opportunity finally arose, through Dr. C. S. Minot, Secretary of the Thompson Science Fund, to illustrate and publish these forms, I found that this was not the case, but that their siphuncles were truly septate and completely closed to within a certain distance from the living chamber by a series of partitions occurring at regular intervals. These forms I shall describe under the name of Diphragmoceras in the *Proceedings of the Boston Society of Natural History*, and I shall endeavor to show that this genus is one of the distal ancestors of the Nautiloidea. This conclusion is based largely upon comparison with the apical, metanepionic substage of development in the shell of the modern Nautilus. The first septum of the shells has appended to it a closed cæcum or bag, the metanepionic representative of the siphuncle, and the second septum is prolonged apically into a closed tube, the end of which fits into this bag and usually lines it with a second or internal layer. In some cases (Fig. 13, p. 363), probably through the displacement of the second septum, this closed termination is carried forward and is then clearly seen to be a closed tube extending into the siphuncle. The bottom of this tube, in fact, forms a septum in the siphuncle, and the resemblance of this early stage to the adult structures of Diphragmoceras becomes perfectly clear. Diphragmoceras had a closed tubular prolongation of the base of the mantle like that of the metanepionic septa of Nautilus and also more remotely similar to that which occurs in Endoceratidæ. But it does not diminish in size towards the apex, hanging like a cone in the middle of the siphuncle; nor does it, as in that genus, also fill the siphuncle below its own extremity with a continuous mass of calcareous matter having a cone in cone structure, nor has it any endosiphuncle. The sheath fits the siphuncle closely and rises step by step with the body, its end forming septa across the siphuncle at the resting stages of this process corresponding in number to those of the shell, but not corresponding in position, each septum being situated just in the interval between two septa, or opposite each air chamber of the conch. Thus the siphuncle becomes divided into air chambers like those of the surrounding shell, but these partitions are not pierced by any endosiphuncle, as are the endocones formed by the sheath in the Endoceratidæ and the solid deposits and peculiar rosettes of the Actinoceratidæ.*

Dr. Charles E. Beecher has been fortunately able to lay hands upon the primitive radical of all of the Brachiopoda through the study of the early stages of the shell and has shown that the common embryonic shell or *protegulum* of recent and fossil Brachiopoda is represented by one of the earliest occurring forms, Paterina. Dr.

* "Genera of Fossil Cephalopods," *Proc. Bost. Soc. Nat. History*, xxii, 1883, p. 272.

R. T. Jackson has accomplished the same result for the Pelecypoda by following the same mode of analysis, and shown that Nucula was the common form to which all bivalve shells can be traced. Among corals, as shown by Beecher, there are satisfactory indications that there is a common ancestral form of at least a large proportion of that class, and the labors of Barrande, Mathews, Walcott and Beecher are leading to similar conclusions for the Trilobites. The theory of monogenesis, or origin of similar forms from one form, is in other words now rapidly passing from the condition of a reasonable inference from the facts of development and evolution, in which it has stood since the time of Von Baer, to that of a demonstrated law of general application.

The individual coiled shell of every nautiloid may be said to pass through the stages of the protoconch and point of the apex, when it is nearly straight;* then it becomes slightly curved or cyrtoceran, and then through a more completely curved or gyroceran stage, in which the first volution of the spiral is completed. After this it continues the spiral, commonly revolving in the same plane and becomes truly nautilian, the whorls on the outside touching the exterior of the inner ones, and spreading so rapidly by growth as to begin to envelop them, and in extreme cases, as in *Nautilus pompilius*, completely covers them up.

The natural inference from these facts would be, that there was a similar succession of forms in past times—the straight in the most remote, the arcuate and the gyroceran in succeeding periods, and the nautilian only in comparatively modern times. This would be a perfectly clear and legitimate mental conception. The structural relations of the adult shells appeared also to demand the same solution, as shown by the researches of Quenstedt, Bronn and Barrande, and later of Gaudry. Barrande's researches, however, demonstrated that this idea could not be maintained, and that there were no such serial relations in time, but that the whole series of forms from the straight to the nautilian were present in the earliest period, and occurred side by side in each Paleozoic formation.

This great author's conclusions have had a curious effect upon

*It is to be noted in this connection that the earliest nepionic substages do not have equal circular bands of growth, even in true Orthoceras, and are never quite symmetrical on the dorsum and venter. In other words, the descriptive term, straight, is only applicable in a general way. The youngest stages of the conch having differentiated venter and dorsum and a compressed elliptical outline which is similar to that of the radical ancestral form Diphragmoceras. See Figs. 10-12, p. 361.

paleontologists. It has been hastily assumed by some, Barrande himself leading in this respect, that the mental conception was more than could be realized in nature; and that the imperfection of the recorded succession was an obvious refutation of the doctrine of evolution, and all pursuit of a solution unworthy of serious attention.

Statistically, the logical picture coincides with the observed succession in time. The straight cones predominate in the Silurian and earlier periods; while the loosely coiled are much less numerous, and the close coiled and involute, though present, are also rare. The close coiled, or nautilian shells, gain in numbers in the Carboniferous, and the involute—meaning by this those that envelop more or less the inner and younger whorls—are much more numerous than in the Silurian; while, in the later times of the Jura, all disappear except the involute.

But suppose we reverse the course of nature and follow back the diminishing number of nautilian and gyroceran shells. We then see, upon arriving at the Silurian, that the vanishing point of these shells, although not traceable on account of the lost records of Protozoic time, could not have been far distant, while the increasing number and varied forms of the straight cones indicates for them a more remote focus in time and consequently a more ancient origin. Thus we are able to see, that antecedent to the Silurian, in the Protozoic, there must have been a time when the straight cones or their immediate ancestors predominated, to the exclusion of the coiled and perhaps even of the arcuate types.

The involute shells of the earliest geological times were, therefore, probably evolved from the straight cones in regular succession; and we may, perhaps, hope to eventually get the evidence of this succession in the fossils themselves. The exact counterpart of our logical picture, as Barrande has truly stated, does not, however, exist in the known geological records of later periods. Judged by the common classification, by the prevalent ideas about the affinities of adult structures, and by the modes of occurrence of fossils in the rocks, the forms seem to be without law or order in their succession, and that eminent author's objections to the theory of evolution have never been fairly met and refuted by any modern writer.

But let us imagine, during the Paleozoic, a different condition of affairs from what is now the general rule. Let us suppose such a thing possible as the quick evolution of forms and structure, and that in these ancient periods, near their points of origin, animals found the earth comparatively unoccupied, and were not only able, but in fact forced, to migrate in every direction into different habitats, and to make perpetual efforts to readjust their inherited structures to the new requirements demanded by these comparatively unoccupied fields. Food and opportunity would have acted, in such localities, as stimulants to new efforts for the attainment of more perfect adaptation and for changes of structure useful to that end. We can neither imagine the effort to change of habitat and consequently change of habits, without their cause the primary physical stimulant of change in the environment, nor the changes of structure, except as results of efforts on the part of the organism to meet the physical requirements of the surroundings. That this process should end in the production of structures suited to the environment is inevitable. *With these factors at work, both without and within the organism, the evolution of their structures obey a physical law which acts amid a thousand disturbing forces perhaps, but nevertheless must act with predominating force in one mean path or direction, the resultant determined by the environment and the inherited structures of the organism.*

One can compare the changes taking place during the whole of Paleozoic time with those known to have occurred in certain isolated cases in more recent times; such, for example, as that of Steinheim, where a single species, finding itself in an unoccupied field, proceeded with unexampled rapidity to fill it by the evolution of new series and many species, all differing from each other, but all referable, by intermediate varieties, to the original form—in this example, a single species, the well-known *Planorbis æquiumbilicatus*.*

The rapid evolution of the entire family of the Arietidæ can also be used to illustrate this point. This family originates from one ancestral species and yet the process is so rapid that eleven distinct series and seven genera arise, culminate and disappear within the limits of a single age of geologic history, the Lower Lias of Europe, South America and North America.†

There are a number of other well-known cases, which could be cited, illustrating the quick evolution of species in locations which

* "Genesis of Tertiary Species of Planorbis at Steinheim," by Alpheus Hyatt, *Memoirs 50 Year Anniv. Bost. Soc. Nat. Hist.*

† "Genesis of the Arietidæ," by A. Hyatt, Smithson. Contrib. No. 673, Mem. Mus. Comp. Zool.

were obviously free when they first entered them. If we admit such possibilities, and then find similar phenomena in the Paleozoic epoch, we shall no longer need our first picture, but can construct a far more natural one.

The Nautiloidea will not then present themselves as a simple chain of being, but as they really were—several distinct stocks or grand series, arising from a common stock or radical, and each of these grand series divisible into many parallel lines of genetically connected forms. In the Lower Silurian, some of these do not have close-coiled forms at all; some of them have: but all, except the most primitive series, which are composed wholly of straight or arcuate forms, have some close-coiled species. These we can often trace directly with the greatest exactness, both by their development and by the gradations of the adult forms, to corresponding species among the straight shells.

The series we have described above, from the straight Bactrites to Goniatites, compares closely with any single genetic series of the Nautiloidea, and shows that this last arose very suddenly in the Protozoic, and evolved true nautilian shells in the Calciferous and Quebec groups on the earliest fossiliferous level known positively to contain the remains of Cephalopoda.

The genera of Ammonoidea evolved in the Silurian and Devonian are structurally much more distinct from each other than any groups of the same value (*i. e.*, genera) in the succeeding formations, and thus, in different but equally plain characters, teach us that they also had a quicker evolution within those periods than in the later formations. Either this was the case, or else the Ammonoidea were created in full possession of an organization only attained by similar parallel series of congeneric, close-coiled nautiloids, after passing through all the intermediate transformations above described.

These comparisons bring out other curious results. Thus although both are orders and taxonomically equal, we cannot compare the whole of the Ammonoidea with the whole of the Nautiloidea, but only with a more or less perfect single series of that order.

The radicals of the Nautiloidea, Diphragmoceras, Endoceras, Orthoceras and Cyrtoceras, evolve through time as an organic trunk giving off an indefinite number of small branches in Paleozoic time, each branch complete in itself and composed of successive species becoming more arcuate, coiled and closer coiled and finally involute. In the Trias the trunk comes to an end, but a small number of branches composed entirely of close-coiled forms continue the existence of the order.

The Ammonoids have similar straight radicals, but these are few in number, dying out in the Devonian, leaving in that period a number of branches of closely coiled and involute forms, the Goniatitinæ. These immediately manifest a capacity for expansion and become the radicals of other involute and more modified involute series which expand in the Trias and Jura, becoming less numerous and degenerate in the Cretaceous and cease to exist with that period or soon afterwards. The history of the Ammonoidea so far as the succession of different forms is concerned is as a whole like that of a single series of the Nautiloidea which can be traced back to a primary straight radical and which has a complete history of modifications, but which necessarily occupies much less space chronologically, evolving and disappearing within perhaps the limits of a single epoch of geologic time.

The trunk of the Nautiloidea is in other words a huge cone-like trunk, clothed with branches but topped only by a few straggling persistent survivors shooting up through time and reaching the present surface with the tip of a single twig. The trunk of the Ammonoidea is only a slender short branch, springing from the Nautiloid trunk, but spreading out and splitting up into many smaller branches. Like a climbing vine of huge proportions it ascends through geologic history, resting upon the level of each age or epoch as upon a horizontal trellis and spreading into great masses of branches at each of these resting places. It shows throughout its evolution less power to resist the action of the surroundings both in the number and high specialization of the forms produced with every change in geologic history, but also in the more rapid and earlier disappearance of each type, and finally in the total disappearance of the entire order.

This comparison fully accords with the true picture of the genetic relations. The remarkably sudden appearance and fully developed structures of these earlier ammonoids finely illustrates the fan-like character of the evolution of forms from centres of distribution, and the quickness with which they must have spread and filled up the unoccupied habitats.

The contemplation of the wonderful phenomena presented by these series has finally led the author to the conclusion that the phenomena of evolution in the Paleozoic were distinct from those of later periods, having taken place with a rapidity paralleled only in later times in unoccupied fields, like Steinheim.

The hypothesis of Wagner, that an unoccupied field is essential for the evolution of new forms, gains immensely in importance, if it is practicable to apply it to the explanation of the morphic phenomena that have been observed. Every naturalist must see at once, by his own special studies, that this is a reasonable explanation of the rapid development of types in new formations and of the sudden appearance of so many of the different types of invertebrates in the Paleozoic.

Newberry's theory of cycles of sedimentation shows that the sudden appearance of types is inexplicable, except upon the supposition that their ancestors retired with the sea between each period of deposit, and again returning after long intervals of absence made their appearance for the first time in a given littoral fauna bearing changed characteristics and different structures acquired by the migrations of their own stock in unknown seas.

With this explanation and that of Wagner the facts that have been observed fully coincide, and amply explain the phenomena, both of sudden appearance in the first deposits of formations, and subsequent quick development in the necessarily unoccupied habitats. The researches of Barrande, Alexander Agassiz, Bigsby, Gaudry and many others, show us that this must have been especially true of the Paleozoic as compared with subsequent periods.

In order to make a logical and generalized picture of correspondence between all the changes in the life of a nautilian close-coiled shell and the life of its own group accord exactly with the facts, care must be taken to limit it to groups quickly evolved, and these exclusively Paleozoic. Among Nautiloidea there are no series traceable directly to arcuate forms after the expiration of the Carboniferous. This is the common story, and we can see that the series must have risen very rapidly during the Paleozoic, branching out on every side from the common ascending trunk of the straight and arcuate forms. The same is true of the Ammonoidea in the Silurian, but only one short series, the Nautilinidæ, arises from the common trunk of straight cones. The close-coiled shells of this one family became the stock form for the whole of the Ammonoidea.

The Nautiloidea of the Mesozoic are all nautilian forms, and their genetic series do not present the rapid changes of form observed in the Paleozoic; they are all close coiled and have, as observed by M. Barrande, small umbilical perforations. This same statement applies also to the Ammonoidea; when near their point of origin in the Silurian their forms are very quickly evolved, but are much less quickly evolved after this period. The smaller genetic groups in the Paleozoic are distinguished by differences between the sutures, which are decided indications of structural distinctions. Thus the groups of Clymeninnæ and Goniatitinæ differ widely in their sutures and position of siphuncle, and smaller groups have also decided structural differences. In later times the families and, in fact, the whole of the Ammonitinæ are more alike. There are many genetic series in the Jura which can be distinguished by the minor details of the ornaments and outlines of the sutures, the differences being less structurally than in the Paleozoic. In other words, the field of variation is structurally decidedly narrower in the Mesozoic than in Paleozoic, whether we consider the Nautiloidea or Ammonoidea.

I have observed the same phenomena repeated in each period and in the mode of appearance of the genera and families in lesser divisions of geologic time. Groups originate suddenly and spread out with great rapidity and often, as in the Arietidæ of the Lower Lias, are traceable to an origin in one well-defined species which occurs in close proximity to the whole group in the lowest bed of the same formation. These facts and the acknowledged sudden appearance of the greater part of all the distinct types of Invertebrata and Vertebrata in the Paleozoic speak strongly for the quicker evolution of forms in that time and indicate a general law of evolution. This has, in former publications, been formulated as follows: *Types are evolved more quickly and there are greater structural differences between genetic groups of the same stock while still near the point of origin than appear subsequently. The variations or differences take place quickly in fundamental structural characteristic, and even the embryos may become different when in the earliest period of evolution, but subsequently only more superficial structures become subject to great variations.*

This law applies only to the epacme or rise and acme, not to the paracme or decline of the same genetic groups or stocks. These last will be shown further on to reverse this law of progressive evolution.

The degraded uncoiled forms of the Nautiloidea and Ammonoidea, wherever they occur, whether in the Silurian or in the Cretaceous, invariably have coiled young, showing that they were the offspring of coiled or nautilian shells, that is, of progressive forms which have themselves been evolved from a series of straight arcuate and gyroceran predecessors. Their uncoiling is a truly retrogressive character, and this tendency is inherited in successive forms in several series, and thus the whole structure is finally affected, the whorl reduced in size, and the complication of the sutures and shells at all stages of growth is degraded until, in the development of the individual, only the close-coiled young remain to testify to their exalted ancestry. In other words, the forms really inherit degraded characteristics at such an early stage that it affects their whole life except the earlier stages.*

If we examine any of the progressive series we find that characteristic modifications or variations tend to appear first in the later stages of growth and, as a rule, in adults, then in successive forms of the same genetic series they tend to appear at earlier stages of the ontogony and finally often disappear altogether or become embryonic, and this is the case also with the degraded characteristics. This is clearly shown in the illustrations given on Pls. ii, iii, iv, especially in the history of the development of the sutures among Ammonitinæ. The simpler sutures of the Nautilinidæ of the Silurian and Devonian have undivided ventral lobes and broad lateral lobes. The more specialized forms of the same suborder in the Devonian have the ventral lobes divided, prominent saddles are also introduced, and the lateral sutures become more sinuous. These characters, especially the division of the ventral lobes, occur in these forms (as in Fig. 17, Pl. 2) in an early neanic substage, having replaced the hereditary undivided ventral of the adults of the Nautilinidæ and forced this characteristic back until it is repeated only in the earlier or paranepionic sutures. In the Ammonitinæ of the Trias and Jura this process is carried still farther. The repetition of the undivided ventral of the Nautilinidæ is confined to the earlier septa, which show sinuous lateral outlines (as in Figs. 2, 3, Pl. 4) and these septa become immediately convex, the

* Several examples are given of such forms among Nautiloidea in the text and the similar uncoiling of the gerontic or senile stage is shown in the ontogony of a number of species in the plates, notably *Eurystomites kelloggi* (Pl. iv, Fig. 1). Among Ammonitinæ see young of *Crioc. studeri* (Pl. iii, Figs. 11, 12), *Crioc. studeri*, after Barrande (Pl. ii, Fig. 40), *Ancyloc. calloviense*, after Barrande (Pl. ii, Fig. 41), and Baculites, after Brown (Pl. iii, Fig. 13).

first one alone being concave, the divided ventral is introduced earlier in the ontogony and, finally, the division of the outlines by digitations occurs in the earliest neanic substage, replacing the simpler sinuous outlines of the preceding suborders.

In the evolution of a series heredity therefore acts according to a definite law of replacement. *The ancestral characters are brought into contact with new adaptive characteristics, which are being continually introduced into the adult and adolescent stages of ontogeny, and these eventually replace the former which are crowded back to make room for them into earlier stages than those at which they first appeared, and in many cases the latter are resorbed and disappear during this process.*

It is a fact, as shown by the writer and especially by Barrande and Dr. Brancö, that the embryonic shell has varied comparatively little throughout time in the Ammonoidëa, Nautiloidea, Belemnoidea and Sepioidea. But these statements do not apply to the earliest times in evolution of these types, when they branched off from the common stock. The embryos of the Ammonöidea and Nautiloidea become quite different from each other, the embryos of the Belemnoids remained like those of the Ammonoids, almost exactly similar to those of the Nautilinidæ as shown by Chalmas and Branco, and finally in the Sepioidea, the protoconch or embryonic shells changed more completely and soon disappeared. Attention has been already called to this remarkable fact in the history of the evolution of these forms, that the separation of the orders took place rapidly, and in the embryos as well as in the adults near the origin of the orders, and that the comparative invariability of the embryo was confined to the subsequent history of these types after separation. There is also considerable ground for the conclusion that the young, not the earliest stages of shell, are more variable among the degraded types than among progressive forms. The facts already stated with regard to the young of Baculites and some crioceran forms show this.

This paper cannot be devoted to the discussion of the apparent reasons for these changes, but we have been able to explain the mode in which they take place. *The mode in each case is the earlier or accelerated development of ancestral characters, which as we have said follow the same law, whether progressive and tending to preserve the characters of the type, or retrogressive and tending to destroy the characters of the type.*

Attention is given to the acceleration of development because it will be used in this paper and also because in looking at the young in the usual haphazard way, naturalists often do not find the strong marks of affinity which the ordinary modes of studying lead them to anticipate. The law of acceleration explains the disappearance of important characteristics which often occur even in short and comparatively small series. It acts frequently within a small group like the Arietidæ, so that the later larval and adolescent stages are unlike the same stages in very nearly related species in the same family. Unless investigators are willing to take a small well-characterized group and follow out all its transformations they cannot hope even to understand the remarkable phenomena which are shown more or less in the history of every complete genetic series.

Embryologists generally consider it essential to associate all forms having similar embryos, and to place widely apart in classification all forms having different embryos. As a matter of experience that is correct, but it does not apply to the earliest times in the evolution of types and the surest guides of affinity are sometimes the adult gradations of forms. These show that the Nautiloidea and Ammonoidea with comparatively distinct embryos are nevertheless more closely related than the Belemnoidea and Ammonoidea which have precisely similar embryos, and Sepioidea and Belemnoidea which have very distinct embryos must also be affiliated.

The embryos of all these must have been precisely similar at their origin, but they afterward became varied in the different orders, and we cannot lay down any hard and fast rule by which the embryo becomes an invariable criterion of affinity. We think there is ample reason in the structures of these shells themselves to account for the embryonic differences, and that it is possible to reconcile them with the affinities indicated by the gradations observed between the adults. These reasons which we have only space to allude to here consist in tracing the gradations of adult structures and in a series of correlations which are plainly apparent between the adult structures, and the habits of the animals, and the power which habits in conjunction with effort have to change the adult structures, and then by the action of the law of acceleration in heredity to change even the embryos, either quickly, when the habits are widely changed, or more slowly when they vary but slightly with the progress of time.

Evolution is apparently a mechanical process in which the action of the habitat is the working agent of all the major changes; first taking effect as a rule upon the adult stages, and then through heredity upon the earlier stages in successive generations. Thus in the open fields of the periods of their origin they expanded into their different habitats, varying to accomplish this purpose with great rapidity, but once in their appropriate habitat, inducements to change or open fields became rarer and we get as a result comparative invariability. As time rolled on and the earth became more crowded, the variability was reduced to less and less important structural changes, except in the retrogressive types. These exceptions are our best proofs of the action of the habitat. The changes in these retrograde forms are again remarkable for the rapidity in which they take place, and some of these types, at least, can be shown to have occupied free fields where they met with new conditions, and to have changed their habits and structures rapidly to accord with these new conditions.

In 1843 Auguste Quenstedt began researches which ought long ago to have led to this solution. He demonstrated by repeated examples, that among diseased types the most extensive changes of form and structure might take place in a single species, and within the narrowest limits of time and surface distribution. Quenstedt was thus the first to show that in diseased forms the shell had the inherent habit of reversing the process of growth and evolution, and of becoming more and more uncoiled by successive retrograde steps. Von Buch and Quenstedt, master and disciple, and the author independently of either of these predecessors, in three successive researches, have arrived at the identical conclusion, that these uncoiled shells are truly distorted, or, as we may more accurately express it, pathological forms. They are not, however, rare or exceptional, as one might at first suppose, but occur in numbers and in every grade, from those that differ but little from the normal forms, to those that differ greatly; from those that are exceedingly confined in distribution, to those which lived through greater lengths of time. But in all cases they exhibit degradation, and are expiring types. The author has repeatedly traced series of them, and studied their young, partly in Quenstedt's own collection. In all cases they show us that great changes of form and structure may take place suddenly; and this lesson could have been learned from Quenstedt's work and example as well forty years since as now.

When we attempt to understand these pathologic uncoiled series and forms, which show by their close-coiled young that they were descended from close-coiled shells, we find ourselves without comparisons or standards in the early life of the individual. The laws of geratology—that the old age of the individual shows degradation in the same direction as, and with similar changes to those which take place in successive species or groups of any affiliated series of uncoiled and degraded forms—here come into use, and serve to explain the phenomena. This correspondence is shown in the uncoiling of the whorls, loss of size, the succession in which the ornaments and parts are resorbed or lost, the approximations of the septa, and position of the siphuncle. It is quite true, as first stated by Quenstedt and also by D'Orbigny, that every shell, when outgrown, shows its approaching death in the closer approximation of the last sutures, the smoothness of the shell, the decrease in size, etc.; but, in order to realize that these transformations mean the same thing as those which take place in any series of truly retrogressive forms, we have to return to the types in which unfavorable surroundings have produced distortions or effects akin to what physicians would term pathological.

This frequently happens in small series of Nautiloidea; and, if we confine ourselves to these, we can make very accurate comparisons: or, on the other hand, in the case of the Ammonoidea, we may trace the death of an entire order, and show that it takes place in accordance with the laws of geratology. Such series, among the Nautiloidea, are abundant in the earlier formations; but they have not the general significance of the similar forms among the Ammonoidea, and can be neglected in this article. There are no known cases of degraded series of uncoiled forms among the ammonoids of the earlier or Paleozoic periods; they may have occurred, but they must have been excessively rare.

In the Trias and early Jura, pathologic uncoiled forms are rare among ammonoids, but in the Middle and Upper Jura they increase largely; and finally, in the Upper Cretaceous they outnumber the normal involute shells, and the whole order ceases to exist. Neumayer has shown, that a similar degradation occurs in all of the normal ammonoids of the Cretaceous, and that their sutures are less complicated than those of their immediate ancestors in the Jura. This proves conclusively, that the degeneration was general, and affected all forms of Ammonoidea at this time; since the uncoiled forms are not confined to special localities, as in the Jura, but are found in all faunas so far as known.

The facts show that some general physical cause acted simultaneously, or nearly so, over the whole of the known area of the world during the Cretaceous period, and produced precisely similar effects upon the whole type as had here and there been noticeable only within limited localities and upon single species or small numbers of species during the previous periods. This general cause, whatever it may have been, affected the type so as to cause the successive generations of the larger part of the shells to become distorted, smaller and more cylindrical in their whorls, smoother and to lose their impressed zones and their complicated foliated sutures. In extreme cases they became again, with the exception of the earliest stages which are usually broken off and lost, perfectly straight cones, like the orthoceratitic radicals. So much alike are they, that it is quite common for those who are not students of this group to mistake the degraded Baculites for the radical Orthoceras. This decrease in size, increasing smoothness, and uncoiling, is precisely parallel with the similar transformations taking place during old age in the normal involute shells of the Jura, which, when old enough, also depart from the spiral, or tend to straighten out, and always lose their ornaments, decrease in size, and so on.

The universal action of the surroundings, as we now know them, is certainly not exclusively favorable to the continuance of life, and may be wholly more or less unfavorable. It certainly perpetually excites the animal to new and more powerful exertions, and, like perpetual friction, wears out its structures by the efforts which it obliges it to make for the support of the structures in doing work. At first this leads to development, the supply being greater than the demand; but sooner or later, and with unvarying certainty, the demand exceeds the powers of supply, and old age sets in, either prematurely, or at the termination of the usual developmental periods. The remarkable and at present unique example of the Ammonoidea places us in a position where we can see the same process taking place in the whole of a large group, with attendant phenomena similar in every respect to those which we have observed in individual shells of the same order.

In numbers of species and genera, and in the complication of the internal structures and the production of the external ornaments on the shells, the order reaches what appears to be the acme of evolution in the Jura; then retrogression begins, and, steadily gaining, finally affects all forms of the type, and it becomes extinct. Smaller series of the Ammonoidea and Nautiloidea go through the same process within their more restricted time-limits, and in the same way, but can be compared with the individual much more accurately and closely. It is evident, then, that the comparison of the life of an individual with that of its immediate series or group reaches a high degree of exactitude, and that the observed phenomena of the life of an individual should enable us to explain, in some measure, the equivalent phenomena of the life of the group; and we are unavoidably led to entertain the expectation that it does explain it.

The evidence is very strong that there is a limit to the progressive complications which may take place in any type, beyond which it can only proceed by reversing the process, and retrograding. At the same time, however, the evidence is equally strong that there are such things as types which remain comparatively simple, or do not progress to the same degree as others of their own group. Among Nautiloidea and Ammonoidea these are the radical or generator types. No case has yet been found of a highly complicated, specialized type, with a long line of descendants traceable to it as the radical, except the progressive: and all our examples of radicals are taken from lower, simpler forms; and these radical types are longer-lived, more persistent and less changeable in time than their descendants.

We find the radicals of the Nautiloidea living throughout the Paleozoic, and perpetually evolving new types in all directions; then this process ceases, and the primary radicals themselves die out. But they leave shells, which are in that stage of progression which I have called the nautilian. These, the more direct descendants of the radicals, become secondary radicals and generate series having more involute shells. These, in turn, as secondary radicals, exhibit a greater chronological distribution than their descendant involute forms. The same story may be told of the Ammonoidea, but substituting at once the close-coiled shell (the secondary radicals) for the primary radicals of the Nautiloidea, even as far back as the Devonian.

This is the essential element of difference between the life of the whole order and that of the individual. One can accurately compare the rise and fall of the individual and its cycle of transformations with that of any of the single series or branches of the same stock which become highly specialized and then degenerate; but, when an attempt to go farther is made, similar difficulties arise to those encountered in tracing the progress of types and orders. The radical and persistent types are still present, and teach us that, as long as they exist sufficiently unchanged, new types are a possibility. I have traced a number of these in the two orders, and have found that they change and became more complicated, and that probably a purely persistent or entirely unprogressive type does not exist among the fossil Cephalopoda.

The most celebrated example of unchanging persistency has been, and is now supposed to be, the modern Nautilus. The similarities of this shell to some of the Silurian coiled forms—which have caused Barrande and others to suppose that it might be transferred to the same fauna without creating confusion—belong to the category known to the naturalist as representative. It is similar in form, and even in structure, in the adults, but has young with entirely distinct earlier stages of development, and belongs to distinct genetic series. The young of the existing *Nautilus pompilius*, shown on Pl. i, can be easily compared with those of their supposed nearest congeneric shells, Barrandeoceras of the Silurian given on Pl. v, Figs. 6–10.

Comparative invariability or persistency is common to all radicals; and they force us to recognize the fact that the orders could have produced new series, as long as they were present, if it had not been for the direct unfavorable action of the physical changes which took place, so far as we now know, over the whole earth. Thus, in making comparisons between the life of the individual and the life of the group, one cannot say that the causes which produced old age and those which produced retrogressive types were identical: it can only be said that they produced similar effects in changing the structures of the individual and of the progressive types, and were therefore unfavorable to the farther development and complication of these types. In their effects they were certainly similar; but in themselves they might have been, and probably were, quite different, agreeing only in belonging to that class of causes usually described as pathological, or those whose nature can be generally summed up as essentially unfavorable to the progress, and even to the existence, of the organism.

In order to understand the meaning of these evidently degraded structures, we must turn back to the first remarks upon the order. The apertures and forms of the retrogressive shells all show that they were exceptional, that they had neither well-developed arms for crawling nor powerful hyponomes for swimming; that, in other words, they could not have carried their spires in any of the ordinary ways. Their habits, therefore, must have been more or less sedentary; and like the sedentary Gastropoda, Fissurella, Patella, etc., as compared with the locomotive forms, they presented degeneration of the form and structure of their more complicated ancestors. Their habits did not require the progressive grades of structure, and they dispensed with or lost them; and in many cases this took place very rapidly. This retrogression was in itself unfavorable to a prolonged existence; and the phylogerontic nature of the changes tells the same story, and one can attribute their extinction to the unfavorable nature of their new habitats, and also call them pathologic types without fear of misrepresenting their true relations to other forms.

II. Principles of Bioplastology.

Relying upon the results of such researches as are described above and especially upon those of Cope, Ryder and Packard, I have in a former publication used the name Bioplastology to designate that branch of research which deals especially with the characteristics of development and decline in the life of an individual and endeavored to show that correlations exist between these and the life history of the group to which the individual belongs. In order to classify this branch of research properly it is necessary to separate it from other allied modes of studying organic phenomena.*

Auxology or Bathmology.†

Mr. Buckman and Bather, both well known for their original and instructive researches on Paleozoölogy in England, have recently, in a joint paper under the title of "The Terms of Auxology,"‡ criticised the nomenclature employed in my papers to designate the stages of growth and decline in the individual. They have also

* The author has given a synopsis of the facts that seem to characterize the different branches of research and their relations to Bioplastology in a paper entitled, "Bioplastology and the Related Branches of Biologic Research," *Proc. Bos. Soc. Nat. Hist.*, xxvi, pp. 59-125; and a brief preliminary abstract appeared in *Zool. Anzeiger*, Nos. 426, 427, 1893.

† Cope, *Proceedings Phil. Soc.*, Phila., Dec., 1871, and *Origin of the Fittest*, p. viii, etc.

‡ *Zool. Anz.*, Nos. 405, 406, 1892.

proposed in view of the correlations which have been shown to exist between the transformations that occur in the stages of development and decline in the individual and those that characterize the evolution of the group to which it may belong, to designate the study of these correlations by the new term "Auxology," This term is open to the objection that it is derived from αὔξη, meaning simply progressive growth up to and including the adult stages, and, although in common with others I have felt that it has claims to be retained, there are good reasons why it should be restricted in application, if adopted, to researches upon growth. I have placed alternative terms at the head of this abstract, because one or the other is likely soon to be adopted and I hardly feel competent to arrive at a decision myself without further study of the facts.

Cope in his "Method of Creation of Organic Forms," used the term Bathmism from *Βαθμός*, meaning a step or threshold, to designate growth force, and it is therefore questionable whether the term Bathmology should not be substituted for Auxology in order to give uniformity to the nomenclature.

Dr. C. S. Minot, who has given the first demonstration of the fundamental law of growth, has shown that the common notions with regard to the action of this force in organisms are erroneous. His plotted curves of the actual additions in bulk to the body by growth during equal intervals of time in guinea pigs show that these increments are in steadily decreasing ratio to the increase of weight of the animal from a very early age. He was so much impressed by these facts that he characterized the whole life of the individual as a process of senescence or growing old.

This law is applicable also to the growth of the body as measured by the ratio of the increase of the shell in all its diameters and by the distance apart of the septa with relation to the ratio of increase of the transverse diameters of the volution. The great rapidity of the growth starting from the apex of the conch is obvious and can be observed in all the figures of the young given in this paper which spread out suddenly in the building of this part of the skeleton. The septa mark successive arrests in this process of construction, and it can be readily seen that the first septa are wider apart in proportion to the diameters of the volution in the nepionic (larval) stage than in the early part of the neanic (adolescent) stage and that more uniformity in the distance apart occurs in the ephebic (adult) stages until the last of the gerontic (senile) stage is reached.

Then the septa alter in this respect and finally in extreme paragerontic substage the approach of extinction is heralded by the close approximation of several septa, as has already been stated above. The greater number of these that show this change indicate that the species possess great vital power and has a prolonged old age changing slowly, and the small number show that senility is a more rapid process. In the higher, more specialized Nautiloids and Ammonoids there are usually only two or three approximate septa in old age; in Endoceras, a radical type, there may be as many as twenty-two which show degeneration in the rate of growth. There are other phenomena of a similar character which might be noticed in this connection, but must be deferred to future publications.

Naturalists have as a rule understood the differences between the organic molecular increase that takes place within cells which is the simplest form of growth, and that which follows this and builds up the tissues of the body by the division of cells. Both of these processes, although distinct from each other, result in additions to the bulk of the whole body of the organism and come properly under the head of growth. But while both are thus constructive so far as the body is concerned, only one can be considered constructive or anabolic while the other is essentially destructive or catabolic so far as the cell itself is concerned.

The function of nutrition and the nature of the organic structure are the two essential factors of growth, and this term, *i. e.*, growth, also obviously applies to the morphology of metabolism, consisting of intracellular increase, or anabolism, and cellular development, or catabolism, and the phenomena resulting from the alternating action of these in ontogeny. This at once shows that growth is not simply progressive addition to the bulk of the body, since the multiplication of cells by fission is in itself catabolic or developmental so far as the cells are concerned. Further than this the ultimate results of catabolism are of the nature of reductions as is shown by Minot's law,* and also by Maupas' observation † on the old age of the agamic cycle in Infusoria and the results of late researches on amitosis in cellular fission. These and the actual reduction of the body taking place in extreme senility show that the term growth

* "Senescence and Rejuvenation," *Journ. Phys.*, xii, No. 2, 1891, and address on "Cert. Phen. of Growing Old," *Am. Assoc. Adv. of Sc.i*, xxxix, Aug., 1890.

† "Recherches expérimentale sur la multiplication des Infusores ciliés," *Arch. de Zool. experim. et gén.*, Sr. 2, vi, pp. 165–277, *et ibid.*, vii, pp. 149–517.

covers decrease in bulk due to development and use as well as increase.

When one passes beyond this and attempts to deal with the characteristics of ontogeny or phylogeny he at once finds himself in the presence of other forces, such as heredity and other processes, namely, the acquisition of new characters and the renewal of the powers of growth in nuclear substances by means of conjugation.

The manifestation of growth energy, in brief, arises from two factors, or, at any rate, is always found associated with two, a living organism and assimilation of nutritive matter, and is an obvious result of their union.

Genesiology.

The term heredity has been used in two senses, one expressing the results of the action of an unknown force which guides the genesis of one organism from another and a second in which it implies the force itself. Clearness of statement demands that some other term than heredity should be used, and I have consequently proposed to designate the study of the phenomena by the term Genesiology, from *Γένεσις*, meaning that which is derived from birth or descent, this force itself as genetic force, and the principle of heredity thus becomes genism.

The continuity of the same element in the agamic division of unicellular bodies, as in Protozoa, makes it comparatively easy to explain the transmission of likeness, but this is growth of the ontogenic cycle. Maupas shows this clearly and continually speaks of the growth, full-grown virility, and senility of his generations of unicellular, agamic protozoans. In fact they are obviously in a disunited form the equivalent of the colony of protozoans, and secondarily, although more remotely, the equivalent of the single metazoan, or individual, which is essentially a cycle of agamic cells reproducing by fission.

While this likeness of agamic daughter cells to the original agamic mother cell which has disappeared in them may be considered a manifestation of heredity, it is also a form of growth and readily separable from the more complicated relations of organism produced by conjugation of two forms. When the transmission of likeness is complicated with the effects of conjugation the difficulties increase until finally, in the bodies of the Metazoa, they culminate in a problem of surpassing difficulty. Heredity is as plainly written in the life history of the Protozoan and in the growth of cells; in the tissues in the budding of the Metazoa and parthenogenesis as in these more complicated forms, but the phenomena ot transmission occurring after conjugation can be separated from growth and considered upon entirely distinct lines.

The theories offered show this. Thus the corpuscular theories, whether gemmules or biophors or pangenes are assumed, assert the need of minute bodies for the transmission of characters, while on the other hand the dynamic theories, maintained principally by American authors, are more in accord with physical phenomena in assuming that there is a transmission of molecular energy, and some of these views support Hering's theory of what may be called mnemegenesis, namely, that heredity is a form of unconscious organic memory, and this, from my point of view, is the only satisfactory one yet brought forward.

Heredity is obviously manifested, for the most part, in the developmental results of growth and appears chiefly in the cytoplasmic structures which Dr. Minot so clearly places before us as constantly increasing with age while the comparative size of the nucleus which represents the power of growth force decreases. Whether this be granted or not, it can hardly be denied that, in describing the development of organisms along ontogenetic and their evolution along phylogenetic lines we are dealing with cycles of progression and retrogression which are quite distinct from the growth of the body as determined by the laws that govern its increase and reduction in bulk, and that one cannot describe the study of both series of phenomena under the same general term without danger of confusion.

Genism, in brief, is the transmission of likeness from one ontogenic cycle to another of the same species. It appears to be due to the same factors as the perpetuation and rejuvenescence of the cycles themselves, namely the union of two distinct forms of the same species or kind.

Ctetology.*

Weismann and his supporters deny that ctetetic or acquired characters are inheritable, but it is safe to make the assertion that this will not be maintained by the students of Bioplastology. Within the limits of my own experience in tracing the genetic relations of varieties and species of fossils Cephalopods and other

* *Κτητός*, something acquired.

groups through geologic time, although I have tried to analyze the behavior of all kinds of characteristics, I have failed to find any such distinctions. If Weismann's theory is true, it ought to be practicable to isolate in each type some class or classes of modifications that would be distinguished by the fact that they were not inherited.

It is practicable to isolate inherited characters from new variations which have not become fixed in any phylum. It is also practicable to point out characters which are transient in various ways appearing in individuals but not in varieties, in species but not in genera, and so on. When one has by this system of exclusion arrived at the end of the list, he finds that there is no class of characteristics which may be described as non-inheritable. The new variations of any one horizon which can be isolated from inherited ones are not distinguishable in any way from others which occurred previously. Later in time these new variations in their turn become incorporated with the younger stages of descendants. The transient characters of the zoön also do not differ in any way from others that are inherited in allied species, genera, etc. For example, the position of the siphuncle is very variable in some species of Nautiloidea, in others of the same order it is invariable within a certain range, and finally, in other species and genera it is invariable. In the Ammonoidea, derived from the same common stock as the Nautiloidea, this organ attains a fixed structure and is invariably ventral from the Devonian to the end of the Cretaceous, although in number of forms and genera the ammonoids far exceed the nautiloids. All characteristics, even those observable in some groups only in old age, are found in the adults of other groups, and finally in the young of the descendants of these, according to the law of tachygenesis. Everything is inherited or is inheritable, so far as can be judged by the behavior of characteristics. Cope has ably sustained this opinion in all his writings and has called it the theory of "diplogenesis" in allusion to the essentially double nature of the characteristics first ctetic and then genic.

It is probable that what has been called effort is the principal internal agent of organic changes as first stated by Lamarck, and subsequently rediscovered and first maintained by Cope and subsequently by others in this country. The modern school of dynamical evolution, or the Neolamarckian school, which has adopted this theory as a working hypothesis, regards effort as an internal energy, capable of responding to external stimuli. They include under this name both the purely mechanical or involuntary, as well as the voluntary reactions of organisms, whether these are simply plasmic, or cellular, or occur in the more highly differentiated form of nervous action.

The word "effort" has mental connections with conscious endeavor, and when we enlarge the definition so as to include purely mechanical organic reactions, this obliges every one to make an effort to rid himself of old habits of associating it with psychic phenomena. It not only imperfectly explains what is meant, but it does not of itself fully convey the idea of a force capable of molding the parts of the body into new forms, and cannot be used at all for the characteristics which originate through its action.

No apology is therefore needed for the use of Entergogenism for the popular term effort derived from ἐντός, meaning within, and ἔργον, meaning work or energy. This term does not interfere with the name given to the general theory by Prof. Cope—kinetogenesis, in allusion to its dynamical character as a theory of genesis—but is supplementary to this more general title. It is also quite distinct from his neurism or nerve force, and phrenism or thought force, although both of these, if we rightly understand him, are certain forms of entergogenism.

Dr. John A. Ryder * has discussed in one of his profound essays the relations of the statical and dynamical phenomena of development and evolution, using the terms ergogeny and ergogenetic for all the modifications produced by organic energy, and he considers kinetogenesis and statogenesis as divisions of the first named. These instructive speculations and observations were written to show that the changes of form produced by motion, and those modifications or conditions which may be properly considered as due to the conditions of equilibrium, are often reached, as is claimed by Ryder, as the result of Cope's law of kinetogenesis and are considered by him as statogenetic. These are interesting in connection with the above, and support the remarks made elsewhere with reference to the use of terms like "avolution," and are substantially in agreement with the general views taken in this paper, although taking up a side of the mechanics of evolution not specifically discussed here.

* "Energy as a Factor in Organic Evolution," *Proc. Amer. Philos. Soc.*, Phila., xxxi, 1893.

The part entergogenic energy or entergogenism has played in the production of normal reactions, hypertrophy, etc., is well known, and the fact that an organism cannot move or respond to external stimuli without its aid needs no illustration. It seems equally plain that modifications of structure and form follow as the results of such repeated actions developing into habits, and this process necessarily ends in the permanent establishment or fixing of these modifications in varieties and species.

This theory accounts satisfactorily for the so-called mysterious suitability of organic structures for the work they have to do. Such a force, capable of producing changes of structure and sensitive to the impinging action of external physical conditions, must work in directions determined by these two factors, *i. e.*, the structures already existent in the organism and the external forces themselves. It is obvious that these actions and reactions must, as has been already stated above, produce habits and changes of structure which are direct responses to the environment.

If one uses the Darwinian phraseology, one can say that the variations thus produced are natural selections, and I have called them in other publications *physical selections*, although it is likely that the use of the word selection in any way may convey an erroneous idea of my meaning. Selection implies the choice of some characters or tendencies out of a number of others, and in the minds of most naturalists it also implies the survival of the fittest chosen by the working of the struggle for existence in two directions, in one direction between contending organisms, and in the other between the same organisms and their surroundings. According to the opinions maintained in this paper, however, the organism has no such power of choosing, in the evolution of its characteristics. It is driven along certain paths and the influence of the struggle for existence and survival of the fittest is, if it has any influence at all, a perturbing force which has to be accounted for but does not seriously affect characteristics until after they originate. Characteristics, therefore, are not evolved fortuitously and in indefinite numbers for the animal to select out those that are favorable and perpetuate only those, but according to the definite law of variation of Lamarck and Cope.

The dynamical school does not reject the Darwinian doctrine, but it uses this hypothesis in its proper applications as a secondary law explanatory of certain phenomena of survival and perpetuation of characteristics after they have originated through the action of this law.

According to my own view of the facts, often published elsewhere, its use is unnecessary for the explanation of the quick evolution of series in the early periods of their evolution near the origin of types, also for the elucidation of the pathologic phenomena in the quick evolution of phylogerontic forms and series.

It can also not be applied to the explanation of experimental results, as is admitted by all experimenters and most Darwinists, in cases where modifications have been produced by the artificial application of physical agencies, of which there are now so many on record in both the animal and vegetable kingdoms.

It is plainly, as Dr. A. S. Packard has pointed out, a doctrine derived from the study of the results of evolution and cannot be applied to the more general and fundamental phenomena of the origin of types, the building up of series or the origin of characteristics. My own experience leads substantially to the same opinion, and I find its use unnecessary except for the explanation of the perpetuation of some characteristics that occur during the acme of the evolution of species. The perpetuation of many characteristics which are fundamental to the organism and species is necessarily provided for by agencies which originated them and by heredity as soon as they become fixed in the organism. I think there is good ground for the statement that in many cases these are plainly not advantageous.

Weismann and his supporters are necessarily Darwinians. No one denies that ctetic characters arise through the action of the surroundings. If these are perpetuated through heredity, evolution is an undeniable corollary and it must follow the path defined by the dynamical school. If, however, ctetic characteristics may originate at the bidding of the surroundings and persist in the successive members of the same genetic series only while the surroundings are comparatively unchanged, or in other words sufficiently alike to continue to force their reappearance, then it must be admitted that the law of the survival of the fittest through the action of the struggle for existence is probably a fundamental law of evolution in organism.

In other words, the battle of the two contending theories is being fought in the domains of ctetology and it is hoped that this paper may be a definite contribution to the Neolamarckian side of the controversy. I cannot give further space here to theoretical discussions of this sort and am obliged to refer any persons interested to my other works, especially "The Genesis of the Arietidæ" and the "Bioplastology, the related Branches of Research,"* in which I have more fully given my own views.

The exclusive Darwinians are, according to the views of the Neolamarckians, as much out of the true path in one direction as are the empiricists in the other in appealing exclusively, as they often do, to the action of the surroundings in accounting for observed modifications.

It is certainly not a very acute analysis of the facts which attributes to external causes exclusive power in producing modifications in many cases as has been largely done by experimental zoölogists. For example, Brauer and the author have both pointed out this defect in the accepted explanations of the famous Schmankewitsch experiments upon *Artemia*, and the same may be said of the explanations of all experimenters who do not take into account the internal reactions of the organisms themselves.

The physical forces of the surroundings must act through medium of entergogenic movements, and this is shown clearly in the nature of modifications produced which are extra growths, substitutions of characteristics due to changes of functions, etc., or partial or absolute obliteration of these due to the failure of genetic force to repeat characteristics in the presence of opposing influences and superimposed characteristics as in accelerated development.

Ctetology should also, however, include the study of the action of physical forces when they either actually do produce direct effects upon organisms or may be assumed to act in this way. Changes in light, food, heat and moisture may cause modifications that cannot be included under the head of entergogenic reactions without danger or confusion.

Maupas gives exceedingly instructive examples of this class, and quotes other authorities who have investigated these effects in Protozoa.

Beddard gives a number of examples of such modifications in his *Animal Coloration*, and Semper has also discussed the same subject more extensively in his *Natürlichen Existenzbedingungen der Thiere*.†

* *Smithsonian Contributions*, No. 73, and *Proc. Bost. Soc. Nat. Hist.*, xxvi.

† Translation by Minot, Macmillan, 1892.

The use of the term entergogenesis makes it practicable to indicate the essential distinction existing between the modifications produced through the mediation of internal forces and those arising as the direct results of the action of external forces by means of the term ectergogenesis and ectergogenic.

These explanatory remarks serve to show that Ctetology is a branch of research which needs to be isolated from researches upon growth and Genesiology, since it is devoted to the study of the origin of acquired characteristics, and therefore necessarily considers all of the internal reactions of the organisms in response to the action of physical forces, as well as the more obscure reactions of structures which are produced solely by (or supposed to be produced by) the direct physical or chemical action of external physical forces.

Bioplastology.

The separation of Auxology or Bathmology, Genesiology and Ctetology show also that the study of the correlations of ontogeny and phylogeny to be distinct from either of these, and this branch of research can be designated by the term Bioplastology from *Βίος*, life, and *Πλαστός*, meaning molded or formed.*

To sum up in a few words the rather ambitious aims of this comparatively new recruit in the army of investigation, it aspires to show that the phenomena of individual life are parallel with those of its own phylum and that both follow the same law of morpho-

* Bioplasm, bioplast, bioplastic have already been used by Beale and others for the living cell and its contents, but the term "Bioplastology" has not been used, nor have the names proposed by Beale been generally adopted. If they were, Bioplasmology would cover the requirements of students of such phenomena, and there is already in use Plasmology with about the same meaning, and Histology for the descriptive side of the study of cellular structures.

Biogeny has been used in extra scientific literature by Fiske with the same meaning as Bioplastology, and Haeckel has named the law of embryonic and ancestral correlation the law of biogenesis, but there is a strong objection to both of these. Biogenesis is the name given to the theory of the origin or genesis of life from life in contradistinction to the assumption of spontaneous generation or abiogenesis and has a well-established place in scientific literature. Therefore, while the law of correlation of the stages of development and those of the evolution of the phylum may, if one chooses, be called a law of biogenesis, it is more accurate to consider it a law of correlation in Bioplastology, or better still, the law of palingenesis or regular repetition of ancestral characters which very nearly expresses what the discoverer, Louis Agassiz, saw and described. The fact that Agassiz was wrong in his theory, not believing in evolution and not recognizing the meaning of his law in this sense, does not absolve those who profit by his labors from recognizing his discovery of the facts and his obviously full acquaintance with the law and its applications to the explanation of the relations of organisms. It is Agassiz' law, not Haeckel's.

genesis, that not only can one indicate the past history of groups from the study of the young, and obviously the present or existing progression or retrogression of the type by means of the adult characters of any one organism, but that it is also possible to prophecy what is to happen in the future history of the type from the study of the corresponding paraplastic phenomena in the development of the individual.

Whether these claims are well founded or not the nomenclature to be employed is a matter of importance and should be accurate, appropriate and convenient for those who are interested in this work.

ONTOGENY. TABLE I.

CONDITIONS.	STAGES.	STAGES.	SUBSTAGES	SUBSTAGES.
Anaplasis.	Embryonic.	1. Embryonic.	Several.*	No popular names.
	Larval or Young.	2. Nepionic.	Ananepionic. Metanepionic. Paranepionic.	
	Immature or Adolescent.	3. Neanic.	Ananeanic. Metaneanic. Paraneanic.	
Metaplasis.	Mature or Adult.	4. Ephebic.	Anephebic. Metephebic. Parephebic.	
Paraplasis.	Senile or Old.	5. Gerontic.	Anagerontic. Metagerontic. Paragerontic.	

Recent researches have, in my opinion, clearly demonstrated that all the stages of development like the embryonic will have to be subdivided in studying many groups. These subdivisions are also relatively important and their differences are often well defined.

The ovum and the extreme degraded substage of the senile period represent the widest departures structurally and physiologically from the adult, one being at the commencement and the other the termination of ontogenesis. Departing from the ephebic stage in either direction towards these extremes one finds the same law. *Contiguous substages of development, when considered in sequence, differ less from each other and from the adult the nearer they are to the ephebic stage, and they differ, on the other hand, more from the adult and from each other in structure and form the nearer they are to the*

*These stages were enumerated and more or less described under the names of Protembryo, Mesembryo, Metembryo, Neoembryo, Typembryo in my paper on "Values in Classification," etc., and to these Jackson added Phylembryo in his *Phylogeny of the Pelecypoda*, p. 289.

two extremes of the ontogeny.' This is an evident corollary from the phenomena of the ontogenetic cycle and need not be dwelt upon here.

The terminology of the different departments of research which come properly under the head of bioplastology is recognized at present only in the case of embryology, but it is obvious to the student of epembryonic development that similar terms for the study of other stages and periods will in course of time be needed, and in fact the old terms—nealogy, ephebology, and geratology—are cited in that sense in the *Century Dictionary,* and may introduce some confusion. It is not now necessary to discuss this question, but only to draw attention to the facts. I therefore pass on to the consideration of the term epembryonic.

Among fossil nautiloids it is rarely practicable, on account of the frequent destruction of the protoconch, to find an embryonic stage. My last work on Carboniferous cephalopods contains descriptions of the entire ontogeny of a number of species, with the exception of the embryonic stages. In such cases the fact that the embryology is wholly omitted can be pointed out by the use of the term "epembryonic stages," and this has already been found useful above. It only remains to add that the same prefix is also useful in designating the exclusion of other stages—thus one can speak also of the "epinepionic" or "epineanic" stages in this same way without danger of confusion with any other term.*

It is often possible to employ a more specific and characteristic designation than epembryonic. Thus among shell-bearing forms one can distinguish between the embryonic shell and the true shell; for example, the protegulum and tegulum of Brachiopoda as defined by Beecher, the prodissoconch and the dissoconch of Pelecypoda as defined by Jackson, the periconch and conch of Scaphopoda, the protoconch and conch of Cephalopoda. In all of these forms it is practicable to speak of tegular, dissoconchial, or conchial stages or periods, meaning thereby all of the epembryonic stages of these types.

Haeckel, in his *Morphologie der Organismen*, sketched the physiology of ontogeny and phylogeny and gave the general correlations of the two series of phenomena, together with an appropriate

* Postembryonic is in use for the young stages among embryologists, and is equivalent to the term nepionic, but it is not consistent with the other terms of bioplastology, and is a hybrid.

nomenclature which has been here adopted, with some necessary changes.

The dynamical relations of three great phases of evolution in the phylum were designated by Haeckel * as the *epacme*, including the rise of the type from its origin, the *acme*, meaning the period of its greatest expansion in members and forms, and the *paracme*, or decline towards extinction, and these phenomena were correlated with the similar physiological phenomena of the ontogeny, and these appear in the table of phyletic terms given below.

Previous to this, in the same volume (p. 76), Haeckel gives his classification of the development of the individual under three headings: "Anaplasis oder Aufbildung (evolutio)," meaning thereby to include the physiological phenomena of all of the stages developed in the four earlier stages of the individual. This is certainly a useful term for the entire series of transformations from the fertilization of the ovum until the progressive stages are all passed through. It does not express nor can it be used for cases of retrogression in which degenerative characters are introduced at such an early age that progression is limited to the embryonic, or to that stage and a part or the whole of the nepionic stage. There are also some examples among parasites in which progression seems to have been reduced so much that one can say it is practically eliminated from all stages succeeding some of the earliest embryonic. For such forms as these the proper term would be Paraplasis, from *παρα πλάσσω*, meaning to change the form for the worse, to deform. Thus the stages of such forms could be collectively spoken of as paraplastic with relation to the ontogeny of others of their own type or allied types, whereas they could not be described as anaplastic.

The explanatory word "evolutio" is here used by Haeckel in a confined and erroneous sense. Evolution really means continuity in time invariably accompanied by change, but whether the modification be progressive or retrogressive, or a combination of progression and retrogression, is immaterial. It is obviously better not to use these terms for ontogenic phenomena. There are sufficient terms in "development," "differentiation of characteristics," "rise," and one has always a slight mental reservation in employing this word for the growth and development of an individual or isolated zoön.

* *Morphologie der Organismen*, Vol. ii, pp. 320-366.

"Metaplasis oder Umbildung (transvolutio)" is used by the same eminent authority for the adult period in a general sense, and it appears to the writer to have useful function as a descriptive term especially, since it is uniform with anaplasis and paraplasis. Thus one can describe the metaplastic phenomena or characteristics of the ephebic stage in any form as metaplasis, and also speak of the general meaning of metaplasis without referring to that stage of ontogeny in any special form. The use of "transvolutio" is obviously objectionable, since it introduces confusion and conflicts with the proper definition of "evolutio" or evolution as given above.

"Cataplasis oder Rückbildung (involutio)," used by Haeckel for the senile stage, is open to the objection that there is no corresponding Greek word, and also that καταπλάσσω, the only Greek verb to which this term can be referred, means to spread over or plaster. Paraplasis, derived from παρα πλάσσω, meaning to change the form for the worse or deform, is an obviously preferable designation. Thus the paraplasis or paraplastic phenomena of all the periods of development or only of the paragerontic substage in ontogeny may be spoken of and correctly described under this term.

The use of "involutio" as a descriptive term is objectionable, not only on the grounds given above, but because "involution" and "volution" are both in common use as descriptive terms for the peculiarities of the whorls of Gasteropoda and Cephalopoda. Any modification of evolution is objectionable because it is misleading. For example, the word "avolution," supposed to mean things that do not evolve or have not been evolved, represents an unnatural condition. One can, of course, conceive of matter in a state of more or less stable equilibrium, but there are other words than "avolution" in habitual use to express this conception. It is also to be regretted that it has been applied by several eminent writers to ontogeny, and is probably fairly established in this application. The growth and development of the tissues is in a general way evolution, as much so as that of a colony of Protozoa. But it is also obvious that the product of the development by division of a single autotemnon, which forms a cycle, or when held together so as to form a colony, and the product of the division of an ovum in Metazoa held together more compactly so as to build up an individual or zoön, are not the same as the product of the evolution of an ancestor into a phylum through successive independent forms or ontogenic cycles. One cannot accurately speak of the "growth" of a phylum, nor ought the word "development" to be used for the phylum. Development should be restricted to the zoön or individual or its morphic equivalent among Protozoa, since it expresses more clearly the differences that exist between ontogeny and phylogeny than their similarities, and for the same reason it is advantageous to use evolution for the phylum alone in the sense in which it is commonly employed. The necessity of subdividing the embryonic stage is admitted, and in all probability this really includes several stages with their own substages, but the discussion of this problem must be left to the future.

The paragerontic stage is in no sense "atavistic" or "reversionary," as it is defined by Buckman and Bather. Reversions are the returns or recurrence of ancestral characteristics in genetically connected organisms which have been for a time latent in intermediate forms. I do not think that we can include in this category purely morphic characteristics which habitually recur in the same individual as the result of paraplasis, or which occur in the paracme of a type more or less invariably. In the individual the resemblance of the smooth round shell of the whorl of the paragerontic ammonoid after it has lost the progressive characteristic of the ephebic stage cannot be considered as a reversion. It is simply analogy of form, not structural similarity of characteristics. A better known and more easily understood case is the resemblance of the lower jaw of the infant before it has acquired teeth and that of the extremely old human subject in which these parts have been lost and the alveoli and upper parts of the bony mandible have disappeared through resorption. The forms are alike, but no one would venture to consider the infant's cartilaginous jaw and that of the old man as similar in structure.

The best example of similar phenomena in the phylum known to me is the close resemblance of form between the straight Baculites of the Cretaceous or Jura and Orthoceras of the Paleozoic, which has been described above, and is figured further on. One occurs in the paracme and the other in the early epacme of the group of chambered shells. They are widely distinct in their structural characteristics, and these differences are greater in the young than at any subsequent stage of their ontogeny, Baculites having a close-coiled shell in the nepionic stage, and Orthoceras is straight from the earliest stage. The return of a similar form in Baculites in the epinepionic periods of development in obedience to the law of the cycle does not carry the structure back with it to a repetition of the orthoceran siphuncle and sutures.

The structure of an individual during its development might be represented graphically by an irregular spiral of one incomplete revolution which describes a curve, continually increasing its distance from the point of departure until the meridian of the ephebic stage is reached, and then beginning to return. Such a curve would always as a spiral rise more or less vertically, and consequently, even if it completed the revolution, must terminate in space. It might, perhaps, reach nearly to the same imaginary vertical plane, but never to any point approximate to that of its departure. Structure separates the extremes of life as widely as possible, and does not permit us to regard them as approximate, nor can one regard old age, however complete its return in external form, as a reversion.

One of the most noteworthy contributions of bioplastology is that it gives proper values to this class of analogies and shows them to be constantly recurring in the individual and in the phylum in obedience to well-ascertained laws of morphogenesis.

The different stages have been described by Dr. Beecher among Brachiopoda, Dr. Jackson among Pelecypoda, and the author among Cephalopoda; and Buckman and Bather and also Blake * in England, and Würtenberger in Germany have admitted their existence, and the last redescribed them. Würtenberger has admirably described the phenomena of bioplastology as they occur among Ammonitinæ, and correctly interpreted the law of tachygenesis and its action in these forms, but failed to quote either Prof. Cope or the author. This omission was not so remarkable as the fact that Neumayr and some other investigators, after they had received the printed records of the work done in the same direction in this country, continued to quote Würtenberger as the sole discoverer of these phenomena and of the law of tachygenesis. Würtenberger's work was apparently independent, and it has higher value on that account, but it needs rectification from a historical point of view.

Buckman and Bather propose to use the prefix "phyl" for forms occurring in the phylum which represent in their adult characters stages in the evolution of the phylum corresponding with those in the development of the ontogeny, and give an instructive table in

* "Evolution and Classification of Cephalopoda," *Proc. Geol. Assoc. Lond.*, Vol. xii, pp. 276-295, 1892.

which Haeckel's physiologic terms are placed side by side with those proposed for the morphic phenomena. In following out the same ideas the following table has been constructed, which differs from theirs in the use of nepionic, as stated above, and also in the use of phylanaplasis, phylometaplasis and phyloparaplasis as correspondents of the similar ontogenetic terms :

SUMMARY, TABLE II.

Ontogeny.		Phylogeny.		
Anaplasis	Embryonic. Nepionic. Neanic.	Phylanaplasis	Phylembryonic. Phylonepionic. Phyloneanic.	Epacme.
Metaplasis	Ephebic.	Phylometaplasis	Phylephebic.	Acme.
Paraplasis	Gerontic.	Phyloparaplasis	Phylogerontic.	Paracme.

Buckman and Bather gave the following appropriate example from Beecher's and my own researches :

"Thus we would say that the Productidæ attained their paracme in the Permian, when they were represented by the phylogerontic Strophalosia and Aulosteges; that the characters of the neanic and ephebic stages of *Coroniceras trigonatum* are phylocatabatic" (here phylanagerontic). While granting the need of using this distinctive prefix for the periods of evolution in the phylum one is likely to become confused unless he fully understands the use of the word "phylum" as applicable to all grades of genetic series. Thus, in ordinary acceptation of the term, a phylum may be the entire class or any subdivision of it, even a single genus, provided the forms can be shown to be genetically connected. It has been employed in this way several times in this text after the names, species, genus, family, etc., the ammonoidal phylum or ordinal phylum, phylum of the Goniatitinæ or subordinal phylum, family phylum, and even a phylum of varieties and individuals.

THE CYCLE.

Phylum expresses genetic connection, cycle the totality of the phenomena, whether morphic or physiologic, which are exhibited by ontogeny or phylogeny. Thus, one can describe the cycle of the phylum in its rise and decline, the epacme, acme and paracme as purely dynamical phenomena exhibited by the increase in numbers of forms, etc., or the cycle of the ontogeny as shown by the increasing complexity of the development and its decline, the anaplasis, metaplasis and paraplasis of the individual; or one may describe the cycle as exhibited by the embryonic, nepionic, neanic, ephebic and gerontic stages, or the cycle of the phylogeny as exhibited by the corresponding phylostages * of evolution designated by their appropriate prefix "phyl."

There appears to be real need of two terms under the head of cycle, one for ontogeny and the other for phylogeny. It is proposed to use in this way ontocycle or ontocyclon for the ontogeny, meaning the cycle of the individual, and phylocycle or phylocyclon for that of the phylum. This will make it practicable to use the terms monocyclon or monocyclic, polycyclon or polycyclic, etc., to describe the number of cycles observed. Thus the ammonoids are polycyclic, the Arietidæ are decacyclic, the genus Coroniceras is an incomplete monocycle.

It is not necessary to defend these terms before students of bioplastology; they will be tested, and, if convenient, adopted. For the benefit of others it may be mentioned that the cycle is of all degrees of development in ontogeny. Thus, Insecta are apt to stop at the ephebic stage and in many other animals there is a similar limitation. On the other hand, there may be the most unexpected development of the cycle. Thus, Podocoryne starting from the hydroid stage passes through a permanent colonial stage built up by budding which gives rise by secondary buds to independent medusæ. The life of an independent medusoid bud ends with a paragerontic substage in which the veil is destroyed, the bell is partially resorbed and turned back together with the tentacles, and the proboscis is left naked and projecting. In this condition the old of Podocoryne is similar to the hydroid with which the colony began. This gerontic transformation has been observed by Dujardin in Cladonema and Syncoryne, by Hincks in Podocoryne and Syncoryne, and by Gosse in Turris.†

Man is not completely ontocyclic, but makes a close approach to this in the loss of the hair, teeth and proportions and shape of the body; and certainly in some parts, as in the mandible described above, there is sometimes a completed cycle.

* This word is a fearful hybrid, and I beg pardon of my classical friends in advance of their merited wrath.

† Dujardin, *Ann. Sci. Nat.*, Series 3, Vol. iv, pp. 257–281, 1845; Hincks, *British Hydroid Zoöphytes*, Vol. i, p. xxviii, 1868.

What the limits of the ontocycle may be has not yet been ascertained, but so far as the facts are known it would appear to be coincident with the limits of agamic reproduction, or, in other words, with the limits of the growth of one autotemnon or of one ovum after cojugation by fission, and includes all agamic generations produced by division or by budding.

The act of self-fission is similar whether it takes place for a certain cycle among Protozoa or Metazoa under purely organic conditions or follows upon the conjugation of two zoöns, and is due to the rejuvenation caused by the union of the nuclear elements of their bodies as among Protozoa, or the more differentiated generative cells of the Metazoa. Under all conditions the cells divide in obedience to the laws of growth, and whether the resulting daughter cells remain fastened together forming colonies as in Protozoa or masses of tissue as in Metazoa, or whether they separate and become distinct autotemnons or distinct zoöns the action is the same.

The product of this autotemnic function in single cells has, as shown by the researches of Maupas, a cycle of transformations which are like those of an individual among Metazoa, although they may reach in some forms over six hundred so-called generations and therefore include thousands of distinct protozoans. It is obvious to the student of bioplastology in reading Maupas' researches * that this cycle among Protozoa Ciliata is the equivalent of the cycle of the individual among Metazoa. Although he uses the word individual for the autotemnon he does not speak of the successive forms as generations but as partitions, "bipartitions" being his usual term, showing clearly that he recognizes these are not generations like those of distinct successive zoöns in Metazoa.

Maupas' researches show, as in fact he himself states, that there is a cycle of partitions produced from one autotemnon after conjugation, when isolated and allowed to propagate by fission without the renewed stimulus of conjugation with others of different broods. The earlier successive partitions are incapable or at any rate do not show any desire to conjugate with their fellows. 'Each of his cultures of isolated autotemnons passed through these youthful or anaplastic stages, and then a series of metaplastic partitions was developed in which the micronuclei became more numerous and

* "Recherches expérimentales multiplication des infusoires ciliés," *Archiv. de zool. expér. et gén.*, Sér. 2, Vol. vi, pp. 165–277; *ibid.*, Vol. vii, pp. 149–517.

conjugation with other broods took place whenever it was permitted by the experimenter.

In the generations immediately succeeding these, degenerative changes, both structural and physiological, took place in the partitions which were distinctly paraplastic, although the cultures were maintained under conditions which precluded the supposition that these changes could have resulted from unfavorable, abnormal surroundings. The successive partitions then had gerontic transformations, lost their micronuclei, became much reduced in size and unable to conjugate with others with the usual normal results, and finally the external buccal apparatus was affected, reduced, or obliterated, and so on. These changes were termed senile by Maupas, who explains the entire phenomena as a cycle comparable with that of the individual among Metazoa.

One is, of course, at this incipient stage of bioplastology, confused by many apparently inexplicable phenomena. When, however, one contemplates the confusion of the most eminent authorities with regard to the relations of the autotemnon among Protozoa and Metazoa, shown by the use of the same term for the autotemnon, the individual, and the zoon, and also the prevalent confusion with relation to the morphology of forms designated as colonies—some regarding the whole product of one egg as an individual and others considering each bud or independent zooid as properly designated by that term and defining the colony as an aggregate of more or less connected individuals—it is surprising that there should not be more difficulties in the path of this new branch of research.

Those who try to find the cycle of metamorphoses in their own special branches of research will be often disappointed and probably deny that it exists at all. Thus, in my own case, I for some time could not find any evidence of its existence among certain cephalopods, notably those having a primitive organization like Endoceras and Orthoceras; but I have since seen well-marked senile stages in these shells. Undoubtedly there is as great distinction between the paraplastic and anaplastic periods, and between phyloparaplasis and phylanaplasis everywhere, as there is between the correlations of the corresponding periods at the extremes of the ontogeny and phylogeny.

Paraplasis essentially differs from anaplasis, as has been described above in treating of relations of analogy between the gerontic and the nepionic stages. The earlier characteristics of the ontogeny are, as the author has striven to explain in several publications, essentially distinct, being in large part in most animals and in some cases almost wholly genetic. In considering the simplest manifestations of the cycle, palingenesis accompanied always by tachygenesis must be taken into account, and also cenogenesis in groups like Lepidoptera, Hymenoptera, most Echinodermata, many Vermes, where a supposed ancient and regular palingenetic record is assumed to have been disturbed by ctetic characters acquired by the larvæ.*

The gerontic characters, on the other hand, and all paraplastic, as well as their corresponding phyloparaplastic characters belong to the category of analogies in so far as they are purely morphic resemblances or equivalents. This is clearly shown in the physiology of all the parts and organs in the anaplastic and paraplastic periods, the former being full of hereditary and perhaps, also, acquired power, and the latter more or less weakened and reduced or worn out by the exercise of those powers and the constant wear and tear of the surroundings.

Retrogressive reductions in every form, although often indicating and accompanying a high degree of specialization, partake more or less of the same nature when considered with reference to their morphic and accompanying functional attributes, and one cannot study such bioplastic phenomena as if they were of the same nature and subject to exactly the same laws as progressive genetic and ctetic characters. As I have pointed out above, and in several other publications, there are all degrees of completeness in the evolution of the cycle, and it is dependent upon a variety of causes whether occurring in the ontogeny or phylogeny. If it were constant and invariable and independent of the surroundings in the

* Such examples are, correctly speaking, not disarrangements of palingenesis, although so translated by Haeckel, if I rightly understand his ideas of a confused record. Cenogenism does occur in such examples in obedience to the same law that governs palingenesis, but it occurs through the introduction of ctetic characters during the larval instead of in the neanic or ephebic stages, and the crowding back of these upon the nepionic and embryonic stages. The use of terms indicating that nature has confused or destroyed its own ontogenic records of the transmission of characters in certain cases assumes (1) that these are exceptional cases, (2) that cenogenesis is not the normal mode of transmission in certain types in which it occurs, (3) that both of these modes of transmission are not affected by tachygenesis, all of these implications being erroneous according to the opinions expressed above. One can assume a disturbance or perturbation, or decided change of mode according to law, but "destruction," "confusion," or "falsification" are subjective terms inapplicable to the objective character of the phenomena to which they are applied, appropriate in metaphysics, perhaps, but entirely out of place in natural science.

phylum, it would not be so closely parallel to the ontogenic cycle, which we know to be subject to great variations in accordance with the surroundings of the individual or species.

The standard of reference in bioplastology is the ontogenic cycle, and this should be studied first in every group. Without a full knowledge of this, the morphology of the group cannot be properly translated, nor can the forms be taxonomically treated with reference to their natural relations. This branch of research aims to complete Von Baer's law and Louis Agassiz's great discovery of the correlations of palingenesis and phylogenesis, and it, therefore, asserts an equal utility for the metamorphoses of the nepionic, neanic, ephebic, and gerontic stages, provided these be applied in each group according to the ontogenetic development of the cycle in the zoön and its phylogenetic evolution in the same group.

III. Ontogenetic Stages.

My own researches have led me to the conviction that subdivision of the developmental phenomena of the nepionic, neanic and ephebic stages are necessary, and for obvious reasons I shall take my illustrations wholly from the shell-covered Cephalopoda.

Those who do not believe that there was a protoconch in nautiloids will have to reconstruct this part of the nomenclature in accordance with their own views. Having been reproached by Prof. Blake in his address before the Geologists' Association in 1892 in London for holding to this opinion, it is only necessary for me to point again to the new evidence with regard to the existence of the protoconch given in the Introduction to this memoir.

Granting, therefore, that the conch begins with the nepionic stage, the first part of this period is the ananepionic substage. This substage is more or less similar in all the nautiloids on account of the existence of the cicatrix on the point of the apex of the conch and the surrounding comparatively smooth area which is, as a rule, elliptical, the apex being in most forms of Nautiloidea, when seen from the side, like a broad cup, and in section a laterally compressed ellipse, the vertical or ventro-dorsal diameter being the longest.

This substage is frequently figured in the plates of this memoir, and has been well shown in figures of several species, in the *Genesis of the Arietidæ*, pp. 10, 11, and in *Nautilus pompilius* in *Fossil*

Cephalopods of the Museum of Comparative Zoölogy, "Embryology," Vol. iii, Pl. iii, Fig. 1, and in a number of figures of Barrande in his *Système Silurien*, Pls. 487, 488, a few of which were drawn and given to Barrande by the author. I first described this substage among the nautiloids under the descriptive name of the "asiphonula," but have since substituted the term, Protosiphonula. Among ammonoids this substage has been forced back into the embryonic stage and has practically disappeared from the conch, probably through the action of tachygenesis. The tendency of the embryo to build a solid calcareous protoconch of imbricated structure may be attributed to the earlier inheritance of the characteristics of the calcareous, apical conch of its nautiloid ancestor.

This explanation has been supposed by Prof. Blake to show that the protoconch of ammonoids was necessarily identical with the apex of the shell or early part of the ananepionic substage, protosiphonula, of nautiloids. It would have such a meaning, perhaps, if there were a cicatrix on the protoconch of ammonoids and if there were not more or less rugose lumps, supposed to be the remnants of protoconchs, covering up the cicatrices of the apices of the conch in some nautiloids as figured above on page 360 of the Introduction. These facts must be reinvestigated by the opponents of this view, and it lies with them to prove that the latter are not the remnants of shriveled, horny protoconchs, and that the cicatrix was not a passageway from the embryo into the shell or at any rate an aperture through which the animal of the protosiphonula communicated with the protoconch, before one can consider the facts in a different light or admit any other hypothetical explanation.

It will be seen below that I have altered my view in so far as the primary origin and nature of the cæcum is concerned. Barrande imagined that my view necessarily implied the passage of the embryo bodily out of the protoconch into the conch, but this was a mistake arising probably from inadequate statements. The young, when it had passed by growth out of the protoconch, or as the anterior parts of the embryo grew out of the protoconch into this position, began to build the shell, and finally at the end of the protosiphonula stage rested in the apex, which was then aseptate and was the first living chamber. The structure of the apex in Endoceras, Piloceras and Actinoceras indicates large and direct, open, tubular connection between the protoconch and the animal when in this first chamber through which the endosiphuncle in the generalized nautiloids, Endosiphonoidea, opened into the protoconch.

The tubular opening of the apex in Endoceras, Piloceras and Actinoceras and other genera having a marked endosiphuncle, is not closed by the cæcum of the siphuncle as was formerly supposed. It is, on the contrary, directly continuous with the endosiphuncle, as was first pointed out by Foord in his *Catalogue of British Cephalopoda.* This is an attenuated, central, more or less irregular tube or axis formed by the extension of the points of successive endocones or sheaths. It is more or less interrupted by pseudosepta, and is a separate and distinct part occupying the axis of the large siphuncle. This organ is continuous with some corresponding part in the embryo which existed in the protoconch. On the other hand, the true siphuncle, including the cæcum of the first air chamber, is a secondary organ formed by the funnels of the septa. The living apical chamber was, as said above, a shallow cup, and its limit in the living animal was probably as indicated by Henry Brooks in the drawings given on Pl. i of this paper. At any rate, his conclusions with regard to the probable situation of the aperture of this stage seem to me to be sustained by observation.

The next substage is indicated by the presence of the cæcum lying within the apex, and this is formed by the funnel of the first septum and in association with the first septum is universal among Cephalopoda, with the exception of some sepioids, so far as the internal structures are concerned. It has been descriptively named the cæcosiphonula. This may be considered as a part of the metanepionic substage in nautiloids, but among ammonoids and belemnoids it is forced back according to the law of tachygenesis into the calcareous apex of the ancestral shell, being consolidated with and disappearing in the aperture of the calcareous protoconch. The limit of the living chamber which rested upon this first septum has been determined in existing form of *Nautilus pompilius* by Mr. Brooks and is shown in his drawings on Pl. i.

In a general way it may be also said that the external characteristics of this age are characteristic of the entire order of Nautiloidea.

Among Nautiloidea the shell of this substage grows less rapidly in all its diameters and may either remain smooth and approximately retain the earlier form, becoming, however, more compressed, or it may become more rapidly altered to a depressed ellipse. That is to say, one with the transverse axis longer than the dorso-ventral and is apt to be ornamented with coarse ridges, whether the shell is subsequently smooth or remains ridged. The septum succeeding the first septum among nautiloids and also belonging to the metanepionic substage has a large siphuncle compared with the ventro-dorsal axis, and this has been called the "macrosiphonula." The remarkable observations of Henry Brooks have amply sustained these statements made in previous publications, as may be seen in diagram Fig. 11, Pl. i.

The macrosiphonula brings before the observer certain internal characteristics which, although much altered, appear to have been derived from the earliest ancestors of the nautiloids, Diphragmoceras. The metanepionic substage is therefore in part in all forms very primitive, in spite of the fact that in highly accelerated nautilian shells it is very much modified and also that some of its external characteristics are derived from the more recent ancestors of its own ordinal or subordinal phylum.

The paranepionic substage begins with the third septum and its accompanying living chamber and, so far as I know, it does not carry any external characteristics derived from a very remote ancestry but usually in nautilian shells points very definitely to some known or unknown gyroceran ancestor. This is broadly shown in the fact that in the greater number of the more generalized forms of nautilian shells the three parts of the nepionic stage occur before the whorls touch. The external characteristics and form of the metanepionic and paranepionic substage have been largely derived from the immediate ancestors of the species. They often have their corresponding phyletic forms within their own genetic group or family, whereas the characteristics of the ananepionic substage are, in large part at least, derived from remote ancestors.

Thus by the aid of direct observation it is not difficult to see *that the substages of development in ontogeny are the bearers of distal ancestral characters in inverse proportion and of proximal ancestral characters in direct proportion to their removal in time and position from the protoconch or last embryonic substage.* It is already generally admitted that this law is true of the embryonic stages themselves with reference to the protembryo, although most observers would hardly dare state this in the same positive terms as here employed because they are confused by what they call abbreviated development. They have not traced the systematic regularity with which the law of tachygenesis works in producing the replacement of hereditary characters in every series of forms, and do not trust or know how to use this law.

The paranepionic substage is consequently among Nautiloids as among Ammonoids of longer duration than either of the preceding substages and of more variable limits. The siphuncle has acquired its ephebic aspect and characters, but it is very often in a different position from that which it subsequently assumes, as it is in *Nautilus pompilius* and other forms figured in this memoir. I have hitherto considered that it included the latter part of the cyrtoceran volution, but it now seems more natural to limit it to that portion of the whorl which assumes the gyroceran curve or, in other words, turns sharply away from the straighter cone of the preceding substages on its return curve towards the apex. This is well shown in Mr. Brooks' drawings and also in the other forms of nautilian shells, especially those of *Barrandeoceras tyrannum* and *Sacheri* of the Silurian. At or near the end of the paranepionic substage in *Nautilus umbilicatus* and *pompilius* there is in almost every shell a more or less sharply defined constriction which marks a permanent aperture. The limits of both substages are subject to variations that will be noticed in the succeeding descriptions, but it suffices here to note the fact that the upper limits of the paranepionic substage are in a general way definable by the limits of the gyroceran form in close-coiled nautilian shells. That is to say, this substage, as a general rule, approaches its end and neanic characteristics begin to appear at or near the completion of the first volution, when growth brings the whorl in contact with the apex or dorsal side of the conch. Tachygenic forms are often notable exceptions to this definition and introduce modifications that have to be studied in each separate series.

The transformations that distinguish the subdivisions of the neanic stage are very well marked in some forms and less distinctly in others, but I have constantly found the need of defining two stages. Ananeanic is a suitable term for the first substage, which is usually well marked in nautilian* shells by the first appearance of

*In my *Genera of Fossil Cephalopods* nautilian forms have been defined as those having the whorls in such close contact that the dorsum of the enveloping or later formed whorl is modified, either flattened or bent inwardly along the area of contact, and has what is called an "impressed zone." There are, however, some shells that are difficult to classify. These have the volutions in contact but do not have an impressed zone. Most of them are transitional between gyroceran and nautilian forms and may be placed in either category.

the impressed zone. This is the name I have given to the area on the dorsum affected by the contact of the dorsum of the growing whorl with the venter of the already formed whorl of the next inner volution. This is either flat, gibbous, or indented in accordance with the form of the venter of the whorl it touches or envelopes, but it is usually indented more or less deeply.

There is a notable exception to this rule when in highly tachygenic shells the zone of impression is inherited and the dorsum becomes furrowed before the first whorl bends. This is one of the most complete demonstrations of the probable inheritance of acquired characters that I know, and an excellent illustration of the law of tachygenesis. It occurs in some groups of nautilian shells of the Carboniferous and also in the Jura, Cretaceous and Tertiary, as well as in the existing species of Nautilus early in the nepionic substage, as may be seen in the drawings of Henry Brooks (Pl. i).

In tracing out the distinct phyla to which different nautilian forms belong, it can be shown that the impressed zone is invariably consequent upon close coiling, never appearing in ancestral forms in the nepionic stage unless through this agency. As a rule, it comes in the ontogeny after this stage, usually in the ananeanic substage of more generalized and less closely coiled shells, but when one ascends in the same genetic series to the more specialized nautilian involved shells this purely acquired character becomes, through the action of tachygenesis, forced back, appearing as a rule in the nepionic stage before the whorls touch. It is therefore in these forms entirely independent of the mechanical cause, the pressure of one whorl upon another, which first originated it. One need only to add that this configuration of the dorsum is never found in adults of any ancient and normally uncoiled shells, so far as I know, nor so far as they have been figured. I have so far found only one form —Cranoceras of the Devonian—in which there is apparently a slight dorsal impression, which may have arisen independently of close coiling.

There are apparent exceptions to this rule in some of the extremely close-coiled forms of nautilian shells of the Calciferous and Quebec faunas (some of which are figured in the plates of this memoir), but in these the first whorl bends so abruptly and enlarges with such extreme rapidity that the inflection of the dorsal side before the whorls touch can be attributed to mechanical effects of three factors, viz., rapid spreading of the whorl, the abrupt curvature and contact or close proximity of the paranepionic stage to the apical part of the conch. Even, however, if this conclusion be doubted and if, in a few forms of extremely specialized nautilian shells of these early periods of geologic history, it can be asserted that the impressed zone has really become inheritable; the position assumed in this paper, that the impressed zone is mechanically generated in the later stages of growth and becomes an inheritable characteristic only in forms with accelerated development, is positively strengthened. The whole argument being based upon morphology, it makes no essential difference how early the impressed zone appears or in what form it appears, provided the shells in which it is characteristic of the first volution before contact are the descendants of those in which this character is transient and obviously due to the moulding during growth of one volution over the next inner volution.

My experience, however, in writing this paper has led me to distinguish two kinds of impressed zones; that which occurs on the free dorsal sides of the young and that which occurs as the direct result of contact. I propose therefore to call the former the *dorsal furrow* and the latter the *contact furrow.*

The ananeanic substage among Carboniferous cephalopods is not only marked by the beginning of the contact furrow but also, as a rule, by the introduction of correlative changes in the form of the whorl. Thus the tetragonal whorl, with an outline similar to that of an inverted trapezoid in section, and consequently an obvious repetition of the ephebic whorl of Temnocheilus, and with sutures also like those of the adults of that genus, appears at this stage in Carboniferous cephalopods of several different genera, showing their immediate descent from Devonian Temnocheili.

The first appearance of the dorsal lobe in the sutures is correlated with closer coiling and is apt to make its first appearance in primitive nautilian shells at this stage in the contact furrow. This lobe however, occurs also before the whorls touch in a number of forms, notably Barrandeoceras of the Silurian, and in one of these, *Barrandeoceras Sternbergi,* it occurs in the ephebic stage, although this is a gyroceran form and no contact furrow is formed. There is also another smaller lobe which appears in the centre of this, the annular lobe. These are not strictly correlative with the impressed zone, since a dorsal lobe appears in some cyrtoceran shells which do not have an impressed zone at any stage in Barrañdeoceras while the dorsum is still convex, and in *Nautilus aratus* it and the annular lobe is found beginning in the third septum, and similar observations have been made on a few other species in the descriptive part of this memoir. The characteristics of the ananeanic substage of *N. pompilius* show how distinct this substage is in existing nautilus from the preceding and succeeding substages. The longitudinal ridges disappear during this substage, and the broad transverse bands of growth become in consequence for a time more prominent. The uniform brown of the paranepionic may begin to be striped on the sides in the latter part of the same substage, but this is often delayed until the ananeanic substage and always become more definite at this time.

In the metaneanic substage the shell becomes smooth, the brown striping extends on to the venter, and the markings become more distinct and more widely separated. The whorl which, during the preceding substage, had lost the subtrigonal outline of the paranepionic and become kidney-shaped in outline, with a deep impressed zone, now acquires a deeper impressed zone and slightly flattened sides and venter, thus forming lateral zones, as in *Nautilus umbilicatus*, and repeating at this stage the form of whorl characteristics of that species. During the paraneanic substage the deposits of porcellanus matter in the umbilical zone begin but do not become a very marked characteristic.

In the ephebic stage these deposits on either side increase and the whorl spreads inwardly closing the umbilici, the whorl in the meantime losing its flattened venter, which again becomes rounded. The metephebic substage begins when the umbilical perforations become obliterated by the ingrowth of the umbilical zones.

The parephebic substage is definable externally only by the cessation of the coloration. This may be due either to the fact that senility is not marked by any peculiar structural changes, as happens often in other highly involute species of Nautiloids and even in many Ammonoids with smooth shells, or because no very large old specimens have been collected.

These remarks do not represent fairly all the ontogenic changes in existing Nautili, which will be treated in another essay, but they suffice for the purposes of this paper and serve, with other facts cited, to show the applications of the nomenclature used in the following pages.

In general terms transition to the ephebic stage takes place in the paraneanic substage or near its termination, and characteristics derived from the ephebic stages of immediate ancestors in the same phylum, such as the trapezoidal whorl of Temnocheilus mentioned above, are completely replaced by characteristics peculiar to the genus and species. While there are often marked distinctions between this and the ananeanic substage, the differences are much less obvious between this and the ephebic stage except in those shells in which this period has degenerate characteristics. In these phylogerontic forms marked distinctions are likely to make their appearance owing to the disappearance of hereditary external ornaments and markings which have been present until near the end of the neanic stage.

The ephebic stage has not been so fully studied among the nautiloids or ammonoids, and in both of these orders it might be considered questionable whether any subdivisions were essential. But I have found it convenient to subdivide this stage in some of the descriptions given in this memoir, and since this stage is much prolonged in some forms of Ammonitinæ, especially those with numerous whorls like the shells of Caloceras, Vermiceras and the like, it is probable that when its characteristics have received more attention subdivisions will be found to be as necessary as in other stages. The gerontic stage has been described above and is necessarily illustrated in the text which follows, and the subdivision of this stage into two or more according to the species is convenient in order to distinguish the well-marked substages of decline.

The limits of the earlier epembryonic stages are somewhat more difficult to define among Ammonoidea than Nautiloidea, because the shells of the former are the bearers of a larger number of hereditary characters, and being more highly specialized descendants of the latter, the history of these stages is more complicated by the intrusion of new modifications through the action of the law of tachygenesis.

The protoconch, with a large aperture connecting with the opening of the conch, is plainly seen in the figures of *Mimoceras compressus* and others on Pl. ii, of this paper, and also in Sandberger's figures of species of Goniatitinæ on the same plate. This is very distinct from the aspect of the apex of the conch in Nautiloidea. In that order the neck of the protoconch must have been at least as narrow from side to side as the scar on the outer surface of the apex, and at least as long ventro-dorsally as the same. In other words, the aperture of the protoconch in Nautiloidea was narrow and elongated vertically, while that of the Ammonoidea in all having cylindrical, straight or loosely coiled young shells, was an open tube, as happens in Clarke's Orthoceran form, in Bactrites and in a number of Goniatitinæ as shown in the figures.

In most groups of Goniatitinæ and the other suborders of Ammonoidea which, as a rule, have invariably closely-coiled first whorls, the effect of contact is to produce immediately a deep, contact furrow and an almost entire obliteration of the umbilical perforation between the neck of the protoconch and the nepionic volution. Two funnel-shaped openings are left on either side, as shown in figures on Pl. ii, and these represent the more complete perforation present in all Nautiloidea and in the earliest forms of Goniatitinæ among Ammonoidea. The probable position of the aperture of the protoconch has been indicated in *Embryology of Fossil Cephalopods*, p. 110, and in Pl. iv, Fig. 1, and this information, gathered from sections, agrees well with the figure given by Dr. Brown of the supposed aperture of Baculites which is reproduced in outline, Fig. 17, Pl. ii.*

The growth of this form out of the protoconch, as in Bactrites, must have been quite different from that of the true Nautiloidea. Nevertheless it is obvious that as the animal grew outside of the limits of the protoconchial aperture, it began to build the shell of the apex of the conch and the first living chamber. This was the ananepionic substage and it in part more or less resembled in some of its essential characteristics and for a short time, the aseptate, apical living chamber of the Nautiloid, but this resemblance must have been transient and much accelerated.

After or during the building of this external skeletal tube it became practicable for the animal to lift itself, or, more properly speaking, to progress by growth out of the protoconch, and the next step can be seen in Branco's Fig. 10, Pl. iii, and the details in my Fig. 7, Pl. iii, both of which, and others also given, show that the bottom of the cæcum occupied the aperture of the protoconch and is formed, as in Nautiloids, of the closed funnel of the first septum. It is therefore inherited earlier, according to the law of tachygenesis, since the first septum and the cæcum occupy the same position with relation to the protoconch as the scar or cicatrix in

* *Proc. Acad. Sci. Phil.*, 1892, Pl. ix, Figs. 5 and 10, 11.

the apex of the shell in Nautiloidea. This and the fact that the protoconch is calcareous are in favor of the opinion that the characteristics of the ananepionic substage of the ancestral nautiloids appeared in combination with the protoconchial stage in ammonoids. Thus the first septum and cæcum in this order is the floor of the first living chamber of the apex of the conch and is one substage earlier in this order than in nautiloids, and should be called ananepionic.

The figures, so far as the shell is concerned, also seem to demonstrate that the cæcum at this substage probably represents some embryonic structure. This is Zittel's explanation of the origin of the siphuncle, it being as stated by him obviously traceable to the cæcum, and this in turn being probably formed out of a part of the body or the shrunken mantle of the embryo, since it lies in the Ammonoidea directly in the aperture of the protoconch.

While, however, this organ fills the diameter of the apex in the median plane, it is narrower laterally, and one feels that this supposition is open to certain objections that will be discussed more fully in a paper now in preparation on the Endoceratidæ. It may be mentioned here, however, that in these ancient forms of the Nautiloidea the opening from the siphuncle into the protoconchial shell is closed in a different way from what it is in the normal Nautiloidea, and in the protosiphonula the endosiphuncle communicated with the protoconchial shell, passing through the bottom of the cæcum and apex. The elements of the walls of the siphuncle surrounding the endosiphuncle in these forms are, however, similar to what they are in the Nautiloids of less primitive organization, and it becomes probable that the cæcum was formed in the metanepionic substage in Nautiloidea as a secondary epembryonic organ, and that this has been crowded out of the metanepionic into the ananepionic in Ammonoids. In other words, like some other characters it was acquired in the epembryonic stages of Diphragmoceras and like these has been inherited earlier in descendants.

One naturally, if disposed to adopt the theories of genesiology as a working hypothesis, looks for the largest representation of ancestral characters in the earliest and most generalized forms. Thus the Goniatitinæ of the Silurian, which belong in all except the terminal members of series like Pinnacites and Celceras to this category, one ought to find the transitions to Bactrites, or, failing these, indications in the young of the less specialized forms of the

Silurian of their immediate derivation from Nautiloid ancestors. This is precisely what actually occurred and in the Nautiloidea such evidence is easily obtained as has already been stated above in the pages of the Introduction and other publications.

It also follows, if the theories advanced by the author are true, that the Nautilinidæ among Goniatitinæ, as ancestors of the Ammonoidea, and especially the genus Mimoceras as the centre of derivation, should also show more prolonged retention of nautiloid characters in their ontogeny than is usual in their supposed descendants. The researches of Sandberger, Barrande, Branco and the author show this to be a fact. The figures of Pl. ii copied from Barrande and Branco exhibit this in *Mimoceras compressum, ambigena* and the whole of the Nautilinidæ of the Silurian, and the essential distinctive characteristic of this family is the nautiloid form of the septa and lateral sutures. The shells of this genus also do not possess a contact furrow, as noted above, and have no annular lobes on the dorsum.

The first suture of *Mimoceras compressum*, Figs. 3, 4, Pl. ii, and in some other allied species of the Devonian is bent into a slight lobe on the venter, which is a purely nautiloid character, and not to be confounded with the ammonoidal lobe in the same situation in the third suture that follows this. This is shown by the occurrence of similar lobes in the Endoceratidæ and some cyrtoceran forms of Nautiloidea and in figures of sutures of *Nautilus deslongchampseanus* and *clementinus* of the Cretaceous, also copied from Branco, which have similar first and second sutures. The aselate first septum is in *M. compressum*, followed on the second septum by a broad, almost imperceptible saddle, also considered aselate by Branco, but which is obviously a transition to the latisellate, or broad-saddle type of suture in the more specialized forms. The limits of the ananepionic substage in this form, which, as said above, is directly transitional to Bactrites, is therefore that part of the whorl which is represented by these two septa and the living chamber in which the animal rested while constructing the second one.

The characters of these two septa, however, are not repeated in the closer-coiled forms of the Nautilinidæ and Primordialidæ. In these the repetition of the outline of the second suture may be entirely omitted, the shell passing immediately in the second septum to the repetition of the peculiar undivided ventral of the

Nautilinidæ, obliterating the primitive characteristics of the second septum and substituting the more advanced characteristics of the Nautilinidæ as is plainly demonstrated in Fig. 16, Pl. ii, of *Anarcestes* (Goniatites) *lateseptatus* and in the Primordialidæ in *Gephuroceras* (Goniat) *serratum*, Fig. 17 of same plate. In the Ammonitinæ and Lytoceratinæ, and probably in the Ceratitinæ, as in most of the Goniatitinæ, this substage is obviously limited to the first septum and the corresponding living chamber. The limits of this living chamber in one form may possibly be indicated by the transverse imbricated line between the third and fourth septa in my Fig. 1, Pl. iv, of *Embryology of Fossil Cephalopods*. This line seems to demonstrate an arrest of growth at this time in the calcareous deposits corresponding to that indicated in Fig. 11 of the same plate which is probably due to a former aperture.

The metanepionic substage must obviously begin with the advent of the characteristics of the tubular microsiphuncle and the ventral lobe in sutures, whether this occurs in the second or third septum or later.

It is limited in duration to the repetition of the characteristics of the Nautilinidæ in certain of the Goniatitinæ. Thus that family of the Silurian and Devonian is phylo-metanepionic, or corresponds in the phylum in its ephebic characters to the metanepionic substage of its descendants. The closely allied family of the Primordialidæ, for example, as shown in Fig. 17, Pl. ii, has several septa with this character appearing in the metanepionic substage, the construction of the divided ventral lobe so characteristic of all normal forms of Ammonoidea not taking place until the shell is nearly or about 3 mm. in diameter in one species, according to Branco's figures, and still later in some other species.

In the Ceratitinæ of the Trias this substage is in many species, as shown by Branco's drawings, prolonged through several septa and there are decided indications that it is subdivisible into two parts, one characterized by the purely nautilinian ventral lobe and lateral sutures with only one broad lobe, and a second older portion having the undivided ventral lobes and lateral sutures of other radical forms among Goniatitinæ, ex. Prolecanites.

In *Trachyceras Munsteri* the eighth suture, according to Branco, is still undivided or nautilinian, and Tropites, according to the same author's figures, has this substage still more prolonged. In Megaphyllites, Pinnacoceras, etc., all more highly specialized forms of the Trias, it is apparently shorter in duration than in the generalized and less complex organization of Tirolites if one can judge by the simple characters of the ephebic stage.

In the Jura and Cretaceous, among the Ammonitinæ and Lytoceratinæ, typical Ammonoids with more highly specialized structures than any Triassic shells, the primitive characters of this substage are, as one can read in Branco's drawings and to a less extent in mine, still more limited in extent, being confined as a rule to a few sutures or to one, and finally, in many forms they are obliterated altogether. That is to say, the divided ventral lobe encroaches upon and finally obliterates the intermediate stage so that the metanepionic substage, which begins with the third septum and microsiphon, is wholly changed in the aspect of the sutures. In other words, the undivided ventral lobe of the Nautilinidæ has been replaced in this substage by the divided ventral of the Primordialidæ which appears in the suture of the second septum.

This is also, like the preceding, an excellent example of what is meant by the law of tachygenesis, the earlier inheritance through the crowding back and replacement of distal by proximal genetic characteristics.

Fig. 3, Pl. iv, shows the prolonged duration of the nautilinian characteristics in this substage in second, third and fourth septa of *Vermiceras* (Arietites) *spiratissimun* of the Lower Lias, the decided change to a divided ventral and two lateral lobes not coming in until the seventh suture.

Fig. 7, Pl. iii, shows the section of *Deroceras planicosta* of the Lower Lias and the delayed approximation of the siphuncle to the ventral side. Fig. 7 shows the primitive structure of this organ in the earlier substages, and the figures from Branco show the duration of characteristics to be in correlation with these primitive characteristics.

Fig. 7, Pl. iii, shows the structure of the siphuncle in the metanepionic substage. The transitional aspect of the second septum can be observed in Figs. 6 and 7 of the same plate. This is a direct reference, as I shall show in another paper, to the similar structure of the ephebic siphuncle, and also the swollen aspect of the early stages of the siphuncle in the Endoceratidæ, although in some species of this family as many as six funnels may take part in the construction of the swollen apical end of this organ. These facts are also in direct correlation with the more specialized and complicated structure of Ammonoidea. They show that these forms do not retain the tendency to form a cæcum with double walls as in Nautiloidea, and such an example as that figured in *Nautilus pompilius*, in which a misplaced second septum necessarily shows a long tubular cæcum like that of the living chamber of Diphragmoceras, probably does not occur. In other words, one of the most persistent of the nepionic characteristics of Nautiloidea does not exist in the more specialized shells of Ammonoidea so far as known.

It is obvious from the preceding that the paranepionic substage begins in most forms of this order with the first appearance of the divided ventral lobe, or what I have called the siphonal saddle and it is limited in extent by the duration of the simple entire goniatitic outlines of the sutures which accompany all the substages of the nepionic stage in all the suborders of Ammonitinæ, except, of course, the stock in which they originated, the Goniatitinæ.

In the Ceratitinæ, Ammonitinæ and Lytoceratinæ it is generally true that this occurs, and the ananeanic substage begins with subdivision of the lobes and saddles into minor lobes and saddles or digitations, and this is often also accompanied by the advent of a minute siphonal lobe in the apex of the siphonal saddle. It is not essential here to discuss the limits of the neanic stage and its substages. They vary so much with the condition of development and the position of each species in its own series or genus and of each series or genus in its own group, that it is impracticable to define them except in very comprehensive terms.

Thus one may say the limit of the neanic stage is reached when the specific characteristics begin to appear in normal progressive forms. But there are exceptions to this in some highly tachygenic species, as in *Oxynoticeras oxynotum*, for example, and many others in which certain characteristics are carried back to earlier substages. Still, as a rule, this definition does good service if the occurrence of exceptions are constantly anticipated.

The limits of the substages can be obtained in some species of each series, and are quite distinct in the external characteristics of the form of the whorl and of the ornamentation. The sutures of the ananeanic substage are different from those of the metaneanic since they are much simpler and less completely digitated, but there is, as a rule, but slight, if any, differences between the sutures of the metaneanic and paraneanic or ephebic sutures. These substages have been described, although not defined according to the nomenclature used in these pages, by Würtenburger in his essay referred to above; by S. S. Buckman in his extensive and monumental work published by the Paleontographical Society in their volume for 1891 on the "Ammonites of the Oölite," and by the author in the *Genesis of the Arietidæ.*

The gerontic stage has also been fully described and separated into two subdivisions by Mr. Buckman and the author, and is easily distinguished from the ephebic by the external characters, and as stated above the septa become more or less approximated in the paragerontic substage and there is often slight but perceptible degeneration in the sutures.

All of the remarks made above apply well enough in a general sense to the progressive series of the Ammonoidea, but although we know the younger stages of only a few species of the retrogressive species, there are indications that they will require modifications to be true also for the phylogerontic forms.

Thus *Choristoceras* (of) *Henseli*, as figured by Branco,* has apparently a considerable number of sutures having the undivided ventral lobe. These are less in number than in some progressive forms like *Tropites subullatus*, figured on the same plate, but unluckily the immediate ancestors of this species are unknown and exact comparisons cannot be made.

The young of the uncoiled forms of the Ammonoidea show however, in all their characters that the early inheritance of gerontic tendencies interferes with and delays the development of the progressive, more complicated structures of the forms from which they must have been derived. This is admirably shown in the drawings of Dr. Brown, some of which are reproduced on Pl. iii.

Fig. 13 shows a complete young shell which is in the neanic stage of growth. Fig. 17 is a restored side view of the protoconchial stage and ananepionic substage with aperture. Fig. 16 gives front view of the first volution in the paranepionic substage which begins at the fourth septum, and Fig. 18 side view at the sixth septum. Fig. 1, Pl. iv, shows the sutures for the same age.

Figs. 14–16 show the gradual diminution of the area of the contact furrow and the decrease in lateral diameters of the volution

* *Op. cit., Paleontogr.*, xxvi, Pl. v.

while the shell is still in the nepionic stage and as it approaches the point of departure from the spiral and the subsequent loss of the contact furrow. Dr. Brown records that the spacing of the septa increases after the deposition of the twelfth septum, and that these partitions are more widely separated. This correlates with a corresponding increase in the lateral diameters and together indicate an increased rate of growth. Nevertheless there is no quickening in the processes of development nor any resumption of progressive characters. The shell becomes a compressed ellipse in section, loses the contact furrow, and the straightened cone does not acquire the digitate sutures and pass into the neanic stage of the Ammonitinæ until after it has departed from the spiral.*

It is clear from this and other examples taken from later stages of growth that these are tachygenetic forms so far as the early inheritance of gerontic characters is concerned. Correlating with this, or in consequence of this, the inheritance of progressive characters in the sutures is delayed, and these parts change more slowly in these phyloparaplastic shells than in the phylometaplastic forms of the same order. The internal structures and the shell itself also, as previously stated, never attains even in the stage of ephebic development characteristics comparable to those of phylometaplastic species.

It follows upon the preceding remarks that the characters of these stages have different duration in different members of the same genetic series, being more prolonged in the more primitive and shortened up through the action of tachygenesis in the more specialized shells of the same series. It is also obvious that the limits of each substage must be defined differently according to the position of the animal in time and in the evolution of its own special series.

There are theoretically no exceptions to this law in its broadest acceptation, but in its practical applications this is not the case.

Thus the protoconchial stage is so nearly invariable in each order that it is characteristic of all Nautiloidea and all Ammonoidea, having peculiar characters in each of these orders, but this comparative invariability is less apparent in the characters of the ananepionic, metanepionic and paranepionic substages, and especially in the neanic stage, which are not as constant. The tendency to change

* Having received specimens of these precious fossils through the kindness of Dr. Brown, I am able to confirm his observations, although I have not yet had proper opportunity to go over all the material and study every detail of the development.

along certain lines of modification in accordance with definite genetic laws becomes, in other words, more apparent in the later than in the earlier substages of the ontogeny.*

In order to give a clear and comprehensible example of the general application of these laws I have quoted below several pages from Buckman's interesting and instructive paper on "Some Laws of Heredity and their Application to Man." †

HOW THE TRANSMISSION OF VARIATION WOULD AFFECT THE ORIGIN OF SPECIES.

"It is not difficult to understand the origin of species if the surmises that I have submitted, concerning the transmission of developmental variation, are correct. The greater and greater elaboration of any particular features in, say, an adult male, as functional modification necessitated by environment, are transmitted to the male sex alone, and appear earlier and earlier in that sex. The greater and greater elaboration of these features results in the course of time in the formation of a marked and distinguishing character in the male sex; and this character being transmitted in accordance with the law of earlier inheritance ultimately appears early in life in the male. Then the character tends to appear in the female sex also, though why it does so is not clear. By such process, however, there arise both males and females which possess characters different to those which their ancestors possessed.

"By the time that this character, influenced by the law of earlier inheritance, appears at an age early enough to be transferred to the female, the male has probably either further elaborated this character—which further elaboration is at first transmitted to the males only—or he has elaborated something else so much that it seems like a new character which is transmitted in the same way. In course of time this further elaboration, or this new character as the case may be, is transmitted also to the females; and so it becomes plain how, merely by the gradual transmission of developmental variations, both sexes of what may be called an incipient species, beginning with a slight variation in one sex alone, are able to diverge wider and wider from the original stock.

"The same laws of transmission would of course hold good if

* The application of this law, however, to the gerontic substages demands a longer discussion than can be given here, and must be deferred to future publications.

† *Proc. Cotteswold Natur. Field Club*, Vol. x, Pt. iii, pp. 258–322, 1891–1892.

the developmental variation arose in the female in response to changes of environment; while if both sexes were exposed to the same changes of environment necessitating the same functional modifications to be acquired to bring them into better adaptation with their surroundings, it is reasonable to conclude that the result would be the production of a greater difference in a shorter space of time.

"Thus it is clear that the gradual accumulation of slight developmental variations transmitted in accordance with the law of earlier inheritance would be sufficient to cause the origin of various species; and at the same time there can be little doubt that this cause has also been assisted by both Natural and Sexual Selection in the production of diverse species from one original stock. I am inclined to think that developmental variation has been more important in the origin of species than has abnormal, or as Darwin calls it, 'spontaneous,' variation. The transmission of such abnormal variations as supernumerary digits seems to be so much more uncertain than the transmission of developmental variation, while practically speaking the origin of Ammonite species seems to be almost entirely attributable to developmental variation.

"Specialized structures like the long neck of the giraffe and the proboscis of the elephant, to take familiar instances, are, in my opinion, developmental variations. They did not arise, in the first place, in certain members of the pregiraffian or preëlephantine species as abnormal or 'spontaneous' variations which gave their possessors such great superiority over their fellows in the struggle for existence that those possessors survived by the law of Natural Selection. These features began imperceptibly—the neck and the nose grew more in proportion to other features during the lives of the individuals on account of the habits of the animals, and they may be compared in this respect to the enlarging skull of civilized Man.

"As the features of the adult become in course of time the features of the adolescent by the law of earlier inheritance, the elongation of nose and neck would become exaggerated from one generation to another. I do not see any reason to suppose, at any rate at first, that the giraffian or elephantine ancestors were the favored individuals of the community, and that the other members died out because they did not possess elongated necks or noses. I do not suppose that all the members of the species possessed these features in the same degree, but I do imagine that a gradually increasing elongation was more or less common to all the members of the pregiraffian or preëlephantine species as a result of their habits.

"To take the case of the giraffe alone, for the sake of clearness —it is hardly necessary to suppose occasional droughts during which those members of the community with the longest necks would survive, while others starved because they were not able to reach such high branches as their longer-necked fellows. An extra inch or so of neck could not make so much difference as this.*

"I do not say that the giraffe or its ancestors have not had the best of it when there was a struggle for existence, and that natural selection has not played its part; the fact of the giraffe's existence is proof enough that it was better adapted to its environment than some of its competitors; and the longer the neck grew doubtless the greater superiority the animal would possess.

"As to the short-necked forms which would connect the present giraffe with the stock from which it originally came, their dying out is not difficult to explain. The law of earlier inheritance allows us to imagine a small beginning becoming more accentuated in all members of a species as time goes on, and as the shorter-necked forms were really the parents of the longer-necked forms, the disappearance of the former would be due, as the lawyers say of a lease, to effluxion of time.

"Arising from and coëxisting with developmental variation there seems to be another factor important in differentiating species, and this is the time when the offspring is produced.

"Offspring produced early and offspring produced late in the life of a parent shewing considerable developmental changes between early and late maturity, or between early maturity and senility, would in all probability differ to a certain extent. It is, I think, reasonable to suppose that if there were, say, a decline of vigor after a certain period of the parent's life, the offspring produced after this time would be more likely not only to be somewhat less vigorous altogether, but would probably exhibit declining vigor at an earlier age than those produced before any decline of vigor set in.

*"The adults would have the best of it in a drought on account of their larger size. Therefore if there were a long-necked 'sport' among the young pregiraffes it would have no chance against the adults unless its neck were of a preternatural length."

"This seems to be a reasonable deduction from what is observed in phylogenetic series of Ammonites, where from the same stock arise one series which continues to progress, another series which retrogrades, though both lived together and were presumably subject to the same environment.

"More marked still would be the effects if from any cause there arose a difference among members of a species as to the time in their lives when offspring were produced. There is the case in Man—the professional classes defer marriage till late in life, agricultural laborers marry very early.

"These surmises illustrate what may be supposed to be accomplished in the differentiation of species by the transmission of developmental variations in accordance with the law of earlier inheritance. Further consideration will shew that, if some members of a species acquire, on account of environment, habits necessitating the increased use of one part, and other members acquire other habits with different results, and so on, there would, in course of time, arise from one original stock two or more species very different from each other or to the parent form—simply because their small initial differences had been constantly increased by the action of the law of earlier inheritance."

IV. Descriptive Terms.*

Before attempting to enter upon the descriptive part of this essay it is essential to define, as briefly as possible, the meaning of the terms which are constantly employed in the descriptions of the different forms. The term "coil" has been applied solely to the whole shell, while "whorl" and "volution" have been used when in the singular or when numbered only for a particular whorl or volution. Thus the first whorl or first volution is the first completed revolution of the shell, and so on. I have also been obliged to use volution for parts of a single whorl in describing substages.

In describing the aperture I have used the terms "crest" for projecting parts and "sinus" for inflections of the outline to distinguish them from the saddles and lobes of the sutures. The ventral sinus of the aperture and lines of growth is here called the "hyponomic sinus," it being due to the large size of the hyponome or

*Special students of Cephalopoda will, it is thought, be grateful for this chapter. Other classes of readers, if there be one who gets so far and has the courage to go farther, can skip and refer to it in connection with the descriptions which follow.

motor organ usually called "fleshy funnel" in the modern nautilus, as has been explained above.

It is useless to discuss the terms "ventral" and "dorsal." There can be no debate on their application, unless it is based upon new anatomical information. The fact is obvious, so far as now known, that in *Nautilus pompilius*, and all other Nautiloids, the outer side of the whorl is ventral and the inner side is dorsal. Whenever, even in straight shells, Orthoceras, etc., the lines of growth can be seen, the ventral side is indicated by the "hyponomic sinus," and in nautilian or coiled shells it is invariably on the outer side.

The term "depressed" is used for the flattening of the whorls, which affects the abdomen and dorsum and acts at right angles to the transverse diameter of the coil; "compressed" for the similar effect on the sides, which acts in the plane of the transverse diameters and at right angles to the plane of coiling. When the sides, lateral zone, or faces are inclined inwardly towards the umbilici, the term "divergent" is applied, and when they incline outwardly towards the abdomen the term "convergent" has been used.

The adoption of these terms has been found to give clearer ideas of the development and true importance to the different characters of the volutions. The term "sides" is used in a general way, and distinguishes the whole of the lateral aspect of the whorl at any stage. The "lateral zones" and lateral faces, etc., as will be seen in the descriptions, are developed as modifications out of the sides of the young and immature whorls. The outer angles occurring on either side in the young or in the biangular forms are in the text named "lateral angles," being really on the sides of the whorl and distinct from the angles arising later in the life of the individual, and later in the evolution of the group. The junction of the "lateral faces" and abdomen are the "abdominal angles," and those of the "lateral faces" and inner faces of the mature whorls are called the "umbilical shoulders," and the inner surfaces are the "umbilical zones." All of these parts are developed in succession and in various combinations, from a round or elliptical form of whorl, having the vertical or ventro-dorsal diameter longer than the transverse, both in the individual and in the evolution of the group.

The venter is the area between the outer angles, whether they be the "lateral" or "abdominal" angles, on the outer part of the whorl, and the "dorsum" is the corresponding part on the inner part of the same, between the "lateral angles" or the "umbilical shoulders." The "zone of impression," or "impressed zone," is the area on the dorsum, which is concave, and lies between the "umbilical zones." The impressed zone may appear independently as a "dorsal furrow," or, after contact, as a "contact furrow." The "zone of inclusion" or "included zone" is the covered area corresponding to this on the venter. The term "zones of involution" or "area of involution" can be used for both of these when the whorls are not separated or it is desired to speak of the two together. The "lines of involution" are the outer boundaries of the "zone of impression" on the dorsum, and the "lines of inclusion" the corresponding lines on the venter.

The terms "involved" and "involution" should be limited to whorls having a "zone of impression" or "impressed zone," that is, to "nautilian" shells. "Coiled" can be applied to all shells that have the gyroceran curve and even to shells with the whorls in contact. Nevertheless these sometimes have closer affinity with nautilian shells of a given series than with the gyroceran shells of the same series.

Whorls with only two surfaces and angles are "digonal;" three surfaces and angles "trigonal;" four surfaces and angles "tetragonal," and when the abdomen is much broader than any other side "trapezoidal;" five surfaces and angles "pentagonal;" six surfaces and angles "hexagonal;" seven surfaces and angles "heptagonal;" eight surfaces and angles "octagonal; nine surfaces and angles "enneagonal;" ten surfaces and angles "decagonal."

The outlines on the Diagram Plate, opposite, page 425, will be found to explain these terms more fully.

Explanation of Diagram Plate.

Diagram A.—Section of compressed elliptical whorl with primitive regions indicated, ananepionic substage of nautilian shells and ephebic stage of many primitive orthoceran and cyrtoceran forms.

Diagram B′.—Section of depressed elliptical whorl occurring older in the ontogeny or correspondingly later in the phylogeny than A.

Diagram B″.—Section of a reniform whorl with a contact furrow. This may be evolved from B′ by the growth and involution

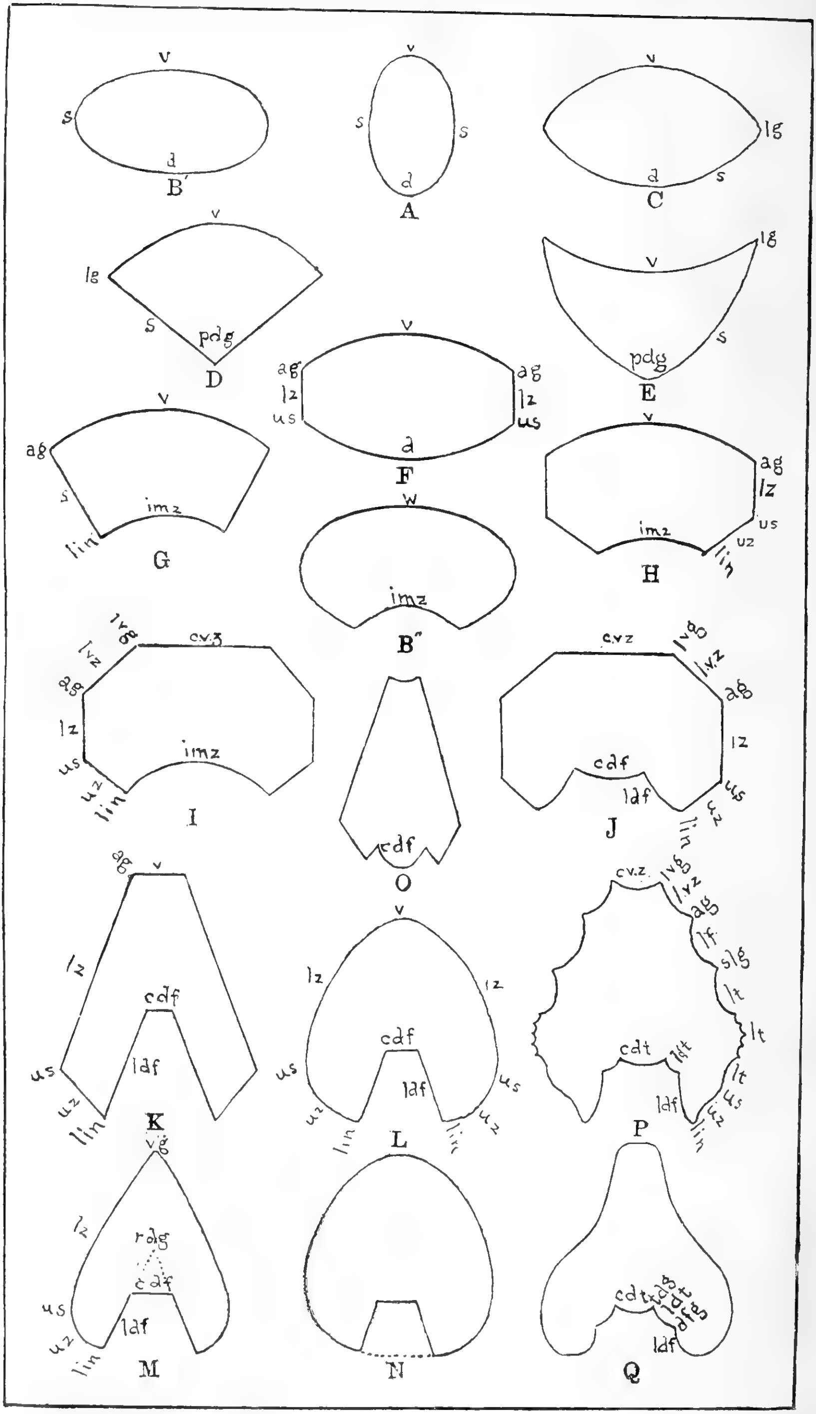

Diagram Plate (Hyatt).

of the whorl,* and may be an intermediate stage leading into a whorl like that shown in H, or it may acquire lateral angles as in C, thus passing into G, or A may pass directly into H.

Diagram C.—Section of a digonal whorl with primitive regions and lateral angles, l. g., occurring in the ephebic stage of orthoceran and cyrtoceran forms and in the young of nautilian forms, Edaphoceras.

Diagram D.—Section of a trigonal whorl with gibbous venter, lateral angles, l. g., and projecting dorsal angle, p. d. g., ex. Trigonoceras.

Diagram E.—Section of a trigonal, shield-shaped whorl, with concave venter, lateral angles, l. g., and projecting dorsal angles, p. d. g. Either D or E may evolve into a tetragonal whorl by the appearance of a lateral zone on the outer part of the sides and the rounding off and disappearance of the dorsal angle, ex. Trigonoceras.

Diagram F.—Section of a tetragonal whorl with gibbous venter and dorsum and lateral zones, l. z. This may be developed from B″ or from C.

The morphic distribution of these forms is as follows: A, B and C may be Orthoceran, Cyrtoceran or Gyroceran, but are more generally Orthoceran; D may be Orthoceran, but is usually Cyrtoceran and Gyroceran; E and F are almost exclusively Gyroceran. All of the remaining outlines belong to Nautilian forms.

Diagram G.—Section of a tetragonal, trapezoidal whorl with a contact furrow nearly as broad as the dorsum, the sides flat and well defined. This may be evolved from C or B″ in development of Nautilian forms. The abdominal angle, a. g., in this form is derived from the lateral angle of forms like C. Sides, s., are still undivided, ex. Temnocheilus.

Diagram H.—Section of a hexagonal whorl with lateral zones, l. z., developed between the abdominal shoulders or angles, a. g., and the umbilical shoulders, u. s., and umbilical zones, u. z., developed between the latter and the lines of involution, l. in. The contact furrow remains primitive or undivided. This may be

*This same diagram can also be used to represent the paragerontic substage of the degeneration. A reniform whorl may result in the gerontic stage from such an ephebic whorl as is represented in H, J, K, or P. Q shows an intermediate stage between P and a reniform paragerontic whorl. No confusion need result from this double use of the same outline, since it does not imply identity of structure, but simply the identity of form at the extremes of the ontocycle in the individual and of the phylocycle in the group.

developed from G or B, or from C, with an intermediate transformation like G, or from B, with an intermediary like B″, and F may give rise to a similar modification when close coiled. A number of Paleozoic forms have this outline, ex. Metacoceras.

Diagram I.—Section of an octagonal whorl derived from H by the building out of the venter and the formation of a central ventral zone, c. v. z., two lateral ventral angles, l. v. g., and two lateral ventral zones, l. v. z., ex. Tainoceras.

Diagram J.—Section of a decagonal whorl derived from I by the subdivision of the impressed zone (contact furrow) and the formation of a central dorsal face, c. d. f., and two lateral dorsal faces, l. d. f., ex. some species of Tainoceras and Cœlonautilus.

In their gerontic substages the whorl of G, H, I and J become more or less rounded and show a tendency to return more or less completely to the outline of B″.

Diagram K.—Section of an octagonal, truncated, cuneiform whorl, usually derived from a whorl similar to H by the convergence of the lateral zones and the subdivision of the impressed zone, c. d. f., central dorsal face, l. d. f., lateral dorsal faces.

Diagram L.—Section of a gerontic whorl derived from K. By farther degeneration the dorsal angles may disappear and the whorl assume approximately the reniform outline of B.

Diagram M.—Section of a heptagonal, cuneiform, anagerontic whorl derived from K. The acute ventral angle, v. g., is formed by the convergence of the lateral zones and the disappearance of the abdominal angles. The dotted lines represent the similar transformation which subsequently takes place in the same form on the dorsum by the convergence of the lateral dorsal faces. The whorl then becomes a hexagonal cuneiform. This outline has been represented with rounded umbilical shoulders, but these have to be considered as equivalent to two angles, and they are often more or less angular.

Diagram L.—Section of a metagerontic whorl of K or M; similar forms may also result from the paragerontic degeneration of Q, ex. *Stroboceras sulcifer*, sp. De Koninck.

Diagram N.—Section of a paragerontic whorl of L. The dotted line represents the obliteration of the zone of impression which may take place in very old whorls in this substage or in the apertures of the ephebic stages of phyloparagerontic species.

Diagram O.—Section of an octagonal, truncated, cuneiform whorl with a concave abdomen in which a gibbous, central, dorsal face is formed and the lateral dorsal faces are excessively narrow. This may be derived from E by involution and the formation of umbilical shoulders and umbilical zones, ex. *Apheleceras, Subclymenia.*

Diagram P.—Section of a highly complicated fluted whorl with concave abdomen. The venter has become subdivided into a fluted central ventral zone, c. v. z., and two fluted lateral ventral zones, l. v. z., these having become incorporated with the lateral aspect, and the intermediate lateral ventral angles, l. v. g., form the borders of what is usually considered as the sides of the whorl.

The lateral zones lying between the abdominal shoulders, a. g., and the umbilical shoulders, u. s., have become subdivided into two lateral faces, the outer one, l. f., is a broad flute, and the inner one is subdivided into three lateral facets, l. t., two of them, the outer and inner facets, fluted, and one of them, the central one, slightly gibbous and ridged.

The contact furrow has a central dorsal facet, c. d. t., two lateral dorsal facets, l. d. t., and two lateral dorsal faces, l. d. f., the angle between l. d. t. and c. d. t. is the tertiary dorsal angle, t. d. g., but is not lettered, and the angle between l. d. f. and l. d. t. is the dorsal face angle and is also not lettered in this diagram, but these are lettered in Diagram Q. The facets are introduced by the subdivision of the central dorsal face, which is at first flat, as in L.

The secondary lateral angle, s. l. g., is developed between the flute of the lateral face, l. f., and the outer facet of the inner lateral face that extends from s. l. g. to u. s. The lateral facets formed out of the surface of this face are three in number, marked l. t., and the angles between these are the tertiary lateral angles, but are not lettered. The angles on the central gibbous lateral facet are due to longitudinal striæ.

Diagram Q.—Section of a gerontic whorl of P. The flutings and other ornaments have been obliterated, but the impressed zone retains its peculiar characteristics. The more advanced paragerontic substage would approximate to Diagram N, but with more depressed venter. Coloceras is a phyloparagerontic form, having an almost reniform whorl in the neanic and ephebic stages.

TABLE III.

LETTERING OF DIAGRAMS TO ILLUSTRATE DESCRIPTIVE TERMS.*

PARTS OF THE WHORL.

(1) REGIONS.	(2) ZONES.	(3) FACES.	(4) FACETS.
v., venter or abdomen	c. v. z., central ventral zone l. v. z., lateral ventral zone		
s., sides	l. z., lateral zones	l. f., lateral faces	l. t., lateral facets
d., dorsum	u. z., umbilical zones	u. f., umbilical faces (None figured)	
	im. z., impressed zone (in these diagrams always a contact furrow)	c. d f, central dorsal face l. d. f., lateral dorsal faces	c. d. t., central dorsal facet l. d. t., lateral dorsal facets
		ANGLES.	
l. g., lateral angles	a. g., abdominal angles or shoulders	v. g., ventral angle always central s. v. g., secondary or lateral ventral angles	t. v. g., tertiary ventral angles (None figured)
		s. l. g, secondary lateral angles	t. l. g., tertiary lateral angles (Occur between the lateral facets of Diagram P, but are not lettered)
l. in., lines of involution	u. s., umbilical shoulders	r. d. g., reëntrant dorsal angle	
	p. d. g., projecting dorsal angle	d. f. g., dorsal face angles	t. d. g., tertiary dorsal angles

*These terms have been chosen in accordance with the following principles: The Regions of the ananepionic whorl, viz., venter, sides and dorsum, are regarded as primitive, and therefore of the first order. The flatter surfaces of the whorl are developed next, and are called Zones, and placed in the second order. The truncations of the angles made by the Zones take place when the Faces are formed, and the last necessarily belong to the third order of modifications, and for similar reasons the Facets, being subdivisions of the Faces, form the fourth order. The angles have been classified according to the same system; those occurring at the intersections of the Regions are of the first order, those made by the Zones are of the second order, and so on.

These diagrams and examples (with the exception of A, B and C) were taken from Carboniferous forms published in the *Fourth Annual Report of the Geological Survey of Texas*, 1892, but they are applicable to all of the Nautiloidea, provided certain distinctions be made. The outline expands by growth from an ananepionic stage, in this case having the approximate outline of A, and may develop into B and C, with decided lateral angles, but in the ephebic stage may sometimes return to the form of Edaphoceras, C. Species of other groups may pass through B′ and, becoming involute, take on the outline of B″, and then, if the shell progresses still more, it may tend towards forms of H.

It must, however, be noticed that fossils of such species occurring in the earliest geologic period have not, as a rule, even approximately well-defined angles, and these being deficient, the zones are not apt to be well differentiated. One can readily see that these shells, even though they may be involute from an early stage, have not the more highly specialized characteristics of the whorl found in some of the Devonian fossils. The latter, in their turn, take rank as a whole below the still more progressive and highly ornamented nautilian shells of the Carboniferous which represent the acme of the order.

The paracme of the order begins in the Trias, and retrogression is plainly manifested in the steady decline of the external ornaments and less angulation of the whorl. The universal absence of all of the third and fourth orders of modifications of the whorl is one of the marked features of this decline, beginning with the Trias and becoming universal in the Jura and other subsequent periods.

The nomenclature of the sutures needs no special description, except with reference to the "annular lobe." This is a small indentation in the sutures, occurring either in the centre of a dorsal saddle or a dorsal lobe. It is pointed or V-shaped. In some forms it may arise before a dorsal lobe is formed in the middle of a primitive but persistent dorsal saddle, or it may arise subsequently in the centre of a broad dorsal lobe. Its development has not been fully described. It is often accompanied by an internal pointed cæcum called the "annular cone," and both are probably connected with the development of the "annular muscle."

It has been usual to measure the distance of the siphuncle and describe its position, with more or less circumlocution, as ventral, dorsal, central, etc., but in these descriptions the following terms have been employed, which are best explained by the following diagram, Fig. 14.

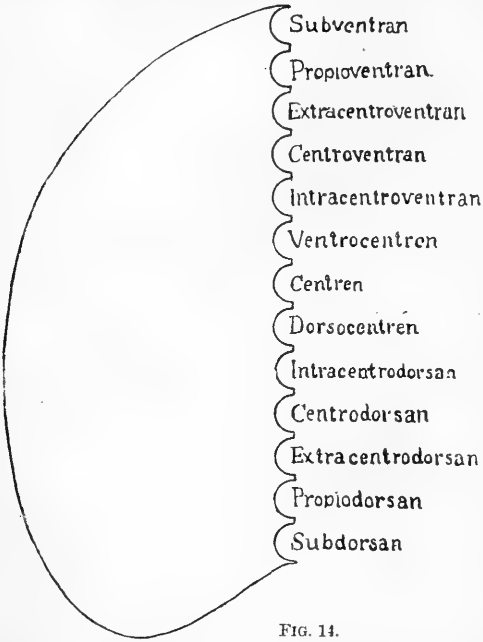

FIG. 14.

Ventran and dorsan express only the position of the shell, this alone being superficial. By using these terms and others, a considerable degree of accuracy can be obtained, and others can also be employed if essentially based on the same system. Thus, for example, proximo-ventran expresses the position of the siphuncle in Nothoceras and Bathmoceras, where this organ is so close to the shell that its own wall is in part absent and in part much modified. Subventran is applicable only to those forms in which the wall of the siphuncle is not altered or modified through contact with the shell, although it may lie quite closely against it. The other terms sufficiently explain themselves, except the use of "extra" and "intra." It is not meant to confine these terms to the two where it is used in the diagram. It is obvious that these prefixes may be employed wherever they are needed. Thus one can say "intraventrocentren" for a location between centren and ventrocentren positions.

It would not be proper, however, to use these prefixes on either side of centren for the reason that the comparisons are all made from the centre towards the dorsum, on the one hand, and towards the venter on the other. Thus everything on the dorsal side of this point is not inside of the centre but dorsad of this point or axis, and everything on the ventral side is not outside of the same axis but ventrad of it. I have also used Wilder's term, mesal, for the plane of the siphon, instead of median.

These terms and others of the new descriptive nomenclature, of which only very few will be used in these pages, because I think it will be essential to discuss them further before applying them to the descriptions of cephalopodan shells, have been gradually introduced in consequence of the labors of Wilder and Gage, in this country, and are in a fair way of being adopted in Europe through the effort of Franz Eilhard Schulze and others.*

Terms like ventran, ventrad, ventral, dorsan, dorsad, dorsal, centren and centran, and so on, strike one at first as awkward and barbarous, but their utility becomes apparent, as in the case of the siphuncle cited above, as soon as one begins to use them, and they can be made to have an exact meaning which it is not practicable to gain otherwise without the repetition in every description of the same explanatory text.

The shells of Nautiloidea and Ammonoidea are divided by transverse partitions or septa into what are called "air chambers," and the intersections or lines made by the edges of these when they strike against the inner surfaces of the shell of the whorl are called the sutures. Fig. 15 shows the edges of these septa as they would appear in *Nautilus umbilicatus* (Fig. 1, p. 345) if the shell there figured had been fossilized, the air chambers filled with infiltrations and the outer walls of the last whorl destroyed except in the umbilicus. The outer empty chamber beyond the suture of the last septum is the cast of the living chamber. The sinuous edge of this is the impression left by the edge of the aperture on the right side. This being a cast artificially made, is somewhat more perfect than natural casts of the interiors of such forms in the rocks and the spreading abutments of the septa against the inner wall are broad bands. Usually, in fossils, the upper extremely thin parts of these bands have disappeared, leaving only a line below corresponding to the lower parts of the bands in this figure and more nearly representing the thickness of the internal part of the calcareous septum.

* See Wilder, *Science*, ii, 1881; Wilder and Gage, *Anatomical Technology*, 1882, and other papers. Also Schulze, *Biologisches Centralblatt*, xiii, Nos. 1, 2, 1893; Hyatt, *ibid.*, Nos. 15, 16; and again, Schulze, *Verh. d. Anat. Gesellcch.*, Versam. Göttingen, 1893, p. 104; and reprint of same, *Deutsche Zool. Gesell.*, Göttingen, 1893, p. 6.

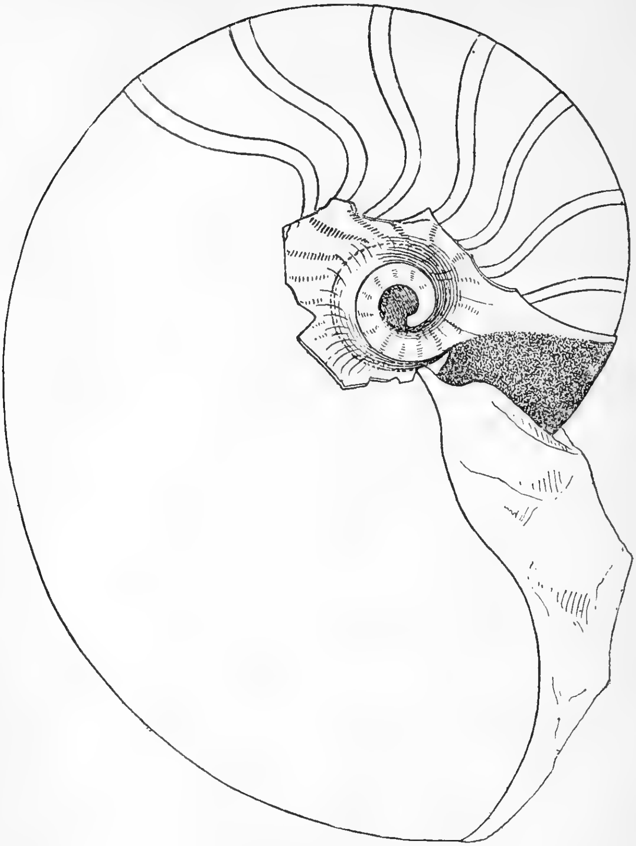

FIG. 15.—*Nautilus umbilicatus.*

V. DESCRIPTIONS.

In treating of the history of the impressed zone it has become essential to describe a number of new genera and also new species. The old names—Gyoceras, Lituites, Nautilus, etc.—convey entirely false ideas of affinity and would serve to confuse the student of these fossils, since the new names ignore these groups. Thus it is not at all in contradiction of the nomenclature if I state that the close-coiled *Tarphyceras prematurum* of the earlier Quebec faunas is the last of its phylum and has no descendants in the Upper Silurian or later; but if I call it Nautilus, and say that *Nautilus* *prematurum* had no descendants, even a tyro would begin to wonder why it bore the same generic title as the existing species.

The limits of time and space have not enabled me to follow out each genetic series in this paper, but it will be readily recognized by naturalists that shells having such very different forms in their younger stages must have belonged to different phyla. I have, however, tried in the introduction and in the parts treating of the history of the impressed zone to discuss the facts and arrange them in more intelligible form than is practicable in the following descriptions.

The families into which genera have been assembled are entirely provisional since more information with regard to the genealogy of the forms is needed before any satisfactory results can be reached in defining these larger groups.

NAUTILOIDEA.

Tarphyceratidæ.

This family includes shells which had elliptical whorls with gyroceran mode of growth or subquadragonal whorls with nautilian mode of coiling, the venter narrower than the dorsum in most forms. The shells comparatively smooth, the sutures with ventral saddles or only slight lobes, shallow, broad lateral lobes and either saddles or faint lobes on the venter of free whorls. The siphuncle is ventrad of the centre.

The genera are as follows: Tarphyceras, Aphetoceras, Deltoceras, Pycnoceras, found exclusively in the Quebec faunas older than the Chazy; Eurystomites and Barrandeoceras,* found in both the Quebec faunas and the Lower Silurian; Planctoceras and Falcilituites, found only in the Lower Silurian.

Tarphyceras,† n. g.

This genus has heretofore been confounded with Eurystomites by Schröder, the species being found together and resembling each other in general aspect. It differs, however, from that genus in having a more discoidal form, more numerous and more slowly growing whorls, in length of living chamber, in form, aperture, and other characters.

* In my *Genera of Foss. Ceph.* I included this genus under the title of Nautilidæ.

† *Ταρφὺς*, close.

The young become almost as close coiled during the paranepionic substage as in Trocholites, differing in this respect from those of Eurystomites. The dorsal furrow appears in some species, perhaps in all, in the paranepionic substage. This might be considered as due to the quick growth and contiguity of the whorls, the dorsum of the paranepionic substage being brought close to the dorsum of the preceding metanepionic and ananepionic substages of the first whorl. This extraordinary condition of the first whorl obtains also in Trocholites and will be discussed more fully under the heading of *Tarphyceras prematurum* and Trocholites. I do not intend, here or elsewhere, as has been stated in other parts of this paper, to express a positive opinion that the dorsal furrow in any of these nautilian forms was originated in the nepionic stage by the mechanical stress of the metanepionic dorsum even in these very closely coiled shells. The evidence that this may have been the cause is not satisfactory, nor is there any positive evidence of an entirely satisfactory character that the dorsal furrow was genetic.

The siphuncle is centren in the ananepionic substage, but becomes quickly propioventran and continues near the venter for a more or less prolonged period, shifting slowly towards the center. In Eurystomites this shifting usually takes place later, or does not occur at all, and the siphuncle is larger.

The septa are less convex usually than in Eurystomites and, as a rule, more numerous in each volution.

The sutures have well-marked lateral lobes and have broad saddles on the venter. This ventral saddle may be rounded or straight or have a slight shallow depression or lobe in the median line. The sutures, as they approach the lines of involution, are usually more inclined forwards towards the umbilicus than in Eurystomites.

The whorl in section has a flattened venter and frequently slightly flattened zones on the sides, so that there is often a decided approximation to the quadragonal form.

The living chamber is somewhat over one-half of a volution in length. The aperture is like that of Trocholites, with a deep, broad hyponomic sinus encroaching upon the lateral zones, these last being bordered by broad crests, with slight sinuses at the lines of involution. There appears to have been a slight crest on the dorsum. The lines of growth are parallel with the borders of the aperture.

The shell usually has strong striæ of growth externally, but no costations; there are only the broad, slight ridges following the lines of growth, which are more or less sporadic in shells of this group. These primitive costæ are probably due to the imperfect resorption of the more or less expanded borders of the apertures occurring in some shells but not in others during the progressive stages of development but common in all shells in the gerontic stage.

The shell is very thick on the venter, somewhat thinner, but still thick on the sides and dorsum.

The type is *Tarphyceras prematurum.*

The species of this genus are as follows: *

Tarphyceras Aucoini, Hyatt, Newfoundland.
" *prematurum*, Hyatt, Newfoundland.
" *Farnsworthi* (sp. Billings, *pars.*), Phillipsburg.†
" *Champlainense*, sp. Whitfield, Fort Cassin.
" *Seeleyi*, sp. Whitfield, Fort Cassin.
" *extensum*, Hyatt, Newfoundland.
" *MacDonaldi*, n. s., near Lexington, Va.

This last species has a form and suture like that of *Champlainense*, but the siphuncle is nearer the venter and the young have flatter and more divergent sides and broader abdomen in the neanic stage.

TARPHYCERAS AUCOINI, n. s.

Loc., Port au Port.

Pl. iv, Figs. 17–22.

The ananepionic substage seen in the somewhat rough casts is given in Figs. 20–22, Pl. iv, from the side and front. These figures

* *Nautilus calciferous* of Billings (*Pal. Foss.*, i, p. 258) is probably a species of this genus surviving in the later forms of the Quebec at Port au Choix. The small siphuncle and its position appears to indicate this, but I have no specimens of this species and have not seen any at Ottawa.

† This species has two or more very distinct species. The one referred to above has an elliptical or oval whorl in the ephebic stage, the dorsum a little broader than the venter. There is a contact furrow in the neanic and ephebic stages. The sutures have ventral saddles, with probably slight dorsal lobes in the zone of involution, and a free living chamber over one-half of a volution in length. The siphuncle is subventran in the ananeanic substage, becoming propioventran in the paraneanic and ventrocentren in the metephebic substage. The diameter of the largest specimen, somewhat compressed, was 140 mm. by 146 mm.; the estimated longest diameter of this through the free living chamber was about 160 mm.

The type of *Farnsworthi* is a very distinct species and belongs to another genus and is cited below under the heading of Aphetoceras.

show the apex to be blunt and rounded, but this rotundity may be exaggerated in this part which had to be in part restored.

The umbilical perforation is present, but it is very small. The whorl grows very rapidly in all of its diameters and the bending of the shell in the paranepionic substage is very abrupt, bringing the continuation of this substage, the dorsum, in contact with the dorsum of the metanepionic and ananepionic parts of the first volution.

In correlation with this, as in Trocholites, a distinct dorsal furrow appears as the shell bends in the first part of the paranepionic substage. The coiling is so close that the slightest variation in the same direction would obliterate the umbilical perforation. The growing mantle while building the shell might have been influenced by the proximity of the metanepionic dorsum and the small diameter of the curve. The dorsal furrow here, as in Trocholites, although occurring in the paranepionic substage before the whorls touch, is perhaps due to the close contiguity of the whorls and the rapid ingrowth of the primitive umbilical zones. This process is still apparent in the first part of the second whorl, a section of which is given immediately above the apex in Fig. 20. This is the first of the ananeanic substage, and the siphuncle shifts from its previously subventran position to propioventran. In the metaneanic substage, in the latter half of the second volution, the elongation of the ventro-dorsal diameters is faster, and the tendency to develop lateral zones by the flattening of the sides becomes marked. The sections of the whorls in the upper half of Fig. 20 are slightly distorted by compression, the lower half is in proper proportion. The aspect of the section is better given in the more enlarged Fig. 21, and the decrease in lateral diameters in proportion to the ventro-dorsal is a marked characteristic and continues in the ephebic stage.

In some specimens this change is not so marked and the flattening of the sides develops later.

In the later stages the siphuncle is slightly nearer the center as in Fig. 19.

Fig. 17 gives the full-grown ephebic stage, and is very close to the original. The section Fig. 19 shows how closely this species resembles *Tarphyceras Champlainense*, differing only in the greater rotundity of the venter and in the position of the siphuncle and in the possession of very slight folds or nascent costations, which appear in some casts, as in the side view Fig. 17.

These specimens occurred in a dolomitic limestone, on a hill to the west of the inside beach of Port au Port, in the calciferous of Murray and Howley.

TARPHYCERAS PREMATURUM, n. s.

Loc., Port au Port, Newfoundland.

Pl. iv, Figs. 12–16.

This species is apt to be confounded with *Tarphyceras Aucoini*, but the whorls increase faster by growth and are much larger at the same age.

Fig. 14 shows in part the nepionic whorl of this species and the ananeanic substage. The section of the ananeanic whorl above the ananepionic apex is restored, and is probably made too angular and the abdomen too broad. The other parts of the figure are accurate. The side view in Fig. 15 gives the same showing the prominence of the early nepionic substages and the first of the paranepionic. Fig. 16 shows the paranepionic and earlier substages from the front. These figures give satisfactorily the differences between the young of this species and *Tarphyceras Aucoini*.

The presence of a very narrow umbilical perforation is plainly evident in this specimen and this is similar to that of *Aucoini*. The metanepionic dorsum is distinctly separated from the paranepionic dorsum, here shown in outline on the inner edge of the septum, by a narrow, smooth space which curves around between them, but in consequence of its ventral curvature as it crossed between them it cannot be seen in a side view. This perforation or bend is larger and wider than in *Aucoini*, and the involution or ingrowth of the nascent umbilical shoulders is less than in *Aucoini*. It is consequently doubtful whether the abruptness of the curvature and the ingrowth of the umbilical shoulders fully accounts for the presence of the dorsal furrow in the dorsum of this specimen. The condition of the specimen is not wholly satisfactory, otherwise a more definite opinion could probably be given. The inner or dorsal surface of the ananepionic and metanepionic substages has been more or less eroded and it is not practicable to say, as in *Aucoini*, that they might have influenced the formation of the outline of the opposing dorsum of the paranepionic whorl as it was bent around the umbilical perforation.

The shell in its later stages, as shown in Figs. 12 and 13, resembled closely *Aucoini*, but the abdomen becomes more prominent and the contact furrow is deeper and broader in consequence of this and the breadth of the venter.

The siphuncle in the paranepionic substage is subventran, becoming propioventran in the ananeanic as seen in section above in Fig. 14, and extracentroventran in the septum seen below in Fig. 12. The position alters slightly in the succeeding stages.

The living chamber is obviously over one-half of a volution in length and is shown in an incomplete fragmentary condition in the outline on the farther side of Fig. 12; the form in section of the same specimen partly restored is given in Fig. 13, Pl. iv. The depth of the dorsal lobes in the sutures is shown upon the venter of the exposed whorl in the upper part of the section which is still covered by the dorsal layer and the remnants of the septa.

VI. figs. 1–4.

Tarphyceras extensum.

Loc., Port au Choix, Newfoundland.

This fossil resembles *Tarphyceras Seeleyi*, but has a shorter living chamber and the living chamber and part of septate whorl are free in gerontic stage. The contact furrow increases in depth with the ephebic stage and then decreases with the approach of the gerontic stage. The ventro-dorsal diameter slightly decreases, as is shown in Fig. 1, Pl. vi, in the paragerontic substage, when the whorl is almost straightened out, and at the same time the impressed zone is found to be wholly lost, as shown in the section, Fig. 2.

In section 4 the inner whorl represents a section of the ephebic stage and the outer whorl is the gerontic stage. The uppermost, with siphuncle nearer the venter and reduced impressed zone, is the anagerontic, and Fig. 2 is the paragerontic substage. The whorls are apparently smooth. The septa are not very concave. The sutures have ventral saddles, dorsal lobes and slight lateral lobes. In the anagerontic substage they are nearly straight on the sides and decidedly inclined forwards.

Tarphyceras Champlainense.

Nautilus Champlainense, Whitfield, (*Bull. Am. Mus.*, New York, Vol. i, Figs. 1, 3, Pl. 31).

Loc., Fort Cassin, Lake Champlain.

Pl. iv, Figs. 4–11.

The nepionic stage of this species, as in others of this group, has a very small umbilical perforation, the bending of the paranepionic stage taking place with great abruptness. When seen laterally (Fig. 4, Pl. iv) the umbilicus shows a much larger perforation than exists internally. This is due to the curvature of the perforation and its decrease in diameter internally. Starting from either side, it is an unsymmetrical cone with a pear-shaped base, which decreases internally and bends in a bow-like curve as it crosses between the dorsan surfaces of the meta- and paranepionic substages. The external orifices are usually owing to the fact that the matrix is difficult to clean out, apparently broader than they really are. The actual diameter is about 1 mm., diminishing to .5 mm. at the center. In section, however, it may be seen, as in Fig. 9, to have a minute perforation between the metanepionic dorsum at the center below and the paranepionic dorsum just above this. The outline of the section (Fig. 10) probably passed not far from the apex in this specimen, probably through the metanepionic substage, judging from the outline of the section (Fig. 9, and the enlarged outline, Fig. 11), which shows transitional characteristics from the dorsoventrally elongated oval of the whorl of the ananepionic substage common to most Nautiloids and the transverse oval of the earlier paranepionic also found at this substage in a large number of nautilian shells. This outline, Fig. 11, is similar to that of the shells of *Nautilus pompilius* at the same age.

The paranepionic substage of Fig. 9 has also an outline similar to that of *Nautilus pompilius* at the same age, being kidney-shaped, with a broad but well-defined dorsal furrow. The presence of this dorsal furrow, although the whorls do not touch, appears at first to justify the opinion that this is a case in which inheritance may be assumed. The paranepionic dorsum is, however, very closely approximated to the dorsum of the metanepionic substage, and it seems possible that this proximity modified the shape of the secreting edge of the dorsal side of the mantle and caused the corresponding impression shown in the shell. At any rate, it is not safe to assume that this represents any hereditary tendency. The exceedingly quick growth from the apex to the paranepionic and the sudden curvature of the early paranepionic whorls might have produced this also, as pointed out in other similar cases. In making another specimen of this species (Fig. 4, Pl. iv) I was fortunate enough to crack the fossil so as to expose the entire length of the cast of the umbilical perforation. I found this to be, as stated above, a bow-shaped, dark, smooth filling, as shown in Fig. 5 and more enlarged in Figs. 6 and 7. Fig. 8 is an ideal restoration of a side view of the nepionic stage, and gives the location of sections shown in Figs. 6 and 7. By the aid of Fig. 7 one can see that the furrow which appears in the dorsum of the paranepionic substage is first found just as the whorl makes the sharp turn to form the umbilical perforation. This shows also that its origin may be purely mechanical. The hard wall of the dorsum of the metanepionic was only about .5 mm. distant from the growing pliable edge of the paranepionic as it made the turn, and this pliable border may have been built to conform to the shape of the internal metanepionic dorsum. This becomes possible when one takes into consideration the rapid growth of the whorl in its lateral and ventro-dorsal diameters at this stage. The increase of the former broadening out the volution causes the involution of the apex on the sides when this is reached, and rapid increase of the ventro-dorsal diameters forces the building shell to make this sudden turn, owing to the more rapid building out of the ventral side.

Immediately after passing this point of greatest pressure, as shown in Fig. 6, the zone produced by it begins to decrease in depth and increase in width, but it does not disappear altogether, because the growing shell immediately strikes the dorsal side of the metanepionic and ananepionic substages and the true contact furrow appears. This is shown in the truncation of the dorsal corner of the outline in Fig. 8 when it strikes the apex. The centre of Fig. 5 is approximately the same as Fig. 6.

A Trocholites-like outline is assumed in the neanic stage (shown in Fig. 5 in section of second whorl below center) and in the ephebic stage the whorl is apt to become slightly flattened on the venter. The outer whorl of section, Fig. 5, is flattened in this way and represents the anephebic condition of the living chamber.

This shell is smooth until the ananeanic substage, as in Fig. 4, and then becomes costated. These costæ are infrequent, low, broad elevations which become less distinct with the incoming of the anephebic substage and are very often absent in the later ephebic substages, beginning however again in the gerontic stage, but are never so constant or prominent as in the earlier stages.

The siphuncle of the metanepionic whorl, if the mark in the centre of the enlarged outline (Fig. 11, Pl. iv) really represents this organ or its general location, is centren. This, however, is a mere spot, so that this must be regarded as doubtful. In the later paranepionic it is unquestionably propioventran or subventran. In the neanic stage it approximates to and attains an extracentroventran position, which it retains throughout life. The position in the gerontic stage was, however, not observed.

Having had an opportunity for close study of Whitfield's originals and also the fine collection of Mr. Walcott (now in U. S. National Museum), from same locality, there is but little doubt that the specific name is correct.

TARPHYCERAS (?) CONVOLVENS.

DISCOCERAS CONVOLVENS, Angelin et Lindst. (*Fragm. Sil.*, xvi, Fig. 3; not Pl. x, Fig. 5).

This form has the sutures and similar position of siphuncle and last part of outer whorl free and the lines of growth similar to other species of this genus, as figured on Pl. xvi of Angelin and Lindstrom. The figure in section on Pl. x, Fig. 5, is doubted, because the whorls appear to be closer coiled and the dorso-ventral diameters increase faster than in other specimens figured.

Eurystomites.

This genus was first described by Schröder,* who saw that the *Nautilus Kelloggi* of Whitfield was generically distinct from his genus Estonioceras. He also included in the same genus *Nautilus Champlainensis*, but this, with *Seeleyi* and similar discoidal forms, are here placed in the genus Tarphyceras.

The siphuncle is subventran in the nepionic and ananeanic substages, becoming extracentroventran in all the later stages of development, or it may remain nearer the venter. The rate of growth of the shell is more rapid than in Tarphyceras and there are fewer whorls in the same diameter. The ventro-dorsal diameters are consequently longer in proportion than in Tarphyceras. The whorl may be rounded until a late stage of development, but usually acquires a more or less flattened venter and primitive lateral zones and ill-defined umbilical zones like those of some species of Tarphyceras. The lateral zones are apt to be more convergent and the abdomen narrower.

* *Op. cit., Pal. Abh. Dames et Kayser*, V, p. 26.

The umbilical perforation is large and the impressed zone is a contact furrow not generated until the whorls come in contact.

The contact furrow is deeper and the amount of involution slightly greater in the ephebic stage than is usual in Tarphyceras. It has been supposed, from the large specimen described by Whitfield, that this shell was close coiled and involute throughout life. There is, however, one large specimen (Fig. 4, Pl. v) in the Walcott collection, U. S. National Museum, which has the entire living chamber and part of the septate whorl free. The living chamber is very variable in length. It is shorter than in Tarphyceras in the adult of *Eurystomites Kelloggi*, and in the aged specimen referred to above it was very long. The aperture, as figured by Whitfield, has lateral crests which are most prominent opposite the centres of the lateral zones, receding into sinuses on the umbilical zones.

The sutures may remain throughout life almost straight, with the slightest of lateral lobes and ventral saddles, or they may become quite sinuous, with well-defined lateral lobes and the ventral saddles entire or divided by median lobes. A distinct dorsal lobe makes its appearance in the contact furrow when this is formed and on the gerontic volution this furrow persists as an impressed zone although entirely freed from contact with the inner whorl (Fig. 5, Pl. v). It diminishes slowly in depth and breadth, but its persistence on the dorsum of this very long free gerontic stage shows that it has acquired a strong hold upon the organization of this specimen. Having no other specimens it cannot be said that this persistence is common to all individuals of the species.

EURYSTOMITES KELLOGGI.

NAUTILUS KELLOGGI, Whitf., *op. cit.* (*Bull. Am. Mus.*, N. Y., i, No. 8, Pl. xxx; not Pl. xxxi, Figs. 4, 5).

EURYSTOMITES KELLOGGI (?), Schröder, *op. cit.* (*Pal. Abh. Dames et Kayser*, v, hft. 4, p. 26).

Pl. v, Figs. 4, 5.

The figures of Whitfield give an excellent general representation of this species. The young are, however, slightly costated in the neanic stage and there are at least two distinct forms placed by Whitfield under this name.

EURYSTOMITES ROTUNDUS.

NAUTILUS KELLOGGI, Whitf., *op. cit.* (*Bull. Am. Mus.*, New York, i, Pl. xxxi, Figs. 4, 5; not Pl. xxx).

Loc., Fort Cassin.

Pl. v, Figs. 21–25.

This species increases more rapidly in the growth of the ventro-dorsal diameters than in *Kelloggi* and retains the siphuncle near the venter for a longer time during the growth. This may be due, however, to the differences in the size, and not a matter of age, since in large whorls it assumes a similar position to that of *Kelloggi*. Fig. 21, Pl. v, gives a view of the first two whorls from the side, partly restored from the study of the section, and the dotted lines explain the position of the last section (Fig. 25, Pl. v) of the centre of first volution.

This figure shows the metanepionic above and paranepionic below, just before the paranepionic comes in contact with the apex. This was the last section taken. Fig. 22 shows the first section, secured through the inner dorsal part of the metanepionic substage, and Figs. 23, 24, Pl. v, show the successive sections connecting this with Fig. 25, and thus demonstrating the large size of the umbilical perforation and the correlative rotundity of the dorsi of the meta- and paranepionic substages.

EURYSTOMITES GIBBOSUM, n. g.

Loc., Port au Port Choix, Schooner Island, Newfoundland.

I mention this new species here without giving figures, because it is important in the consideration of the relations of the dorsal lobe and impressed zone and it is so peculiar that it can be easily recognized.

The general aspect is like that of *Eurystomites Kelloggi*, but the septa are more deeply concave than in any species of these faunas and the lateral sutures run forward on the sides as in Tarphyceras. The outlines of the whorls in section at all epinepionic stages is like that of the last whorl of the specimen of *Nautilus Kelloggi*, here *Eurystomites rotundus*, as figured by Whitfield on Pl. xxxi, Fig. 4; Bull. Am. 1886 and in section the whorls at all stages are ovals similar to the metanepionic substage of *Eurystomites rotundus* (Fig. 25, Pl. v), but the abdomen is rounder. No lateral zones or umbilical zones are differentiated, but there is a faint approximation to the digonal form probably in the early neanic substages. The sides are only slightly convex and slope evenly and divergently outwards and consequently appear flattened in some specimens.

The envelopment covers the abdomen, which last is prominently convex.

The length of the sub-V-shaped dorsal lobe in the sutures is greater than in any species I have yet seen, and this is very instructive. Occurring as it does in a shell which is not very involute, and with a contact furrow but little exceeding the ordinary dimensions, it shows that the depth of the dorsal lobe in the sutures is not only correlated with the extent and depth of the contact furrow but also largely dependent upon the concavity of the septa. In other words, if this species had had septa of ordinary concavity the dorsal lobes in the sutures would not have been so deep and sub-V-shaped as they are. The sutures have also broad lateral lobes running well forward to sharp saddles at the lines of involution. There are broad saddles at the abdominal angles and shallow ventral lobes or straight sutures across the venter. The siphuncle becomes intracentroventran in the ephebic stage and is very large, as it is in *Eurystomites Kelloggi*. The whorls come in contact in the ananeanic substage. The shell grows quite large, but, so far as I have seen, none have any part of the last whorl free.

Eurystomites Virginiana.

Nautilus Kelloggi (?) (*pars*), Whitf. (not figured).

Loc., near Lexington, Va., and Fort Cassin.

This shell had more cylindrical whorls and more numerous and straighter sutures at all stages than in *Kelloggi*. The siphuncle is nearer the venter, and in the type-specimen, which is over 90 mm. in diameter (in collection U. S. National Museum), it is still almost subventran at the entrance into the living chamber. This last is less than one-half of a volution in length. The whorl is almost circular in this specimen at all stages observed, including the neanic stage, and the involution is very slight; the dorsal lobe correlates with this, being correspondingly shallow and narrow. The sutures otherwise resemble those of *Kelloggi*, but are straighter, and the three specimens from Virginia do not show the ventral lobes that often occur in *Kelloggi*.

There is a young specimen in the American Museum under the name of *Kelloggi*, from Fort Cassin, that appears to belong to this species, having similar sutures, form of whorl and involution.

Eurystomites undatum.

Nautilus undatus, Hall (*Pal. New York*, i, p. 52, Pl. xiii and xiii *bis*).

Loc., Poland, Herkimer county, N. Y., Black River Limestone.

Pl. v, Figs. 1, 2.

This species has much broader whorls in the young than in Eurystomites of the Quebec faunas. The position and size of the siphuncle, the large umbilical perforations and the sutures and the flattened abdomen of the adult stage and comparison with the heavily costated forms like *Discoceras antiquissimum* and others show that this shell is probably a member of the genus Eurystomites.

The nepionic stage has a very large umbilical perforation and in correlation with this the whorl has a rounded dorsum at this age. The metanepionic substage has a broadly elliptical form and subventran siphuncle; the paranepionic, on account of the rapid transverse growth, has a subdigonal whorl, as shown in Fig. 2, Pl. v. The shell does not increase so fast transversely in the neanic stage and the whorl becomes rounder, a slight contact furrow appearing when the whorls come in contact, and the living chamber at this age is less than one-half of a volution in length. Light costations also appear in this substage, but the nepionic whorl is smooth with the exception of strong lines of growth. The abdomen becomes flattened in the paraneanic substage, and the sutures show slight, ventral lobes and very slight lateral lobes.

The siphuncle is propioventran in the paranepionic substage and neanic stage. The costations become stronger in the paraneanic substage but are reflected on casts only to a very slight extent.

The young are, however, quite variable, and the figures, Pl. v, give probably an extreme form so far as the retention of the broad subdigonal form is concerned. In other varieties or species, for I think there are several species usually placed under this name, the sides and venter become slightly flattened in the metaneanic substage, or even before this. In the specimen figured this change had not yet taken place, although the shell was in the metaneanic substage.

The aperture in this specimen flared out laterally, but is removed in the section Fig. 2, Pl. v.

Slight, foldlike costæ are better developed in the ephebic stage, and, although always present, they are only occasionally developed into decided costations even in full-grown specimens.

The shell grows quite large, but so far as I have seen none have any part of the last whorl free. The largest shells often have compressed whorls, with abdomens much narrower and flat, and sides much flatter than in the earlier stages.

Planctoceras.

This group was first described by Remelé under the name of Ægoceras and subsequently under that of Tragoceras, but both of these being preoccupied, Schröder proposed that of Planctoceras.*

Schröder considers it to be a subgenus, and that the only distinction between this and Estonioceras lies in the fact that it was probably not close coiled at any stage.

As Estonioceras is here limited, however, the sutures are different and have ventral and dorsal saddles with lateral lobes, as in Falcilituites. The young and all stages so far as seen have also compressed elliptical instead of depressed whorls. That is to say, they are probably never digonal, and do not resemble those of Estonioceras at any stage, unless in the very earliest or nepionic stage which is not known. The whorls, as shown by Schröder in his fine figures, have the dorsum and venter somewhat depressed and very nearly equal and distinct from the side in the young. In other words, there is a faint tendency to form a quadragonal whorl. Later, probably in the ephebic stage, the dorsum may exceed the venter in breadth, and in the gerontic stage the whorl becomes almost circular.

The lines of growth are similar to those of Falcilituites, *i. e.*, they have broad ventral sinuses and a broad latero-dorsal crests.

The volutions are attenuated and the living chambers very long.

The siphuncle is small and about twice its own diameter removed from the venter, or, in my nomenclature, is extracentroventran in the neanic and ephebic stages as measured on Schröder's figures.

The only species referred to this genus in Europe is the *Planctoceras* (Orthoceratites) *falcatum*, sp. Schlot., which, judging from the figures of Dewitz, Schröder, Quenstedt and Eichwald, probably includes several quite distinct species. *Planctoceras Quenstedi* (Lit., *falcatus*, Quenst.), for example, has distinct sutures and outline

* Dames et Kayser, *Pal. Abh.*, v, hft. 4, 1891, p. 41.

from the species figured either by Dewitz or Schröder. In fact, the figures show that there are very likely three species under this one name.

This genus is described here partly because it is an excellent illustration of the correlation of the dorsal and ventral saddles with elliptical compressed whorls and gibbous abdomens and gibbous dorsal sides such as occur in many cyrtoceran and gyroceran forms, and also because of its resemblance to Aphetoceras.

Aphetoceras,* n. g.

The shells of this genus are remarkable for their resemblances, until a late stage of growth, to the cyrtoceran genus, Melonoceras, from which they differ in having open apertures, and in this case they would probably compare more closely in these stages with Oonoceras. These shells are, however, coiled with an even gyroceran curvature that does not bring the whorls in contact at any stage.

The form of the whorl in section is compressed elliptical or oviform, the venter narrower than the dorsum. This outline is common to all of the epembryonic stages as far as known. The nepionic substage has, however, not been seen as yet.

There is no impressed zone at any stage.

The whorl probably deviates from the spiral in the paragerontic substage, but this has not been observed, unless *Farnsworthi* is a true member of this generic phylum.

The shell is invariably smooth so far as known.

The sutures have very nearly the same form throughout the epembryonic stages, so far as known, having dorsal and ventral saddles and broad lateral lobes in correlation with gyroceran characters of the coil.

The siphuncle is subventran or propioventran and probably does not vary much from these positions in any species.

This genus is separable from Planctoceras by the gyroceran mode of coiling, by the form of the whorl in section, by the length of the living chamber and position of the siphuncle.

Aphetoceras Americanum, n. s. (Pl. vi, Figs. 5–8, > ⅓).

Loc., Port au Choix, Newfoundland.

This shell has an open gyroceran coil and, so far as could be

* Ἀφετός, free.

seen, it was not in contact at any stage, but the earlier and probably nepionic whorl was not seen.

The whorls increase slowly by growth, especially in the transverse diameters; the ventro-dorsal growth is somewhat more rapid, but not sufficiently so to close up the volutions. In the gerontic stage the living chamber begins to depart slightly from the preceding curve of growth, as shown in the drawing (Fig. 5, Pl. vi).

The shell is probably smooth.

The whorls in section are compressed, the dorsum wider than the venter, and the dorso-ventral diameter much larger than the transverse, especially in the ephebic and gerontic stages. The abdomen becomes more or less flattened in the last two stages, but is rounded in the neanic stage. The dorsum remains rounded and gibbous throughout all the stages so far as known.

The sutures have ventral and dorsal saddles and broad lateral lobes in the neanic stage and probably also in the later nepionic stage. After the abdomen becomes flattened, slight ventral lobes are developed in the sutures of the ephebic and gerontic stages.

The siphuncle is large, propioventran in all the stages observed.

APHETOCERAS BOREALE, n. s. (Pl. v, Figs. 15–17, > 1/3).

Loc., Schooner Island (on southeast side), Newfoundland.

This resembles *Aphetoceras Americanum*, at the same age, in sutures and form, but the siphuncle is slightly nearer to the venter and the coiling is obviously distinct and the abdomen has not the well-marked, flattened aspect of the former.

It is doubtful, of course, whether the whorl actually does form a coil in the specimens collected; but, if it does, the inner whorls were probably more loosely coiled than in *Aphetoceras Americanum*, since the curvature of this fragment is larger than in any corresponding part of *Americanum*.

APHETOCERAS FARNSWORTHI.

LITUITES FARNSWORTHI, Bill. (*pars.*) (*Geol. Surv. Canada*, Pal. i, p. 21, Fig. 24).

Loc., Phillipsburg.

This species probably belongs to a distinct genus, and is cited here provisionally under this name because it may be merely a highly degenerate species of Aphetoceras. It is also coiled in the neanic stage, but apparently the whorls are not in very close contact. There are certainly two species, and probably three, usually included under this name. One is separated above as *Tarphyceras Farnsworthi* and the other below as *Aphetoceras attenuatum.* The type is that figured by Billings, and this had the living chamber free and deviating strongly from the spiral. It was 91 mm. long on the dorsal surface and more than one-half of a volution in length when this measurement was applied to the coil of the preceding whorls. The siphuncle in the ephebic stage was propioventran and the septa much closer together than is usual in this genus.

APHETOCERAS ATTENUATUM.

LITUITES FARNSWORTHI, Bill. (*pars.*) (*op. cit.*, p. 21).

Loc., Phillipsburg.

This species is founded upon the specimen described by Billings on p. 21 of his *Paleozoic Fossils* as having first two whorls in contact and making a coil an inch across. These whorls are, however, not in contact on his specimen, if my drawing of this is correct. The specimen is of nearly the same size as the type of *Aphetoceras Farnsworthi*, but one and a quarter volutions are free, so as to leave a gap of 8 mm. before the completion of the first quarter of the septate part of the eccentric volution, and at the end of the same this gap has increased to 13 mm., and in the next quarter, at the end of the living chamber, it is 25 mm. The departure of the free whorl of *Farnsworthi* increases, as shown in Billings' drawing, in less than one-half of a volution to 40 mm.

The septate part of the eccentric volution in this specimen is 58 mm. long, the living chamber is 88 mm. long. The former would occupy about three-fourths of a volution if it followed a regular open spiral curve, and the latter would be about one-half of a volution, estimated in the same way.

The septa are similar to those of *Farnsworthi.* The fragment of the siphuncle observable in the neanic stage changes in the length of 10 mm. from nearly subventran to propioventran.

Deltoceras, n. g.*

The shells of this group resemble those of Aphetoceras, but are just one grade more complicated. The whorls are similar in section, but grow more rapidly in the ventro-dorsal diameters, the siphuncles in some species are very large and ventral. The sutures are simi-

* Δέλτος, a scroll.

lar to those of Aphetoceras, but the whorls are in contact either in the earlier epembryonic stages or throughout the ephebic stage. A departure from the spiral regularly takes place in the gerontic stage or earlier; sometimes the entire ephebic stage is free.

No impressed zone has been found at any stage, although a slight flattening of the dorsum was observed in one species.

This group is represented by several species in the Newfoundland basin of the Quebec fauna, but it is only necessary here to describe one.

Deltoceras planum, n. s.

Loc., Port au Choix, on north side, Newfoundland.

This fossil is apparently very close to *Barrandeoceras natator*, but it increases more rapidly in the dorso-ventral diameters and has a larger siphuncle, and this is closer to the venter and it differs also in the greater compression of the form.

In the neanic stage it agrees more closely with *natator* in aspect, but the siphuncle is subventran. In the ephebic stage and anagerontic substage it becomes propioventran and increases in size until it becomes 7 mm. in diameter ventro-dorsally where it enters the living chamber. The transverse diameter was not measurable, but it is undoubtedly less than this in correlation with the compressed character of the volution. The ventro-dorsal diameter of the last whorl through the living chamber is 53 mm., the transverse only about 28 mm. to 30 mm., the whole diameter of the coil at this place being 163 mm.

The incomplete living chamber is over one-quarter of a volution and has departed slightly from the closer spiral of the ephebic stage. This departure is very gradual at first until the gerontic stage begins, and then becomes more apparent and widens more rapidly. The whorls are in absolute contact only in the neanic stage. The venter appears to be rounded at all stages of growth.

Barrandeoceras.

This genus was described in my *Genera of Fossil Cephalopods* to include shells having large umbilical perforations, compressed slightly costated or smooth whorls. The venter usually narrower than the dorsum, the whorls barely in contact or with very slight contact furrow, siphuncle near but above centre, septa deeply concave, sutures having usually ventral and dorsal saddles and lateral lobes. This last statement is true of all the forms having the gyroceran mode of coiling, but not of those which have the closer nautilian form. In these there is a slight dorsal lobe and a different form of the paranepionic whorl which may eventually lead to their generic separation.

The type is *Barrandeoceras* (Naut.) *natator*, sp. Billings.

BARRANDEOCERAS MINGANENSE.

Loc., Mingan Islands.

There is a specimen from the Chazy limestone of the Mingan Islands in the collection of the Museum of the Geological Survey at Ottawa which has very similar characters to those of *Barrandeoceras natator*, but is distinct in some of its characters. The living chamber is short and, if complete, about a quarter of a volution in length. It is free and in section is compressed oval, the abdomen broader than the dorsum, but the centro-dorsal diameter is longer than the transverse.

The siphuncle is nearer the centre, being ventrocentren. The neanic, or perhaps an ephebic stage has slight annulations or raised lines of growth, judging from the marks on the section. This is labeled as coming from the white limestone of Large Island.

There is no impressed zone at any stage observed. The ephebic stages have a whorl similar to that of *Barrandeoceras convolvans* in the neanic stage, but the abdomen is broader.

BARRANDEOCERAS CONVOLVANS.

LITUITES CONVOLVANS, Hall (*Pal. of New York*, i, p. 53, Pl. xiii, Fig. 2).

Loc., Watertown, N. Y.

The specimen figured by Hall has in the ephebic stage sutures with slight dorsal lobes. This, however, may have been a mistake in drawing or an abnormal individual variation. A specimen in the Museum of Comparative Zoölogy from the same locality, exhibiting the form of the whorl and the sutures of the ephebic stage, does not have such lobes.

The characteristics otherwise are so close to Hall's description and figure that, in spite of this and the supposition that the siphuncle was ventral, I have referred this and a suite of sections of the same to his species.

The whorls are variable in the coiling, and in some specimens are plainly not in contact at any stage. In others the neanic volution is in contact, but this is so slight that no contact furrow is formed. The whorls are mostly gyroceran in the character of the coil becoming excentric in the ephebic stage.

The section is a much compressed oval, the ventro dorsal diameter much longer than the transverse, the abdomen narrowly rounded and dorsum broader, but also gibbous. The neanic stage has a more rounded outline in section.

The shell is smooth.

The sutures have ventral and dorsal saddles with broad lateral lobes in the neanic and ephebic stages.

The siphuncle varies from centroventren to intracentroventran in the neanic and ephebic stages.

BARRANDEOCERAS NATATOR.
NAUTILUS NATATOR, Bill. (*Can. Nat.* iv, No. 6, 1859).
BARRANDEOCERAS NATATOR, Hyatt (*Gen. Foss. Ceph.*, p. 299).
Loc., Mingan Islands.

This species has volutions compressed oval in section, the dorsum somewhat broader than the venter; siphuncle is extracentroventran, even in the neanic stage; septa deeply concave; sutures with dorsal and ventral saddles and the lateral lobes as in other species of this genus.

The volutions are in contact, but no contact furrow was formed at any age. The contact takes place as in the young of *Estonioceras perforatum*, Fig. 9, Pl. vii, on the venter of the paranepionic volution.

The volution in the neanic stage, dorso-ventral diameter 13 mm., has a much narrower venter in proportion to the dorsum than in the adult. The venter was rounded at all stages and also the dorsum. The ananeanic and nepionic stage were not present in the original specimen in the Museum at Ottawa, but in following out the same lines it is easily ascertained that the umbilical perforation must have been enormous, at least 15–17 mm. in diameter. The living chamber was somewhat over one-fourth of a volution in length. The whole diameter was about 108 mm. It was reported as having been found in the Chazy limestone.

BARRANDEOCERAS STERNBERGI.
NAUTILUS STERNBERGI, Barr. (*Syst. Sil.*, Pl. xxxvi, xxxvii).
Loc., Bohemia. Pl. xiv, Figs. 2–5.

This species has, as is usual in transitional species with gyroceran mode of coiling, very variable aspects, owing to the closer coiling of some specimens than of others.

There is no impressed zone in most specimens at any stage, although there is a slight flattening of the dorsal side and an obvious although very slight modification of the dorsum, which takes place in the most closely coiled shells.

The whorl in section is closely similar to that of *natator* and the siphuncle similarly situated. The sutures are similar, with the exception of a faint dorsal lobe that appears in this species.

The whorls do not touch in some specimens at all (Pl. xiv, Fig. 2); in others they may touch in the neanic and ephebic stages. In some they may become excentric in the gerontic stage, and in others this may occur earlier in the ephebic stage. Very likely there is more than one species included under the name, but it is obvious that they are transitional to *Barrandeoceras Sacheri.*

Barrandeoceras Sacheri.

Nautilus Sacheri, Barrande (*Syst. Sil.*, Pl. xxxix). Pl. v, Fig. 11–14.

Loc., Bohemia.

The large umbilical perforation is shown and the almost straight form of the ana- and metanepionic substages. The paranepionic substage has sutures with dorsal lobe (Fig. 13) and form with flattened dorsum (Fig. 14), precisely like that of the close-coiled forms of *Sternbergi* in the ephebic stage. In *B. Sacheri*, however, the coiling is not variable and a contact furrow is invariably formed after contact, which takes place always as in Fig. 11, at the apex.

The sutures in the ana- and metanepionic substages have ventral and dorsal saddles and form in section with similar position of siphuncle to *Barrandeoceras natator* of the Chazy and resemble *Sternbergi* only in the paranepionic substage. In the neanic stage, after the impressed zone is generated, the whorls become more compressed and this resemblance is less noticeable.

Barrandeoceras tyrannum.

Nautilus tyrannus, Barr. (*Syst. Sil.*, Pl. xxxviii). Pl. v, Fig. 6–10.

Loc., Bohemia.

This species is similar to *Sacheri*, but has a smaller umbilical perforation and is somewhat closer coiled, the contact furrow appearing sooner and the *Sternbergi* stage of the paranepionic is considerably shortened. Its first appearance in the outline of the aperture is shown in Fig. 6 in the paranepionic substage.

Figs. 6–9, Pl. v, show the side and front views of two specimens, the smaller in the metanepionic and part of the paranepionic substages and the other older. These are magnified to show the ananepionic substages, and Figs. 6, 8, and 10 show the cicatrices on the apices of both of these. The longitudinal striæ shown on these are necessarily exaggerated, these markings being perceptible with difficulty under a magnifier. It is interesting to compare these with the young of the existing Nautilus on Pl. i, and it is also obvious that if found without their older stages in any locality they would certainly be described as cyrtoceran forms.

BARRANDEOCERAS (?) ELRODI.

GYROCERAS ELRODI, White (*Eleventh Ann. Rep. Geol. Indiana*, p. 356, Pl. xxxvii, Fig. 1).

Loc., Hartsville, Ind.

This species has an oval outline in the full-grown and senile stage figured by White, with siphuncle slightly above centre by description, but slightly below centre in the figure. The living chamber is not quite one-half of a volution in length, but it is very large, and this, together with one-half of the last volution, are free. The younger whorls are closely coiled, but not more than two and a half, if so many, are in contact; the remainder of the third and first quarter of the fourth are free and the last part excentric. Dr. White describes them as rounded outline in section, giving the impression that there was no impressed zone.

The rate of growth in the ventro-dorsal diameters is rapid, and consequently the living chamber on the last of the third and first of the fourth volution is very large, especially in the ventro-dorsal diameters.

The form and sutures are similar to those of *Barrandeoceras Sternbergi*, and the species, if it is a member of this genus, is interesting on account of its appearance in the Niagara group, the close coiling of the young, and the length of the free whorl.

Pycnoceras,* *n. g.*

This genus has shells similar to those of Aphetoceras in the nepionic stage, with siphuncle subventran, similar form in section and similar sutures, with ventral and dorsal saddles and shallow lateral lobes. This may be seen by comparing figures of Apheto-

* Πυκνός, close.

ceras (Pl. vi, Fig. 5) with the figure of the young of *Pycnoceras apertum* (Pl. v, Fig. 18). The nepionic stage has rounded dorsum and more rounded venter than appears in the Fig. 19, Pl. vi, because of the presence of a thick band of shell on the venter, consisting of its own shell which is not present on the sides and also of the corresponding part of the shell of the dorsum of the next older whorl that has been broken away. A slight contact furrow is present at the beginning of the ananeanic substage when the whorls come in contact at the point indicated in Fig. 18 by the end of the outline of the restored apex. This zone is further shown by the band of shell left on the venter from the dorsum of the next older whorl, which was the neanic volution. Upon this, also, there are remnants of the septa of this stage, showing that this zone was immediately accompanied by the advent of dorsal lobes in the sutures. These replaced the dorsal saddles of the nepionic stage.

In the ephebic stage the siphuncle assumed a propioextraventran position and retained this until the gerontic stage.

The form of the whorl remains quite similar, the ventro-dorsal diameters being longer than the transverse, but the venter becomes broader in proportion than the dorsum in neanic and ephebic stages.

In the gerontic stage the living chamber and part of the septate last whorl alone are free in some species, in others the age at which the whorl becomes free varies greatly.

The type of the genus is the young specimen, Fig. 18, which shows that the young are distinct from those of Tarphyceras, being much less closely coiled and having distinct form of whorl and large umbilical perforation.

There are several undescribed species of this genus in the fauna of Newfoundland.

Pycnoceras apertum, n. s. Pl. v, Figs. 18–20.

Loc., Port au Port, Newfoundland.

This single specimen was found in the dolomitic limestone or calciferous in company with the closer coiled young of Tarphyceras.

The nepionic stage is prolonged and has the oval form of whorl and sutures of the adults of the cyrtoceran genus, Melonoceras, and of the nepionic and neanic stages of the gyroceran form, Aphetoceras, its nearest affine, which occurs, however, later in the fauna of the Quebec group.

The characteristics have already been given in the generic descriptions and the presence of the contact furrow in the neanic stage noticed. It only remains to call attention to the fact that this and the dorsal lobes of the sutures are generated together as the whorls come in contact.

PYCNOCERAS CALCIFERIFORME, n. s.

Loc., Port au Choix and Schooner Island, Newfoundland and Phillipsburg, Canada.

This species is sufficiently abundant at Port au Choix, and seems at first identical with *calciferus* of Port au Choix, but the latter is probably a species of Tarphyceras, having the small siphuncle of that group.

The shell reaches a considerable size, 128 mm. in the entire diameter. This specimen has a living chamber somewhat over one-half of a volution in length, and a similar living chamber occurs in a younger specimen longer than in Eurystomites.

The whorl in section is an oval with evenly rounded sides, no umbilical shoulders, and the abdomen broader than the dorsum, but in the neanic stage, and perhaps in the early part of the ephebic stage, the sides are evenly rounded and very gibbous, and the venter may be narrower than the dorsum, measuring through the thickest inner part of the whorl ventrad of the impressed zone.

The siphuncle is very large, measuring just before entering the living chamber about 7 mm., and is propioventran in position, but less than its own diameter distant from the venter. It has a subventran position in the ananeanic substage, the earliest age observed. Billings described the siphuncle in *Tarphyceras calciferus* as small at the diameter for the whole shell of three inches, and the septa as numbering about twelve to the inch along the venter at the diameter of three inches. At this diameter in *calciferiforme* the septa are six or eight to the inch, and the siphuncle is about 5 mm. in diameter.

The contact furrow is very slight at all stages. The septa are deeply concave, approximating to those of *Eurystomites gibbosus*, but owing to the slight amount of involution the dorsal lobes are shallow; thus showing the dependence of this character upon the amount of involution, as well as the concavity of the septa. There are broad ventral saddles with almost straight suture or slight lobes, broad lateral lobes trending forwards to narrow saddles at the lines of involution.

The shell is smooth except from strong striæ of growth, and occasional folds as in other species of this group, the casts are all perfectly smooth. A specimen from Phillipsburg has identical form and position of siphuncle, and is in collection of Museum of Cómp. Zoölogy.

Falcilituites.

This genus set apart by Remelé, the type selected being *Lituites Decheni* equal to *Discoceras subcostatum* Ang. et Lindstrom.* This species has a very close-coiled whorl in the nepionic stage, the umbilical perforation not being figured at all by Angelin and Lindstrom, a fact of essential importance when comparing this type with Estonioceras. The coiled volutions are three in number according to their figures, but the centre may be erroneously drawn.

The shell has a decidedly quadragonal whorl like that of some species of Schroederoceras, and the abdomen is even slightly concave along the median portion? The lines of growth are strongly marked and have a different aspect from those of Estonioceras. The hyponomic sinus is deeper and broader and apparently the lateral lines rise towards the dorsum in crests, but these really join across the dorsum, forming one huge broad, dorsal crest. In other words, if figured correctly, the aperture on the free volution must have had a very deep hyponomic sinus and huge projecting dorsolateral crests undivided by any dorsal sinus as in Estonioceras. The closely coiled volutions may have had lines of growth with dorsal sinuses, but if so these disappeared on the free part of the whorls. These volutions may also have had a contact furrow, but it must have been slight, since it entirely disappears on the early part of the free volution in both of the European species mentioned below.

The sutures have also ventral saddles with deep lateral lobes. Dorsal sutures are not given.

The siphuncle is much smaller than in Estonioceras and is nearer the centre, being but little above this point or centroventren. This organ is ellipochoanoidal according to Angelin and Lindstrom figures which are very clear and apparently exact.

There are only two species as yet described, *Falcilituites Decheni*

* I have not been able to obtain from any library in this vicinity Remelé's principal works, but there is no doubt that he selected *Discoceras subcostatum*, as described by Angelin and Lindstrom. His papers were published in the *Festsch.* 50 *jahr. Jubelf. d. Forstakad. Eberswalde,* and the *Untersuch. u. d. versteinerngsf. Diluvial.*, etc.

Remelé, sp. Ang. et Lindstrom, and *Facilituites ? Muellaueri*, sp. Dewitz. This last has the ventral saddles and approximately quadragonal form of this genus. The sutures also have dorsal saddles and the siphuncle is small and centren. There is a slight contact furrow in the coiled volutions, which is still retained, but shows to a less degree in the free part of the whorl as figured by Dewitz, and the dorsal part of the aperture is flat, not concave. The living chamber was evidently entirely free in these two species when full grown, since in the figures by Angelin and Lindstrom and by Dewitz this is shown. The umbilical perforation in *Muellaueri* is so much larger than in *Decheni* that I refer this species to this genus with considerable doubt. The close-coiled volutions are only two in number.

Trocholitidæ.

This group was formerly included by the author under the family name of Tainoceratidæ, but was separated in Carboniferous Cephalopods Fourth Ann. Rep. Geol. Surv. Texas, and is here placed under its proper title. The shells are smooth, or with heavy transverse ridges, which are really primitive costations, but are never very prominent. The whorls are nephritic or depressed subquadragonal or trapezoidal, the venter generally broader than the dorsum, and the form is usually nautilian. The sutures as a rule have broad and slight ventral lobes and lateral lobes.

The siphuncle is dorsad of the centre. The genera are as follows: Litoceras and Trocholitoceras confined to the Quebec faunas, Schroederoceras and Trocholites found in both the Quebec faunas and the Lower Silurian.

Schroederoceras.

This genus has been described by Schroeder and others as Discoceras, and as having close affinity with Trocholites.

The affinity with Discoceras is apparently close, but when one considers the heavily costated shells of that genus and the younger stages of the conch, it becomes obvious that the species having such distinct characters and different modes of development cannot be associated according to the mode of research adopted here.

There are some species like *Schroederoceras Eatoni* and *Eichwaldi*, which approximate in the number and form of the whorls to

Trocholites, but this is not sustained by closer approximation in the early stages. The nepionic stage has whorls which depart more widely from the trocholitean form of the same age than the later stages of growth.

The umbilical perforation is large, the whorls are few in number and increase less rapidly by growth and change more in form than in Trocholites, the sutures are more sinuous, the siphuncle is not so close to the dorsum, the apertures narrower in transverse and longer proportionately in ventro-dorsal diameters and have deeper narrower hyponomic sinuses, the living chambers are much shorter, varying, so far as known, from less than one-fourth of a volution to somewhat more than one-half of a volution, and the size is very much greater at the same age in all dimensions and there are fewer whorls.

The resemblances consist in the surface ornamentation, which, although much coarser, is similar to that of Trocholites.

But even here the deep V-shaped dorsal sinus found in some species is quite distinct. The aspect of the neanic stage before the whorl acquires the flattened abdomen and sides is similar, but this likeness becomes of less importance when the younger nepionic stage is considered. The ananepionic substage may possibly have very fine straight transverse striations, which are not usually visible, but it is apparently smooth as seen in my specimens and in the figures given by others.* The metanepionic stage has strong transverse bands of growth with finer striæ on the surface of the bands. The borders of the bands are prominent and crenulated, the crenulation being due to short longitudinal depression and intermediate folds that occupy the edges of the bands and are discontinuous between them.

The costations also begin to appear in this substage, and these are in some species apparent as obscure folds on the casts. These are distinct from the bands of growth being less numerous on the surface and more widely separated. The crenulations disappear subsequently probably before the completion of the second whorl, but there are often a few continuous longitudinal raised lines perceptible on the centre of the venter and near the umbilical shoulders. The cyrtoceran form is retained longer in the nepionic stage than in Trocholites and the change to the gyroceran curve that brings

* See Schroeder's figure of *Schroederoceras* (*Troch.*) *Damesi*, *Pal. Abh.* v, Pl. xxviii, Fig. 2*a*.

the whorl finally into contact is more gradual, so that the umbilical perforation is larger and the contact occurs in the usual way on the ventral side of the ananepionic substage, instead of on the dorsal side of the metanepionic substage, as in Trocholites.

The whorl has short ventro-dorsal and longer transverse diameters, or broad whorls like many species of Trocholites, but is like a broad whorled typical nautilian form from the earliest stage and has not the kidney-shaped outline so common in sections, especially of the younger stages of the shell in Trocholites.

The modifications of this outline through the flattening of the abdomen and lessening of the gibbosity of the sides occurs doubtless at different stages in different species, but in *Schroederoceras angulatum* and *Saemanni* it is fully developed only in adults.

The contact furrow is well marked in the young and continues in some species to be a well-defined depression throughout life, becoming, however, somewhat less marked in the free part of the whorl or gerontic stage. In some species it is very faintly marked apparently before this stage is reached. It seems to be dependent upon the closeness of the coiling and involution, which is as a rule very slight at all stages in the ontogeny and all stages in the phylogeny. It is consequently somewhat remarkable that this zone should persist upon the dorsum of the shell so long after the whorl becomes free of pressure on that side in the gerontic stage.

The siphuncle does not apparently, so far as is seen, materially change the position it has at the end of the first whorl. It may, as in *Saemanni*, become slightly more removed from the dorsum, but in *angulatum* it is very close to the dorsum, even in the ephebic stage. The walls of this organ are thick, and it is often preserved in the middle of loosely crystalline calcareous deposits under conditions which are not usually considered favorable for the preservation of siphuncles.

SCHROEDEROCERAS ANGULATUM.

LITUITES ANGULATUM Saem. (*Palentogr.*, iii, Pl. xxi, Fig. 1*a–b;* not *c–d*).

Loc., Brevig, Norway.

The original of the *Lit. angulatus* of Saemann (Fig. 1*a–b*) is in the Mus. of Comp. Zoölogy. It has a subquadragonal whorl in the ephebic stage with a flattened and slightly concave abdomen. The shape in cross section is peculiar and quite different from that in Fig. 1*d*. The abdomen on the living chamber is slightly elevated the flat zone being narrower than the transverse diameters immediately internal to this. This may be due to compression, since on the septate portion the lateral curve from the abdomen to the umbilical shoulders show the somewhat flattened aspect given in Saemann's figure. The umbilical shoulders are rounded. The abdomen not so broad as the dorsum, that is not so broad as the transverse diameter through the umbilical shoulders.

The cast shows faint broad fold-like costations bending apically which were more prominent on the shell, as is shown by other specimens from the same locality. Saemann's figure is correct in outline and proportions, but it is incorrect in that it does not give the sutures which are apparent on the original, and it also brings the cast of the whorls in close contact, whereas these are separated by the thick dorsal and ventral shell layers. The whole surface of the cast is also erroneously given, since it is marked by obscure costations, which must have been more prominent upon the exterior of the shell. These are more prominent in the young than upon the full-grown whorls. The sutures have well-marked ventral and dorsal lobes and lateral lobes with saddles at the abdominal angles and umbilical shoulders. The sutures are numerous and close together as in most species of this group and in Trocholites.

The siphuncle is nearer the dorsum than that given in Fig. 1*c*.

The apex is smaller than in the original of Figs. 1*c* and 1*d*, and the umbilical perforation smaller and the rate of increase by growth less, so that the species is smaller than *Saemanni.*

The living chamber in *angulatus* is free as figured by Saemann on the outer part only. In the original of Fig. 1*c–d* it is free for nearly the entire length.

The prominent costæ of the true *Disc. antiquissimum* are not present in this shell nor in its allies, and the differences in form are supplemented by the close coiling of the living chamber in *antiquissimum.*

Saemann's original is 91 mm. in diameter, and has somewhat more than three and a half volutions. The living chamber measured along the median lateral line is 53 mm. in length from aperture to suture. The transverse diameter of the septal floor is 26.5 mm., the dorso-ventral diameter in median plane is 20.5, both without the shell. The aperture is narrower in proportion to the ventro-dorsal diameter, owing to the flaring of the lips and the slight constriction. Only one-half is preserved and it is slightly distorted ; it may be a little too narrow in the figure on account of the necessary restoration, and the ventral sinus is somewhat too narrow and too deep owing to a mistake of the artist. The impressed zone continues on the free part of the living chamber, but becomes distinctly shallower and is almost obliterated in the dorsal outline of the aperture.

SCHROEDEROCERAS SAEMANNI.

LITUITES ANGULATUS Saem. (*Paleon.*, iii, Pl. xxi, Fig. 1*c–d;* not Fig. 1*a–b*).

Loc., Brevig, Norway.

The two specimens used by Saemann, one for his section Fig. 1*d*, and other for the siphuncle, Fig. 1*c*, are both in the collection of the Mus. Comp. Zoölogy and cannot be considered identical with *Lituites angulatus* (Figs. 1*a–b*).

The characteristic differences have been noted under description of that species. The abdomen of the ephebic stage is flat and slightly convex, broader than the dorsum, and the sides are slightly flattened in the full grown as in the Saemann's Fig. 1*d*, which was taken from the exposed last septum or floor of a living chamber in the metephebic substage on the last quarter of the third volution, a substage preceding that in which the whorl became free, which I have considered as the parephebic substage. The sides incline inwards and the umbilical shoulders are hardly perceptible.

There is an impressed zone broader and deeper than in *Schroederoceras angulatum.* The sutures are similar, but have a broader ventral, dorsal and lateral lobes. The saddles on the abdominal angles and those at the lines of involution are also narrower.

The siphuncle is propiodorsan on the first quarter of the fourth volution, as figured by Saemann. It is nearer the dorsum in the younger whorl, being less than its own diameter distant from that side on the early part of the third quarter of the second whorl.

The sides are gibbous and the abdomen rounded throughout the earlier whorls until the beginning of the third whorl in the anephebic substage.

The ventrodorsal diameters increase by growth more rapidly than in *angulatum,* and the whole shell is consequently larger at corresponding stages of development.

The living chamber is longer as well as in every way larger on the third whorl in the anephebic substage before the free part of the whorl is reached, than it is in *angulatum* at a later age in the early part of the parephebic substage as figured by Saemann. In this specimen, the original of Fig. 1*d*, it is about 75 mm. in length along the median lateral line from suture to aperture. The transverse diameter of the septal floor of this given by Saemann in Fig. 1*d* is 29 mm., the ventro-dorsal diameter in the median plane being 24 mm.

The aperture at this stage spreads laterally, slightly flaring but without any preceding constriction. The hyponomic sinus of the aperture was not preserved, but judging from the lines of growth in both species it was broader and perhaps shallower than in *angulatum*. In the larger specimen, the original of Fig. 1*c*, the living chamber was measured along the umbilicus, it being incomplete. The whole diameter of this shell, consisting of nearly four and three-fourths volutions, when complete was over 112 mm.

The length of the living chamber measured along the inner part on the umbilical line, corresponding to the line of involution, was about 75 mm. As estimated by measurements corresponding to this along the median lateral line to a point opposite the termination of the inner line of measurement, this living chamber was certainly over 100 mm. in length. The transverse diameter of the venter of this living chamber at 35 mm. beyond (orad) the septal floor was 34 mm. without the shell. The shell would increase this to between 2 and 4 mm., according to the place of measurement, whether between or on the ridges. There are well-marked narrow ridges or costæ at more or less irregular intervals on this shell with coarse lines of growth between them. These ridges are not perceptibly reflected on the cast of the interior as in *angulatum*, even in the young stages of one specimen, but in another they are faintly shown on the cast of the side of part of the third whorl.

I have been entirely unable to find the usual marks on the exterior of the siphuncle of this species, or any other similar form which usually accompanies the short funnels of ellipochoanoidal forms, but Holms and Schroeder's statements are specific, and they have had better opportunities for their studies, so that I merely suggest a doubt with regard to the structure of such siphuncles as appear in this species and which have usually been described as annulated. The contact furrow is well marked in the neanic stage and in ephebic and metaphebic substages, but in the paraphebic stage it is perceptibly lessened and shows a decided tendency to disappear on the free whorl. The dorsum was distorted near the apertural end so that the exact amount of this diminution could not be seen, but it was clear that the impressed zone had become narrower and shallower. The termination of the living chamber being also absent, it could not be ascertained whether it finally disappeared or not on the dorsal rim of the aperture.

Schroederoceras tubulatum, n. s. Pl. vii, Figs. 1–3, and Pl. xiv, Figs. 6–12, $>\frac{1}{3}$.

Loc., Brevig, Norway.

This species was included by Saemann under the head of *angulatum*, but it has much broader whorls, increases more slowly in size and the free part of the whorl is longer, not only the living chamber but a considerable portion of the septate whorl being free.

A cast of the latter part of the first or first part of the second whorl is costated, and the narrowness of the side shows that the young whorl was not so broad ventro-dorsally as in *angulatus* at the same stage.

One specimen shows the living chamber in the ephebic stage before the uncoiling begins. This is of about the same age as that figured by Saemann in his *angulatus*, Section 1*d*. The ventro-dorsal diameter of the septal floor of this is 26 mm., and the transverse about 32 mm. The venter was the broadest part at this stage as it is in the early ephebic stage of *angulatum*. The umbilical shoulders do not exist even in the rounded form that they take on in the adult of *angulatus* and in the ephebic and gerontic whorls of *Saemanni*. The sides incline or diverge outwardly more decidedly and are flatter than in *Saemanni* at the same stage.

The shell has coarse lines of growth upon this living chamber at more or less irregular intervals, with finer lines between them, and at still rarer and less regular intervals there are the usual narrow ridges which are the remains of the costæ of earlier stages. The ventral sinus is broader and deeper than in *angulatus* or *Saemanni* at the same stage, and there is a deep sinus in the impressed zone on the dorsum with a shallow subacute V shape.

The type of the species is the specimen showing the extended last whorl figured in this paper, Pl. vii, Fig. 1.

According to my estimate this specimen must have had at least five complete whorls. The diameter of the coiled part was probably about 118 mm., and this is estimated to contain nearly five volutions, the length of the free part was over 115 mm. measured along the median lateral line, along the dorsal line of this mould of the outer whorl it could be measured more readily as 105 mm.

The incomplete living chamber occupied 75 mm. of this free part as measured above the median lateral line from the broken edge to the imperfect remnant of the septal floor.

The transverse diameter of the termination of the third whorl was 15 mm. without the shell, the breadth of the side 10 mm., the ventro-dorsal diameter in the mesal plane, as estimated, was of about the same length. The transverse diameter about the middle of the last quarter of the fourth whorl was 22 mm., the ventro-dorsal in the mesal plane was 17 mm. both without the shell.

The shape of the living chamber must have been greatly altered near its termination. The fragment of mould of one side and part of the dorsum preserved shows that the impressed zone had become narrowed and disappeared completely. The dorsum remained slightly flattened, but this flattening given in the restored section, Fig. 3, Pl. vii, is probably greater than it was in the fossil. The lines of growth on the dorsum of the first part of the free living chamber have such a faint sinus that they would ordinarily be described as straight, the lateral crests are much reduced, the ventral sinus was not visible, but it also probably became reduced or shallower. The transverse diameters were also much reduced, and aspect of the aperture changes so that the ventro-dorsal diameter is much longer than the transverse. The outline given may be defective in making this diameter somewhat too long and the abdomen not quite flat enough, but certainly there is an entire change in the proportions of the whorl and an approximation to this reconstructed outline.

The sutures do not differ materially, if at all from those of *Saemanni* so far as could be seen. They are visible on the third whorl and had the usual curvatures. The two last on the fifth whorl were visible on the dorsum and partly on the side. These had a deep dorsal lobe, with saddles and lateral lobe as in *Saemanni*, and were very interesting, since they showed that the dorsal sutures had not been immediately affected by separation of the whorls. The last suture is given in Fig. 1, on Pl. vii.

The zone of impression is fainter, but still perceptible in the dorsum of the first part of the living chamber, but has entirely disappeared on the latter part of the same. It is more strongly marked on the dorsum of the third and early part of the fourth whorls than on the latter part of the fourth, but it is broad and still quite distinct just before the whorl becomes free on the last quarter of the fifth volution (Fig. 2).

The nepionic stage of this species is given in Figs. 6–7, Pl. xiv. The advent of the hyponomic sinus can be seen in the lines of growth of the metanepionic substage in the front view, Fig. 6. The umbilical perforation is larger than it appears to be in the side view, Fig. 7, because it is in part overlapped by the inward growth of the umbilical zones of the paranepionic volution.

The lines of growth are entire and very fine lines on the ananepionic and metanepionic substages, and there are no longitudinal ridges. The sides are convergent and rounded, and the abdomen is rounded and narrower than the dorsum in these substages. At the beginning of the paranepionic the abdomen becomes suddenly flattened, the sides also tending to become flatter and the whorl spreads laterally very fast, the venter becoming wider than the dorsum. Slight crenulations also appear, and in consequence of these faint longitudinal lines may be seen with a magnifier.

Regularly spaced transverse lines are first noticeable in the paranepionic forming the forward edges of broad laminæ on the surface and having finer lines of growth between them, as in Fig. 10, Pl. xiv.

The septa in this substage are deeply concave and have broad ventral saddles divided by narrow V-shaped central ventral lobes, as in Fig. 10, Pl. xiv. There are shallow lateral lobes and dorsal lobes in the contact furrow.

The siphuncle is propiodorsan in this substage as given in Fig. 9, but was not seen in earlier ages. It is slightly nearer the dorsum in the succeeding stages of development of this specimen.

A distinct dorsal furrow appears in this shell in the early part of the paranepionic and deepens until replaced and enlarged by the contact furrow. Contact takes place upon the area of the scar, but not on the dorsal side of this area. I was not able to define the exact line of contact because the apex had been slightly fractured in making the preparation, but it was quite clear that contact did not occur upon the dorsum of the ana- nor metanepionic substages as it does in Trocholites. The involution is greater and the contact furrow deeper in the ananepionic substage, where it begins, than at any subsequent substage, as shown in Fig. 8, Pl. xiv.

In the meta- and paraneanic substages the more prominent lines of growth described above on the edges of the broad bands become subcostal in aspect, but are somewhat exaggerated in Fig. 11. In the ephebic stages these subcostæ are less prominent and do not have any corresponding ridges on the cast, which is smooth. The venter is also less elevated, the ventro-dorsal being less in proportion to the transverse diameters and the whorl assumes the broad depressed outline in section of this species.

SCHROEDEROCERAS RAROSPIRA.

CLYMENIA RAROSPIRA (*pars*) Eichw. (*Leth. Rossica*, Pl. I, Fig. 1*a–b*, Fig. 3; not Fig. 2*a–b*, nor Fig. 6*a*, *b*, *c**).

This species has the aspect of *Schroederoceras Saemanni* on the latter part of the second and third whorl, but the early part of the same whorl in section is rounded and without a zone of impression. The whorls increase faster by growth in the ventro-dorsal diameters than in *Saemanni*. If Eichwald's figures can be relied upon the species are distinct. The distribution of the prominent striæ of the neanic stage is instructive. They occupy all of the first whorl except the apical part and are lost upon the last half of the second whorl, persisting somewhat longer than in *Saemanni* or *angulatum*. The siphuncle is depicted as very large, and according to the figure is nearer the dorsum in the first and second whorl than it is in the same age in *Saemanni*. The faster increase in dorso-ventral diameters makes the adult somewhat larger in diameter of the coil at the same age.

The fact that the last volution is not free at the end shows probably that the specimen figured had not reached the gerontic stage of degeneration. It is of course to be expected that some species of Schroederoceras never become uncoiled, and this may be one of these. Eichwald's Fig. 1*b* also shows that the impressed zone is deeper on the second whorl in the anephebic stage than it is subsequently on the third whorl in the parephebic when a tendency towards uncoiling begins to show itself in this way. The sutures as shown in Figs. 3*a*, *b*, *c*, are like those of *Saemanni*.

SCHROEDEROCERAS TERES.

LIT. TERES, Eichw. (*Sil. in Esthland*, p. 105).

LIT. TERES, Dewitz (*Schrif. physical-okonon. Gesell.*, Kõnigsberg, xx, Pl. iv, Fig. 4).

LIT. TERES, Schroeder (*ibid.*, xxii, Pl. ii, Fig. 2).

DISCOC. TERES, Schroeder (*ibid.*, xxiii, p. 96).

* See *Trocholitoceras Eichwaldi*.

LIT. TERES, Holm (*Pal. Abh.*, Dames et Kayser, iii, hft. i, Pl. v, Fig. 5–8).

Loc., Kandel, Esthland.

The smooth whorl has in section an abdomen somewhat broader than the dorsum as figured by Dewitz and the siphuncle closer to the dorsum than in Odini. The living chamber is free and the aperture like that of *angulatum*. The impressed zone is continued to the edge of the aperture. It suffers, however, a certain obvious diminution and the dorsal edge of the aperture is merely flattened instead of being concave as is the dorsum at the beginning of the living chamber. This peculiarity is described by Schröder, who gives the best figures.

Holms' figures of the young have been copied in outline on Pl. vi, Fig. 21–27. These sections show how closely the young resemble those of *Schroederoceras Eatoni*, and if correctly identified and drawn indicate considerable variation in the form of the young and the relations of the umbilical perforation. In Fig. 21, it is between the ananepionic and paranepionic; in Fig. 22, it is situated as in Trocholites, viz., carried more on to the metanepionic substage, and is differently shaped.

The young (Figs. 23–27) give a rare opportunity for the study of the nepionic stage. The ananepionic substage (Figs. 26–27) is like that of *Eatoni*, and one sees the peculiar shape of the apex and the great comparative depth of the apical chamber. The first septum and cæcum of course belongs to the later metanepionic substage, but the whorl itself is ananepionic, and this a broad elliptical section as seen in the front view of Fig. 26. The dorsum broader than the venter and rounded. The shape is here decidedly cyrtoceran. The first septum and cæcum is seen in this view and the siphuncle is subventran. In the metanepionic it changes as in other forms towards the centre. This is shown by its becoming extracentroventran in the third septum, which belongs to the later age of the paranepionic substage. At the angle of the turn a faint, but plainly marked dorsal furrow appears. The point at which this impression occurs is like that of similar forms of early faunas, and the shape of the whorls show a very rapid increase of the lateral diameters and the usual approximation to the kidney-shaped whorl which characterizes rapidly growing shells of Nautiloids at similar substages. It seems probable, therefore, that this may have been produced by the mechanical effect of the proximity of the stiff wall of the metanepionic substage. It would be extremely instructive to make a number of such preparations and study comparatively the amount and variability of this characteristic with relation to the size of the umbilical perforation, its position, etc.

SCHROEDEROCERAS? BANDONIS.

SCHROEDEROCERAS? BANDONIS, Rem. (*Unter. verstein. Diluvial-gescheibe*, i, Pl. iii, Fig. 4).

SCHROEDEROCERAS ODINI, Vern. (*Geol. Russia, Pal.*, ii, Pl. xxv, Fig. 8).

This entirely smooth shell has rounded whorls, the ventro-dorsal diameters in adults longer than the transverse. There are deeply sinuous sutures with slight ventral lobes on the abdomen in the neanic stage, and these are replaced by flattened saddles (if correctly figured) in the ephebic whorl. It is obviously, if the characters are correctly depicted, quite distinct from *Schroed. teres*. These species agree in general aspect, but not in the form of whorl of the coiled stages of growth, and differ also in the sutures and in position of siphuncle and in the shape of the free whorl.

In *Odini* there is no impressed zone on the free whorl, and probably this was very slight in the neanic stage, as shown by Verneuil's Fig. 8*c*.

SCHROEDEROCERAS DENCKELMANNI.

LIT. CORNUARIETIS, De Vern. (*Pal. Russia*, Pl. xxv, Fig. 7).

LIT. DENCKELMANNI, Rem.

DISCOCERAS DENCKELMANNI, Rem. (*Zeitsch. deutsch. geol. Gesell.*, xxxviii, 1886, p. 468).

This is a completely smooth shell with rounded and more numerous whorls at the same size than in *Schroederoceras angulatum* and a less deeply marked impressed zone.

SCHROEDEROCERAS DAMESI.

TROCHOLITES DAMESI, Schroeder ("Ceph. d. Untersil.," *Pal. Abh.*, Dames et Kayser, v, Pl. xxviii, Fig. 2).

This shell was erroneously referred to Trocholites by Schröder, if his figure is correct. The young has the large umbilical perforation, the large whorls and rapid increase by growth, as well as the characteristic surface markings of this genus. The last whorl has also the form common in the neanic stage of species like *Schroederoceras angulatum* and especially *Saemanni*, which it very closely resembles. It is obviously an immature shell of some species of this genus.

SCHROEDEROCERAS EATONI.

LITUITES EATONI, Whitf. (*Bull. Am. Mus.*, New York, i, No. 8, Pl. xxviii (?), Fig. 5–7 et. Pl. xxxii, Fig. 1; not Fig. 2).

DISCOCERAS EATONI, Schröder ("Sil. Ceph.," *Pal. Abh.*, Dames et Kayser, v, p. 22). Pl. vi, Figs. 28–35, and Pl. vii, Figs. 7–8.

Loc., Fort Cassin, Lake Champlain.

Having had the original of this species, I am able to state that the apex or nepionic stage is closely similar to that of Holms' figures of *Schroederoceras* (*Lit.*) *teres*. The single specimen, Fig. 35, Pl. vi, that showed this section has a large apical or air chamber very deep and cap-shaped in outline, with abrupt ventral side, exactly as in Holms' figures, the second chamber being proportionately somewhat less in depth. The umbilical perforation is, however, much larger, as may be seen in this section, and in Fig. 31, Pl. vi.

The septa continue throughout the first and larger part of the second whorl, that is during the nepionic and neanic stages, to be proportionately wider apart on the venter and nearer together on the dorsum until the decrease by growth in the ventro-dorsal diameters in the anephebic stage makes them more equal on the first quarter of the third whorl where they begin to assume the usual depths. The siphuncle begins subventran in the first chamber, inclining centrally in its passage through the first and succeeding septa until near the end of the first whorl, when it becomes centren. It is in other words nearer the venter than the centre during the cyrtoceran or nepionic stage and becomes centren in the ananeanic substage, as in the figure from Whitfield's specimen and in other figures, Pl. vi.

The sutures have the usual broad ventral saddles and lateral lobes in the nepionic stage and probably dorsal saddles, but these last were not distinctly seen.

The siphuncle in the metaneanic and paraneanic substages trends slowly towards the dorsum until the third quarter of the second whorl is reached, and after that the approximation proceeds more rapidly until it reaches the centrodorsan position in the anephebic substage at the beginning of the third whorl.

The ventro-dorsal diameters also slowly decrease by growth correlatively with this movement, along the mesal plane and proceed with equal steps, correlative with changes in the septa, and relative dimensions and shapes of the air chambers and the shifting of the siphuncle towards the dorsum to the first quarter of the third whorl where they take on the adult proportions and aspect.

These facts are admirably well shown in the figures of *Schroedero-ceras* (*Lit.*) *teres* by Holm, reproduced here if allowance is made for the more cyrtoceran or less involute form of *Eatoni*, which has a larger umbilical perforation. The third septum in both forms, however, comes internally to the same point, the end of the cyrtoceran stage, when the whorl makes a sudden bend and assumes the gyroceran curvature that brings it at the end of the first whorl against apex of the conch. In Figs. 21 and 22, from Holm, this bend is more abrupt and more like that of Trocholites than in this species. The dorsal side of the last quarter of the first whorl actually strikes and lies upon the dorsal side of the first air chamber, whereas in this species the contact takes place farther towards the apex. In *teres* also, according to Holm's figures, the approximation of the siphuncle towards the dorsum takes place more rapidly and probably earlier than in *Eatoni*. Holm found no signs of a cicatrix on the apex of *teres*, but no shell is represented in his figures and he describes the whorls as so very closely approximated that there was but one shell wall. The young shell is very thin, and probably this explains the difficulty of separating the whorls. At any rate, the absence of the cicatrix is not established by his observations. I think he must have overlooked the shell wall, this not being absent in any other forms that I have examined.

Fig. 34, Pl. vi, gives the aspect of an accidental section, the location of which is shown by the line through Fig. 35, taken from the center of Whitfield's original of this species. The sections passed subdorsan to the shell, cutting across the two first septa of the metanepionic substage. The peculiar aspect of this part of the section is due to the continuity of the lateral shell lines on either side with those of the paranepionic whorl which is given in section of volution immediately under this. The convex line dividing the metanepionic from the paranepionic volution, the projecting third septum. The reverse, the splinter from which this section was taken, is given in Fig. 31, Pl. vi. The core of the umbilical perforation was exposed, the metanepionic volution is smaller and younger, the paranepionic section is older and is shown to be convex on the gyroceran turn or curve around the core. The state of the section left this observation open to some doubt owing to the fact that it was slightly clipped on one side, exposing an older part of the same whorl. On wearing this same section down a shade farther the beginning of a dorsal furrow became apparent, and is given in Figs. 32, 33.

It is, however, obvious that the dorsal furrow is very slight and it occurs in the usual place on the paranepionic dorsum; the rotundity and form of the metanepionic whorl was perfectly well defined. The umbilical perforation in this fossil was very small, and the occurence of a dorsal furrow at the place designated in the drawing could be accounted for as due to the contiguity of the dorsum of the growing whorl of the paranepionic to that of the stiff wall of the metanepionic substage.

The position of the siphuncle in the apex could not be determined, but its place in the other whorls was plainly seen and agrees closely enough with the positions determined by Whitfield in the young of *Eatoni*, with which also the characters of the sutures of the older whorls agreed in this specimen.

The contact furrow is deeper relatively in the neanic stage than it is subsequently, when one takes into account the form of the whorl and the relative extent of the sides covered by involution. It is, however, very well marked in all stages, and its disappearance upon the latter part of the last whorl, as has been shown in Whitfield's figures and those given in this paper, is a significant and instructive fact that has been discussed in other parts of this essay. The aperture of Fig. 7, Pl. vii, was removable, and this being taken off the last vestige of the impressed zone is seen on the dorsal side of the free whorl in the front view of the same specimen, Fig. 8. The portion removed is so short that it is possible it may represent the rim of the aperture itself.

The sutures of the anephebic stages differ considerably from those of the adult, being straighter and more like those of Trocholites, and it may be questioned whether this should not be called the paraneanic substage on account of its close resemblances to Trocholites.

In the full-grown shell of the parephebic and gerontic age, as shown in Whitfield's figure, Pl. xxxii, and in my figure, the oldest sutures are more sinuous than those of an earlier stage just under the free part of the living chamber, as given in my copy of his figure, with sutures drawn in from the original chambers (Fig. 28, Pl. vi). They have normally in the ephebic stage ventral and dorsal lobes, with lateral lobes and saddles at the abdominal angles and umbilical shoulders.

The length of the living chamber in a full-grown specimen is over one-half a volution, and the latter part is free, as given by Whitfield and in my Fig. 7, Pl. vii.

SCHROEDEROCERAS CASINENSIS.

LITUITES EATONI, var. CASINENSIS. Whitf. (*Bullet. Am. Mus.*, New York, i, No. 8, Pl. xxxii). Pl. vi, Figs. 36–38, and Pl. vii, Figs. 4–6.

Loc., Fort Cassin, Lake Champlain.

This is a distinct species, the sutures being straighter in the ephebic stage than in true *Eatoni*, the venter and sides are more decidedly flattened, and the relative proportions of the last whorl at the same age different.* The ventro-dorsal and transverse diameters are about equal, whereas in *Eatoni* the transverse is considerably longer than the ventro-dorsal in the mesal plane. The amount of involution in *Eatoni* and the depth of the contact furrow in the ephebic stage is also greater.

Whitfield's figure is given on Pl. vi, Fig. 36, with some emendations taken from the original specimen. This shows that the ephebic stage had not a free living chamber, and that shown in my Fig. 4, Pl. vii, represents the gerontic stage. The front view, Fig. 5, shows the deeper contact furrow and the dorsal lobes in the dorsum of the metephebic substage and the slight but imperceptible change which takes place in the broader, shallower zone of the early part of the gerontic living chamber below. The free part of this chamber is at first concave just beyond the broken end of the metephebic whorl, then flattened, and finally convex on the dorsum, as shown in Figs. 5 and 6.

The length of this living chamber was nearly three-fourths of a volution, beginning somewhat beyond the broken part given in

* Whitfield himself thought this was probably a distinct species, as shown by his remarks on page 332.

Figs. 4 and 5. The siphuncle is very large and propiodorsan in the ephebic and gerontic stage.

Litoceras.

This genus was described in *Genera of Fossil Cephalopods*, page 259.

The siphuncle is very large and is dorsad or below the centre in adults, but is ventrad in *Litoceras Whiteavsi* in the neanic and earlier stages, and is very likely ventrad in the young at some stage in all species, as it is in those of Schroederoceras that have been studied. The young are slightly costated also and the adults smooth, as in other genera of similar groups. The umbilical perforation is of good size, and in the nepionic stage the shell is cyrtoceran and similar to the shells of Schroederoceras of the same group, but with much broader whorls and deeper umbilici. These differences are maintained in the later stages of growth, the whorls being much larger, broader and have in the ephebic stage similar abdomens and convex, divergent sides without umbilical shoulders, resembling the neanic stages of species of Schroederoceras.

The increase by growth in the lateral diameters of the whorl is rapid, as in the young of Schroederoceras and other allied genera, but it continues longer, and even the adults may have very broad whorls, so that these adults resemble in form the neanic stage of Schroederoceras.

The aperture is less compressed than in the full-grown shells of Schroederoceras, and resemble those of the anephebic stage of that genus, but are not flaring or trumpet shaped, as in Trocholites. In fact, there has been a slight turning in of the edges in all the specimens observed, but this, however, may be due to compression. The hyponomic sinus is smaller and shallower than in the ephebic aperture of Schroederoceras.

The contact furrow is broader and deeper than in Schroederoceras and the involution more marked on account of the rotundity and breadth of the abdomen, which is covered in.

The end of the whorl, even in full-grown shells, is not free, and in this respect also the species resemble the neanic stage in Schroederoceras. The living chambers are, so far as observed, longer than in Schroederoceras and shorter than in Trocholites.

The sutures have deep dorsal lobes, saddles on the lines of involution and broad lateral lobes, and the invariable ventral lobe of Schroederoceras is replaced by a saddle or nearly straight suture.

The type of this genus, when it was first described, were the specimens in Geological Museum at Ottawa identified as *Nautilus versutus* of Billings, but these appear here as *Litoceras Whiteavsi*, since there is every reason for supposing that they are not the species described by Billings under the name of *versutus*.

LITOCERAS WHITEAVSI.

NAUT. VERSUTUM (?) (*pars*), Bill. (*Geol. Can.*, *Pal. Foss.*, i, p. 258).

Loc., Point Rich and Gargamelle Cove, Newfoundland.

Having examined the so-called originals of this species, so far as they exist in the Geological Survey Museum at Ottawa, I have found that none of them came from Billings' locality, Bonne Bay, and none of them agree with Billings' description. Billings' species had ten septa to the inch; this species has the sutures about one-quarter of an inch apart, a difference showing essential distinction.

The young on the second whorl has the siphuncle ventrocentren and are slightly costated. These costæ disappear before the end of this whorl and the surface is marked only by the lines of growth. The siphuncle also shifts gradually, becoming centrodorsan, but in the adult it does not approximate to the dorsum, remaining nearer the centre than the dorsum. The abdomen is very broad in the later stages, and in the adult the diameter through the abdominal angles is longer than the ventro-dorsal diameter.

The sides are divergent; that is, slope inwardly. They are rounded and have no umbilical shoulders, the dorsum being coextensive with the contact furrow which covers the abdomen completely. The sutures are sinuous, having well-marked ventral saddles, lateral lobes and probably dorsal lobes, although the latter were not seen. The specimens from which this description was taken were collected at Gargamelle Cove, near Billings' locality, and probably belong to this species, as it is identified by the Geological Survey of Canada. The form of the whorl is not so broad laterally, the chamber of habitation is less than one-half of a volution in length and smaller in every way than in *Litoceras insolens*.

A section of the whorl is more like that of *insolens* in the ephebic stage than in the specimens in the museum at Ottawa, but the sides are rounder at the stages of growth observed.

The siphuncle is similarly situated and somewhat smaller than in *insolens*.

The diameter of the largest and most perfect specimen was about 150 mm. The transverse diameter of the fourth whorl at the whole diameter of 75 mm. was 42 mm., and the ventro-dorsal 25 mm. The diameter of the siphuncle at this stage was 4 mm. The diameter of this organ increased slightly to the living chamber, but probably did not exceed 6 or 7 mm. On the last quarter (probably of the fourth whorl), just before the living chamber was reached, the siphuncle was found to be misplaced, as is not uncommon in species from this locality. This organ has very thick walls and often maintains its form and proportions when unsupported by the septa, although thrown out of place by the movements in the matrix, as happened in this case. It is thrown over to the left and arches towards the venter rising above the centre. The specimen being excavated, however, it was found to be in its usual place, a few septa younger than the point at which it appeared. The entrance into the living chamber was not, however, satisfactorily observed, the septum being broken by compression, although the entrance seemed to be in the usual place, between the centre and the dorsum. The septa were about 6 mm. apart as measured on this siphuncle.

The shell was very thick near the aperture, which was similar to that of *insolens*, but appeared to have a narrower hyponomic sinus than in that species. The way in which the lateral crests run forwards to the lines of involution indicate that there was a crest on the dorsum also, but this could not be observed.

LITOCERES INSOLENS (?).

NAUTILUS INSOLENS (?) Bill. (*Pal. Foss.*, i, p. 258). Pl. vi, Figs. 9–11, nat. size.

Loc., Gargamelle Cove, W. Coast Newfoundland.

This species is so similar in dimensions and characteristics to the one described by Billings and was found so near his locality that I have ventured to apply the same name, although he does not distinctly state whether the siphuncle was dorsad or ventrad of the centre.

The types were not to be found in the museum at Ottawa during my visit to that museum several years ago.

The young of this species increases in the transverse diameters with great rapidity. The ananepionic stage, Figs. 9, 10, Pl. vi, has the usual straight, fine striæ and the metanepionic and succeeding substages throughout the first, and a part of the second whorls have the costations which are common at the same age in other shells of this family. The umbilical perforation is of considerable size; the whorls change from the rounded, cyrtoceran form of the ananepionic substage, which apparently has the ventro-dorsal longer than the transverse diameters, very rapidly as the gyroceran stage approaches on the latter part of the first half of the first whorl or the metanepionic substage. In the paranepionic on the last half of the first whorl and before the whorls touch, the whorl is like the metanepionic volution as shown in section in Fig. 11, Pl. vi, trigonal, the venter broader than the dorsum, and the angles are rounded. In the ananeanic substage, after the completion of the first whorl, the whorl becomes digonal, with a contact furrow. Near the end of the first whorl, in the paranepionic substage, the ventro-dorsal diameter was 3 mm., roughly measured; the transverse through the abdominal angles were approximately 6 mm.; half of a volution beyond this, in the ananeanic substage, the transverse had become 10 or 11 mm., and the ventro-dorsal about 6 mm.; less than one-half volution later in the paraneanic the transverse had become 16 mm. and the ventro-dorsal about 7 mm.; somewhat more than one-half volution later, in the anephebic substage, the whorl had become changed to kidney shaped in section, and the septum at the base of the living chamber was exposed. The transverse diameter was 29 mm., the ventro-dorsal 12 mm., both taken without the shell.

Fig. 11, Pl. vi, shows a sectional view of the metanepionic, neanic and ephebic volutions. The diameters through the umbilical zone, parallel with the mesal plane, were equal or about the same, roughly measured, as the ventro-dorsal diameters.

The anaphebic sutures of the septum at the base of the living chamber in the specimen figured has a well-marked median saddle, narrower than in a full-grown shell, and on either side of this were faintly marked ventral lobes. These last were continued on the sides, rising steeply to the umbilical zones, where they culminated in broad saddles. These descended abruptly in the contact furrow, forming a broad, deep, dorsal lobe. These sutures are quite distinct from those of full-grown shells. The siphuncle was propiodorsan, being a shade less than its own diameter removed from that surface, its diameter being 3 mm.

The whorl is still kidney shaped in section in this substage, with rounded lateral zones, elevated rounded abdomen and rounded abdominal angles, but there is an evident tendency to broaden on the sides and to form steep, horizontal umbilical zones. These parts, being developed out of a digonal whorl, have the usual primitive form of the kidney-shaped whorl, but the slightest flattening of the lateral zones would convert the section into a quadragonal outline. There is a deep wide contact furrow at this age, and the involution completely covers the abdomen of the next inner whorl to the abdominal angles, the umbilical zones actually bulging inwards, and encroaching somewhat on the umbilici, comparing closely with the younger stages of *Trocholitoceras Walcotti*, Fig. 12, Pl. vi.

The living chamber of this specimen, Fig. 9, although incomplete, was nearly one-half of a volution in length at the end of the third volution. About one-quarter of a volution from the septal floor it measured in transverse diameter 33 mm. and the ventro-dorsal 15 mm., showing that the rate of growth in the transverse diameter had begun to lessen considerably. The depth of the umbilicus measured from the umbilical shoulders was 15 mm. at about the end of the last half of the third whorl. The shell was very thick on the venter even at this age.

During subsequent growth the sides are apt to become broader and flatter, but the transverse diameters always exceed considerably the ventro-dorsal. The fossils are all apt to be more or less distorted by pressure, so that it is difficult to draw the line between this species and *Litoceras Whiteavesi*, except in the young. In these the whorl is of greater breadth and the siphuncle nearer to the dorsum than the last mentioned.

As the sides become better defined the sutures change. The ventral saddle disappears in a broad lobe or almost straight suture, slight saddles appear at the rounded abdominal angles and the broad lateral lobes ascending to the lines of involution and the blunt saddles, as in the young, on the primitive and rounded umbilical zones are all better defined. The broad deep dorsal lobe also remains as in the young in the contact furrow.

The whorl was not free at the aperture in any specimens observed.

The diameter of the largest specimens was estimated at 177 mm.; the imperfect living chamber in this was somewhat less than one-half of a volution in length. The transverse diameter of the septal floor of this chamber was, estimating by half measurement, more than 74 mm., the ventro-dorsal about 50 mm. The siphuncle from which the measures were taken may not have been in the centre in this specimen, so the measurements of the transverse diameter may be faulty. The living chamber in this and the next specimen described reached well into the first half of the fifth volution, as estimated by careful comparison with the young specimen above described and figured.

The most perfect fossil of this species was 140 mm. in diameter. The living chamber showing lines of what appeared to be the rugged edge of an aperture was just one-half of a volution in length. The suture of the septal floor was similar to that described above. The transverse diameter at the septal floor was about 60 mm., the diameter through the side about 31 mm. The transverse diameter midway in this chamber became nearly 74 mm., and the diameter through the side 40 mm.

Near the aperture the ventro-dorsal diameters continued to increase and the transverse decreased, or in other words the aperture was not so broad as the middle of the chamber which was slightly expanded. The shell was enormously thick on the venter, showing age, it was near the middle about 2 mm. in thickness, and near this aperture 6.5 mm. in thickness. The lines of growth indicated a very large, broad and deep hyponomic sinus and broad lateral crests, but these were not distinctly seen.

The siphuncle, in the specimen 177 mm. in diameter, reached the large size of 11 mm. at the septal floor, and less than one-half of a volution younger was 6.5 mm. in diameter. The septa were only 6 to 6.5 and 7 mm. apart as measured on the siphuncle at this age near the living chamber. They were nearer together than in adults at this gerontic stage as is usual in outgrown specimens. The last two sutures of the smaller fossil described as 140 mm. in diameter were 7 mm. distant, which is probably the average distance of a full-grown shell, judging also by the remains of an isolated siphuncle in the collection belonging to this species.

LITOCERAS BIANGULATUM, n. s.

Loc., Pt. Rich., Newfoundland.

This shell appears in the collection at Ottawa under the name of

Nautilus versutus. The sides, however, until a late stage are angular, forming a truly digonal whorl with broad rotund abdomen.

The ventral saddle is more plainly marked and more prominent, and the whorls more numerous at the same age. There are saddles at the abdominal angles and lateral lobes; the dorsal sutures were not seen. The contact furrow is about the same as in *Litoceras Whiteavesi.* It is simply a species retaining the digonal, neanic whorl until a late stage, probably throughout life.

LITOCERAS ? HERCULES.

NAUTILUS HERCULES, Bill. (*Rep. Geol. Surv. Can.*, 1856, p. 306).

Loc., Charleton Pt., Anticosti.

This smooth shell found in the Lower Silurian of Anticosti has the digonal form of whorl similar to that of *Litoceras biangulatum* and the young of *Litoceras insolens.* It is, however, a very much larger and more rapidly growing shell. The sutures have ventral median saddles, and on either side ventral lobes as in the young of *insolens.* The abdominal angles have saddles and there are well-marked lateral lobes rising to slight saddles at the lines of involution. The diameter of Billings' specimen was 6½ inches with incomplete living chamber.

Trocholitoceras, n. g.

This genus has been framed to include forms which are essentially similar to Trocholites, but have the siphuncle ventrad of the centre in the earlier substages of development.

The forms stand in development and adult characters between Litoceras and Trocholites.

Type is *Trocholitoceras Walcotti.*

TROCHOLITOCERAS WALCOTTI. Pl. vi, Figs. 12–20.

Loc., Fort Cassin.

The series of sections drawn in Figs. 14–19, Pl. vi, gives the history of the development of the shell and siphuncle in this interesting species. The first sectional cut (Fig. 14, Pl. vi) shows the round ananepionic volution, the umbilical perforation and below this the paranepionic volution with the siphuncle ventro-centren, and the outline beginning to broaden and approximating to the kidney-shape, above the round ananepionic section is the ananeanic whorl with the siphuncle centrodorsen. It will be observed that this section cuts at right angles to the long axis of the narrow pear-shaped umbilical perforation and that there is a faint but well-defined dorsal furrow in the dorsum of the paranepionic volution. In Fig. 15 a somewhat older section is shown and the siphuncle of the metanepionic substage is propioventran. The umbilical perforation is narrower in consequence of the approximation to the dorsum of the parenepionic whorl and the dorsal furrow is well-defined at this bend, and broader and deeper than it is beyond this in Fig. 16.

The birth of the dorsal furrow is shown in Fig. 16, since one can see here the distinct outlines of the metanepionic volution broadening out internally, and the dorsal side of this remaining stiff and rounded while the plastic dorsal side of the growing paranepionic volution was bent into a dorsal furrow while being built around this abrupt bend. In Fig. 17 the section has passed inside of the paranepionic whorl, and the aspect begins to be confused by the fact that it cuts across the septa and shell. This and Figs. 18 and 19 are similarly confused, and are of value only for tracing the positions of the siphuncle. This organ obviously begins in a subventran position, becomes propioventran in the metanepionic and paranepionic, centrodorsan in the ananeanic after the completion of the first volution, and finally subdorsan in the metaneanic substage on the third volution. This position is retained throughout life, as is shown in the section, Fig. 13, Pl. vi.

The innermost volution shown in the side view of the same specimen (Fig. 12) is the last quarter of the third and first quarter of the fourth volutions. The smooth, still kidney-shaped whorl of the last quarter of the third volution in Fig. 13 shows the paraneanic substage. The third sectional outline of a whorl below the central rounded ananepionic tip gives this age, and the third sectional outline of a whorl above the same ananepionic centre gives the section across the first quarter of the fourth whorl, which is the anephebic stage, and has a very distinct outline. Owing to the decrease in the rate of growth of the lateral diameters, the sides and abdomen have become contracted and the kidney shape of the earlier ages has been exchanged for a helmet shape in outline.*

The living chamber in this specimen occupies at least the greater part of one-half of a volution, but its exact length could not be ascer-

* This section is unluckily in a position which is the reverse of that of Fig. 12.

tained. The aperture was not very plainly discernible, but was approximately as given in the figure.

The ephebic stage has raised lines or bands of growth straighter on the sides than in the gerontic stage, which has evidently begun on the last whorl. This has moderately heavy ridges which are reflected on the cast of the living chamber.

It is separable from *Schroederoceras Eatoni* by the broad whorls of the young and the near approximation of the siphuncle to the dorsum in the neanic stage.

TROCHOLITOCERAS (?) EICHWALDI.

CLYMENIA RAROSPIRA, Eichw. (*Leth. Rossica*, Pl. l, Fig. 2, a, b, c, and 6, a, b, c; not Fig. 1, a-b, and 3).

The descriptions and figures of Eichwald show conclusively that this is widely different from *Schroederoceras rarospira* and is nearer to true Trocholites. The form of the whorls in the young, the slow rate of increase in the dorso-ventral diameters, the rotundity of the sides and abdomen in the young and even in the full-grown whorls, the small diameter and close approximation of the siphuncle to the dorsum, make this shell very like a species of Trocholites.

On the other hand, the sutures are more sinuous, having deeper ventral and lateral lobes than are common in that genus. The living chambers are less than one-fourth of a volution in length, with the lateral crests of the aperture most prominent about the centre of the lateral aspect.

The question of affinity can of course only be definitely settled after the development of the siphuncle in the apex of the conch has been studied. The appearance of the umbilicus, as shown in Fig 6 of Eichwald, is similar to that of other species of this genus, but this of course may be due to erroneous draughting.

Trocholites.

This genus has been fully described and correctly defined by Schröder,* and the following description is largely taken from his work and adapted to the needs of this work. The shell of the nepionic stage, as first shown by Holm,† is so closely coiled that no umbilical perforation is externally visible. Observations of two young specimens of T. described below have, however, shown the

* "Unters. ub. sil. Ceph.," *Pal. Abt.*, Dames et Kayser. N. F. (current Vol. v), heft 4.

† "Sil. Ceph.," *Pal. Abh.*, Dames et Kayser, iii, Pl. v, Figs. 9, 10 and 11.

existence of lateral depressions or open nepionic umbilici, and the usual umbilical perforation is present, although rendered very small by the closeness of the coiling.

The first air chamber observed in two specimens is unusually deep and broadens laterally by growth with extreme rapidity. I have not been able to expose a complete apex so as to see the cicatrix, but have seen the outline of the umbilical perforation at the centre. The siphuncle is closed at the end, but not perceptibly swollen into a pouch as in most Nautiloids. It is not close to the dorsum in the first chamber, but the cæcal end is centren as shown in the section of the ananepionic substage (Fig. 24, Pl. iv).

It clings closely to the dorsal side as in the young of *internastriata*, as shown in Fig. 25, which represents a truncated apical chamber and the paranepionic substage of the first whorl. Holm and Schröder's observations have shown that it is ellipochoanoidal or has in other words short funnels and a porous wall between contiguous septa. Schröder's observations apply to the full-grown shell and Holm's to the young.*

The extremely rapid expansion of the whorls ceases before the first whorl is completed, but it gives to the nepionic shell, when seen from the venter, the aspect so common in Ammonoids during what is usually called the goniatic stage. So far as now known to me, no other Nautiloid possesses this peculiarity to such a remarkable degree in the nepionic stage, Fig. 39, Pl. vi.

The mode of growth of the siphuncle is independent of the close coiling, since it has the same history in *Trocholites internastriata*, with a large umbilical perforation, as in true Trocholites of later times, with a more minute perforation.

The septa as in most nautiloids are much wider apart, at first gradually decreasing until the end of the first whorl or thereabouts, as shown in Holm's figures, when they assume the normal distance and are less deeply convex. The sutures exhibit corresponding differences, having large ventral saddles, deep lateral lobes and probably, although these were not clearly seen, dorsal saddles in these earlier stages.

The lines of growth are much straighter in the nepionic stage than subsequently. The hyponomic sinus is so broad and shallow that it is hardly observable on the third quarter of the first whorl

* Holm's observations and mine are similar and I have reproduced his figure in Pl. iv of this paper.

and the lines are almost straight on the sides. The lines of growth alone are visible. There are no prominent bands marking permanent apertures, nor are the characteristic costæ of Trocholites visible, nor any longitudinal ridges in my specimens. Growth lines show that in the nepionic stage not only the form and sutures were distinct but also the aperture. The apertures are trumpet-like in the ephebic stage and have a moderate hyponomic sinus with broad lateral crests, increasing in prominence towards the dorsum. Whether there are sinuses in the contact furrow has not been determined, but one infers their presence because the lines of growth incline apically just before reaching the lines of involution. The form of the whorl continues rounded in all species of this genus, although in some there is a distinct tendency towards angulation of the sides.

The contact furrow appears very early in consequence of the close coiling of the whorl. This zone is not deep, but it is well marked and may extend nearly to the abdominal angles in some species and it remains throughout life. So far as known no specimen has been found with even a part of the last whorl free. The form of the whorl in section is consequently nephritic, except in some species having flatter sides and more pronounced abdominal angles than usual.

In one species only, *T. circularis*, is there any tendency to form a pentagonal whorl and this was not only very obscure but observed only in one specimen, the type form. The whorl is therefore very primitive.

The length of the living chamber is given as usually about three-quarters of a volution by Schröder, but some of his species have it less than one-half of a volution. *T. Remelei* and *T. ammonius* have one invariably somewhat less than one-half of a volution in length. It is obvious that in this genus it varies between these limits.

TROCHOLITES INTERNASTRIATA.

LITUITES INTERNASTRIATA Whitf. Fort Cassin Foss. (*Bull. Am. Mus.*, New York, i, No. 8, Pl. xxix, Figs. 5–8). Fort Cassin.

This species, of which I have studied the originals, has young of cyrtoceran form, with a good-sized umbilical perforation, as in Schroederoceras and Litoceras. The siphuncle is centren in what is probably the second septum, and it has not the prolongation beyond this septum, as figured by Whitfield. It inclines rapidly towards the dorsum, attaining a fixed position in the fifth septum, if I am right in estimating the first septum drawn by Whitfield as the second.*

It is much larger in the nepionic stages, contracting as it nears the sixth, and becoming a narrow tube in the seventh septum. Subsequently it again increases by growth as the shell grows larger, so that it has the usual large diameter common in this group. If the trend of the siphuncle towards the apex from the dorsum to the centre is followed out it can be seen that the cæcum must have been situated somewhat on the ventral side in the apical chamber.

The rapidity with which the siphuncle becomes propiodorsan, attaining this position in the metanepionic substage or as the first whorl bends to assume the gyroceran curve, shows affinity apparently for Trocholites, but the position in the second septum and the size of the siphuncle and the sutures of later stages are not in favor of this view. The form of the whorl is very similar to that of *Schroederoceras Eichwaldi*, but from this it is separated by the sutures, which in the ephebic stage on the fourth whorl have slight saddles instead of lobes on the venter and the siphuncle is not so close to the dorsum and is larger. The suture of the earlier stages are straight and are trocholitean in aspect, with well-marked dorsal lobes, as is also the form and ornamentation of the young whorls, which are slightly costated.

There is a well-marked contact furrow, and I did not find the tendency of the last whorl to become free, as described by Whitfield, the contact furrow being well defined at the termination of the whorls in the original of Fig. 5, Pl. xxix, of his work.

The slower growth and distinct form of the apex, which is more cylindrical and not cap shaped, and the development of the siphuncle, separates it from the young of *Schroederoceras Eatoni*, and also that of *Schroederoceras teres* and *Trocholitoceras Walcotti*.

Although the position of the siphuncle at an early stage is not yet known in species of Litoceras, this species is obviously distinct because of the narrowness of the whorls, which resemble those of *Eatoni* in outline. Besides the ventral saddles, the sutures of the fourth volution have well-marked lateral lobes and dorsal lobes in the contact furrow. The whorl remains throughout life in transverse section depressed, elliptical, as in Trocholites,

* I am not satisfied with this correction. The aspect of the first chamber is more natural in Whitfield's drawing than in mine.

and the markings resemble those of that genus, as does also the development of the siphuncle. The larger size of the umbilical perforation is interesting, but this alone does not warrant generic separation.

TROCHOLITES CANADENSIS, Pl. iv, Figs. 23 and 24, and Pl. vi, Figs. 39 and 40.

Loc., Falls of Montmorency, near Quebec.

The four specimens representing this species came from the Bronn collection. They are similar to *T. ammonius* in form, but differ in being broader proportionately in the transverse diameters of the whorls and have deeper umbilici. The whorls are rounded, there being no tendency to angularity, either of the sides or abdomen, and in these specimens the size is small. There are fold-like costæ from an early neanic stage and the living chamber may be considerably over one-half of a volution in length. The exterior is marked by longitudinal lines along the venter and often on the sides, but these have none of the regularity and prominence observable in Conrad's figure, and that figure shows no costations which are more prominent and fold-like in this than in *T. ammonius* or any other described species of Trocholites.

The extremely broad aspect in section of the ananepionic volution is given in Fig. 24, as seen from the front. The umbilical perforation between this and the larger paranepionic volution is very narrow. In Fig. 23 looking through the transparent paranepionic volution one sees the umbilical perforation and the metanepionic volution as it is turning or revolving around the core of the perforation. The outlines in both of these views belong to different ages and are, consequently, quite distinct. The upper section of a whorl in Fig. 24 is the ananepionic substage; the upper section in Fig. 23 is a visual section of the metanepionic whorl just before it changes by growth into the paranepionic, which is seen below in same figure, and this last in turn is younger than the lower section in Fig. 24, which is a later age of the same substage. Taking these in regular order, it is seen that the ananepionic has a rounded dorsum and almost digonal whorl on account of its very rapid transverse growth; that this, as it becomes older, acquires a concave dorsum in the metanepionic of Fig. 23. Then, as the whole revolves while growing, at a later age but part of this same substage, after the shell has passed this bend and is freer to grow on the dorsal side, the centre of the dorsum again begins to round out, but traces of the primitive dorsal furrow remain in the depressions on either side of the central, gibbous dorsal face formed by this outgrowth, as in Fig. 24.

This gibbous face is immediately suppressed when the whorls come into contact, and its transient appearance can only be accounted for as due to the genetic tendency of the paranepionic whorl to resume the gibbous metanepionic form of dorsum as soon as the pressure resulting from the abrupt curve is slightly relieved.*

TROCHOLITES AMMONIUS, Hall.

This species, of which the collection of the Museum of Comparative Zoölogy possesses a very large number, collected by Mr. C. D. Walcott, has a very peculiar, rough, fretted surface, and only very few specimens show longitudinal lines such as are described and figured in *T. planorbiformis* by Conrad. This surface is due to the minute crenulations or waves in the outlines of the projecting edges of the laminæ of growth. When these are wide enough apart one can distinguish crenulated transverse lines; when too close they interfere and the regularity and continuity of the lines are broken into a multitude of more or less discontinuous, short lines. Sometimes a network of lines is formed by the regularity of the intersection of the crests of the crenulations in successive laminæ. This cuticular ornamentation is so easily destroyed that it is often present only on parts of the same specimen.

Longitudinal lines may be seen through it, but, as stated by Hall and observed by the writer, these are rarely present in the New York specimens. They do, however, sometimes exist all over the abdomen and sides, and are well defined in specimens in which the cuticular corrugations are absent.

The lines of growth are extremely crowded, and what are called the costæ occur at wider intervals and more irregularly. They are probably the traces of former apertures. These are more prominent in some specimens than in others, but never seem to have the aspect of true fold-like costations.

The lines of growth form deep, broad sinuses on the venter; rise into lateral crests on the sides, sinking towards the lines of involution, and forming a sinus in the contact furrow. These are

* This opinion would be more convincing, if it were not for the fact, that in Cranoceras similar transformations occur in an adult cyrtoceran form of the Devonian.

parallel to the outlines of the apertures, but these last not infrequently have shallow, broad constrictions and slightly projecting or trumpet-like lips in full-grown whorls.

The specimens of *T. ammonuis* from the same locality may vary from very broad-whorled forms to those with much narrower almost cylindrical whorls, the former being slightly deeper umbilici and the latter being shallower, as in *T. circularis*. The venter and sides are, however, almost invariably projecting and rounded, unless angulated by compression, whereas in *circularis* there is a distinct tendency towards truncation or flattening of the abdomen and sides.

The sutures in the ephebic stage may be nearly straight, but there are in most specimens broad ventral lobes, saddles at the abdominal angles, lateral lobes and saddles on the umbilical zones and lobes in the contact furrow. These inflections are, however, always slight, and the sutures give the impression of being almost straight in most specimens.

The contact furrow is distinct but not deep in the ephebic stage and continues to be present in the aperture of the whorl, which is never free.

TROCHOLITES INCONGRUUS, Ang. et Lindst.

CLYM. INCONGRUA, Eichw. (*Leth Rossica.*, Pl. l, Fig. 7).

CLYM. INCONGRUA, Schröder (*Ceph. d. Untersil.*, *Pal. Abh.*, Dames et Kayser, v, heft 4, Pl. ii, Fig. 2–4).

TROCHOLITES INCONGRUUS, Ang. et Lindst. (*Fragm. Sil.*, Pl. ix, Figs. 15–18).

This species is beautifully figured by Angelin and Lindstrom and the living chamber and the lines of growth and sutures fully given. It is obviously a smaller species than *T. ammonius*, with deeper umbilical whorls much broader proportionately, abdomen very broad, but sides rounded as shown by Schröder.

TROCHOLITES HOSPES.

PALEONAUTILUS HOSPES, Remelé (*Zeitsch. deutsch. geol. Gesell.*, xxxiii, 1881, Pl. ii, Fig. 1).

TROCH. HOSPES, Schröder (*Ceph. d. Untersil.*, *Pal. Abh.*, Dames et Kayser, v, heft 4, Pl. i, Figs. 8, 9).

This species, supposed by Remelé to be distinct generically from Trocholites, is merely, as shown by Schröder, a species of Trocholitæ, with very broad whorls quite similar to those of his *T. contractus*.

TROCHOLITES DEPRESSUS.

CLYMENIA DEPRESSA, Eichw. (*Leth. Ross.*, Pl. 1, Fig. 5).

TROCH. DEPRESSUS, Schröder (*Ceph. d. Untersil.*, *Pal. Abt.*, Dames et Kayser, v, heft 4, Pl. i, Fig. 4).

TROCHOLITES MACROSTOMA, Schröder (*Ceph. d. Untersil.*, *Pal. Abt.*, Dames et Kayser, v, heft 4, Pl. i, Fig. 1).

TROCH. CONTRACTUS, Schröder (*ibid.*, Pl. i, Fig. 2).

Excessively broad whorls and deep umbilici but no lateral zones. Living chamber about one-half volution in length according to Schröder's drawings. Schröder also describes the following species:

TROCH. ORBIS, Schröder (*ibid.*, Pl. i, Fig. 23).
" MACROMPHALUS, Schröder (*ibid.*, Pl. i, Fig. 5).
" SORAVIENSIS, Schröder (*ibid.*, Pl. ii, Fig. 1).

TROCH. REMELEI, Schröder (*ibid.*, p. 18), was described as *T. incongruus* by Ang. et Lindst. (*Frag. Sil.*, Pl. ix, Figs. 15–18), and this has a living chamber not quite one-half a volution in length. His *Troch. damesi* (*ibid.*, Pl. v, Fig. 2) shows sculpturing and form of the young which appears to place it in the genus Schroederoceras rather than in Trocholites and it has been referred to that genus.

Trocholites circularis, Mill. et Dyer, of the Cincinnati group of the Hudson river, is probably a distinct species. The type is in the Museum of Comparative Zoölogy. This has an aperture like that of *T. ammonius* and length of living chamber as in that species about one-half of a volution. The whorls are not so stout as in *ammonius*, the sides being slightly compressed, the abdomen narrower than the dorsum.

TROCHOLITES DYERI, n. sp.

This is a form in the Dyer collection from the Cincinnati group, having a form of whorl broader and quite like that of *T. ammonius*, but with a longer living chamber and distinct aperture.

The living chamber is considerably over one-half of a volution in length and the lateral and ventral edges of the aperture are flaring like the mouth of a trumpet. This gives extraordinary prominence to these parts and especially to the hyponomic sinus. The umbilici were not seen, but are probably deeper than in *T. ammo-*

nius or *circularis* and the involution of the whorl, although not distinctly seen, is also apparently greater.

Trocholitus minusculus, Mill. et Dyer, is a small species having such extraordinary sutures that one suspects some distortion, nevertheless there is no proof of any action that would have brought this to pass. The form, except the size, is like that of *T. ammonius*. The incomplete living chamber is somewhat less than one-half of a volution in length. The sutures have flexures like those of the lines of growth in other forms, *i. e.*, they form a deep, broad sinus on the venter, rise into prominent saddles on the sides which internally sink towards the lines of involution, probably forming a lobe in the contact furrow. These outlines are unique among the species of Trocholites. The shell is shown on part of another specimen, and the hyponomic sinus in the lines of growth on the venter is narrower than the ventral lobe of the sutures.

T. planorbiformis, sp. Hall, may be distinct from *T. ammonius*, since the name has been adopted by Hall, who has studied the type, and this may be the same as *T. planorbiformis*, Conrad.

TROCHOLITES BLAKEI.

TROCHOLITES PLANORBIFORMIS, Blake (*British Ceph.*, Pl. xxix, Fig. 9).

This species, considered by Blake as identical with *planorbiformis* Conrad, is obviously a distinct form. It has deep ventral lobes in the sutures and costæ which are figured on either side of the abdomen. No longitudinal ridges are described, although the surface was studied and the transverse markings were plainly seen.

Blake states that this is identical with *Lituites hibernicus*, Salter,* but the latter is a ribbed species with part of the whorls free and does not even belong to the same family. There are probably several species confused under this one name.

It occurs in the Bala beds at Llandovery.

TROCHOLITES ANGUIFORMIS.

NAUTILUS (TROCH.) ANGUIFORMIS, Blake (*Brit. Ceph.*, Pl. xxviii, Fig. 2).

This is also a true member of this genus.

* Murchison's *Siluria*, p. 220, Fig. 3.

TROCHOLITES SCOTICUS.

NAUTILUS (TROCH.) SCOTICUS, Blake (*Brit. Ceph.*, Pl. xxix, Fig. 6, Pl. xxviii, 14).

Blake's figures show sutures, but he states that none are discernible. The aperture and form of whorl and striæ indicate that this is a species of Trocholites.

Hercoceratidæ.

In "Carboniferous Cephalopods," second paper, *Fourth Annual Report Geol. Survey of Texas*, I separated the Tainoceratidæ, including the Temnocheilus, Metacoceras and Tainoceras from the Hercoceratidæ, but further study leads me to think that this is not advisable considering the approximation in form and characters of the two sets of genera and have reunited them here under the old name.

In genera of fossil Cephalopods I regarded *Ptyssoceras* (*Cyrt.*) *alienum*, sp. Barrande, as the arcuate radical type of this family. It has a single row of large, lateral tubercles, sutures nearly straight, whorl in section depressed, elliptical and siphuncle ventral, and it has no dorsal furrow. The genera properly included under this family name are as follows:

Ptyssoceras, Trochoceras, Hercoceras, Anomaloceras, Lower Silurian; Centroceras, Devonian; Temnocheilus, Devonian to Dyas (Permian); Metacoceras, Tainoceras, Carboniferous and Dyas; Foordiceras,* Dyas.

I have also provisionally placed Coelogasteroceras in this family on account of the general resemblances of the form of the nepionic stage, the smooth shell and the hollow ventral zone in the abdomen.

Ptenoceras,† n. g.

Under this name I propose to place all those forms formerly included under the name of Hercoceras in my *Genera of Fossil Cephalopods*, whether turbinate or coiling in the same plane, which have no impressed zone at any stage. The whorls are open, or barely in contact, and are rounded in the early stages and subquadragonal later in life. The apertures are similar to those of Herco-

*All these genera are mentioned or redescribed below as far as needed for the purposes of this paper except Foordiceras and Tainoceras, which have been described in "Carboniferous Cephalopods," quoted above.

† *Πτηνός*, winged.

ceras, but are more widely open and often have spreading lips to the lateral sinuses as in *Ptenoceras* (*Gyr.*) *alatum*, Barrande, Pl. xliv.

These forms are interesting because of their obviously close genetic affinity with Hercoceras, and yet the entire absence of an impressed zone at any stage in consequence of the loose mode of the coiling.

Ptenoceras flexum, sp. Barrande, Pl. xliv, and *Ptenoceras tardum* should also be included in this genus, and probably Barrande's *Trochoceras nodosum*, Pl. xxv, but his other forms described under this name belong to widely different genera.

Hercoceras.

This genus described by Barrande (*Systeme Silurien*, ii, Text i, p. 152) should be limited to such species as those placed under this name by this author. I formerly included also under this name certain gyroceran and trochoceran forms. These are separated here, but so far as regards their near affinity, I still hold the opinion that they belong to the same family group, and are genetically connected. Hercoceras includes only nautilian forms, having a small umbilical perforation, the impressed zone being present only after the whorls come in contact. They have peculiar contracted apertures, figured by Barrande, depressed whorls broader on the venter than on the dorsum, often with large spines or nodes, siphuncle subventran, and are often trochoceran in their mode of growth.

The section of *Hercoceras mirum*, the type of this genus, given in Figs. 13, Pl. viii, shows the small comma-shaped umbilical perforation, deep apical chamber and septa of the nepionic stage. The cæcum is very small and is packed away in the ventral angle of this chamber under the septum. The siphuncle is phenomenally small in this genus in the nepionic substages, but increases subsequently to a respectable size. This and the absence of longitudinal ridges on the exterior of all of this genus and its allies has a genetic significance which is not yet understood.

The young are sometimes in contact only in the neanic stage, and in the same species this may vary so that the whorls remain in contact throughout the ephebic stage, the last whorl with the living chamber being free as in *Hercoceras* (*Gyroc.*) *nudum*, sp. Barrande. *Hercoceras* (*Troch.*) *transiens*, sp. Barrande, Pl. xxx, is a species of this genus, and it seems to me quite possible that Barrande's

Gyroceras minusculum (Pl. xxx) may also prove to be related to species of this genus.

The young of these forms are all closely coiled and have contact furrows when the volutions are in contact, and these are also retained more or less in the gerontic stages.

The section is at first rounded, then broadens out to a digonal form, which in some species may remain more or less digonal or become quadragonal.

The young of Hercoceras has the subquadragonal form in some species like that of the adults of Trochoceras.

Hercoceras (*Adelphoc*) *secundum*, sp. Barrande, is a giant form of this genus, with the impressed zone retained in the gerontic stage.

HERCOCERAS IRREGULARIS.

HERCOCERAS MIRUM, *var.* IRREGULARIS, Barrande (Pl. xliii). Pl. viii, Figs. 14–15.

This is a distinct species having different and less closely coiled young than the typical *Hercoceras mirum*, and is transitional between Hercoceras and Ptenoceras. The nepionic stage given in Figs. 14–15, Pl. viii, shows that the metanepionic whorl is a depressed ellipse, the paranepionic volution is more rounded, the ventro-dorsal slightly longer than the transverse diameter, and the neanic whorl may be subquadragonal, or pass from this directly to the digonal form of the ephebic stage.

The exterior of the nepionic and neanic volutions have very coarse, transverse ridges without any longitudinal markings.

The cæcum is large in the apex. It is not correctly given in Fig. 15, and is ventrocentren. In another specimen at a somewhat younger age, it was very large compared with the diameter of the ananepionic volution and centren. In this also it remained in the mesal plane in later ages, although shifting to propioextraventran position.

The umbilical perforation is small and comma-shaped, and although it seems impracticable that the paranepionic whorl should succeed in growing around the apex without enveloping it, this really occurs, and no impressed zone is formed in the ananeanic substage. The volutions come in contact later, and a faint contact furrow appears in the metaneanic substage, which becomes deeper in the ephebic stage as figured by Barrande.

There is obviously a great variation in the coiling of the shells of this transitional species as is shown by Barrande's figures. One shell has no contact furrow at a very late substage of development. It is possible, however, that there are several species included under this name.

A slight impressed zone or flattened dorsum is retained in the gerontic stage. Considering the slight coiling of the shells, this fact is important.

Anomaloceras.

This genus was described in *Genera of Fossil Cephalopods*, p. 283, and includes nautilian forms having close-coiled young with a small umbilical perforation. The whorls are depressed oval, kidney-shaped or digonal with a deep impressed zone. The sutures are almost straight, or with slight ventral and lateral lobes.

The siphuncle is subventran, and in the type is always laterad of the mesal plane.

ANOMALOCERAS ANOMALUM.
NAUTILUS ANOMALUS, Barr. (Pl. xxxiv). Pl. vii, Figs. 16–20.
Loc., Bohemia.

This species possesses very closely coiled whorls, and is of great interest in connection with the history of the impressed zone, as is demonstrated by the sections given on Pl. vii. These sections began with Fig. 16, which passed through the larger end of the comma-shaped umbilical perforation. The paranepionic section just below the centre is distorted slightly by the obliquity of the direction of the cut, and has a septum crossing it just below the siphuncle, and this organ is excentric and not so near the venter as in the later stages. The section of a volution above the perforation is also paranepionic, but older, and shows rapid expansion in lateral diameters and a tendency to assume the nephritic outline, and has in correlation with this a very slight dorsal furrow. The lateral asymmetry of this whorl is probably in part due to a slight obliquity of the section. The siphuncle is subventran as in all later stages. The metaneanic substage appears in the second outline of a volution below the perforation, and this has a digonal nephritic form.

This becomes trapezoidal and more rounded in the sections of the outer ephebic volutions above and below those described above, and in the full-grown specimens of some shells may become a much depressed oval, as shown in Barrande's figures. Fig. 17 gives a cut farther in towards the narrower part of the umbilical perforation and shows the paranepionic substage younger than in Fig. 16, and with more depressed and approximately digonal outline. Above this the paranepionic whorl is older than in Fig. 16, and with a more decided impressed zone and broader transverse diameter approximating to the nephritic shape.

In Fig. 18 the cut has passed beyond the perforation and shows the paranepionic volution above when it first touches the dorsum of the metanepionic or ananepionic substage below. The latter is distorted because the cut goes through the inner or dorsal side of the curve of the metanepionic and ananepionic substages. The oval in the centre is apparently due to a cut through the fundus of the first septum, which must be deeply concave. In Fig. 19 the cut has approached nearer the ventral side of the apical chamber and is apparently wholly within this and shows the increase in depth of the impressed zone as the ananeanic substage begins and also the decidedly nephritic outline which this at once assumes. This also shows that the digonal outline of the volution below the centre belongs to the neanic stage. In Fig. 20 the cut has passed close to the outer side of the ananepionic substage and as in the centre it does not intersect any septum it is probably wholly within the apical chamber. This chamber must be very deep, as it is in Hercoceras and some other forms. The broader shaded outline of the ananepionic substage is the shell which is cut obliquely by the section. The sections of the ananeanic whorl above and the metaneanic below intersect a number of septa and show the passage to the farther side of the umbilical perforation from that with which the series began in Fig. 16.

Temnocheilus.

This genus is very similar in its general aspect to Hercoceras and Anomaloceras, but it has distinct young and this shows that it has been directly evolved from a cyrtoceran form and not from either of these nautilian genera.

The form known as *Gyroceras proximum*, sp. Barrande, Pl. ciii, has the tuberculations on the lateral angles, a trapezoidal whorl, the siphuncle subventran and sutures and impressed zone as in this genus, but until it is better known it is not practicable to decide whether it belongs to this genus or to Hercoceras.

I have also examined another young specimen of a different species of this genus which has a much larger umbilical perforation, but is otherwise quite similar in the characteristics of the nepionic stage. The contact furrow begins in this specimen with a very slight impression late in the neanic stage and the tubercles appear earlier than in *Temnocheilus subtuberculatus.*

TEMNOCHEILUS SUBTUBERCULATUS.

NAUTILUS SUBTUBERCULATUS, Sandb. (*Verst. Nass.*, Pl. xii, Fig. 3). Pl. x, Figs. 27 and 28.

The umbilical perforation is large and open (Fig. 27, Pl. x). The nepionic stage has the first apical chamber very deep. The first suture has the usual ventral saddle and lateral lobes, but on the dorsal side there is a well-defined dorsal saddle. The apical chamber and the inner parts from the second to the fifth are coated with calc spar, while the centre is filled with iron pyrite.

The second suture has a dorsal lobe in place of a saddle and this persists in later stages. In the paranepionic substage a digonal whorl is developed and the lateral saddles appear dividing the lateral lobes from ventral lobes that replace the ventral saddles of the metanepionic substage. Contact takes place in the metaneanic or paraneanic substage after the digonal whorl has been replaced by a trapezoidal outline.

The form of the whorl soon after contact is shown in Fig. 28 and this has the adult outline with the exception that the contact furrow and the tubercles have not yet made their appearance.

This description was taken from a specimen in coll. Museum of Comparative Zoölogy, from the lower Devonian of Wissenbach.

Metacoceras.

This genus, which has been described in my *Genera of Fossil Cephalopods* (p. 268), and subsequently redescribed in "Carboniferous Cephalopods," *Second Annual Report of Texas, 1890,* and *Fourth Annual Report of Texas, 1892,* is of no special value in this connection except as an illustration of a number of genera of the same genetic stock as Temnocheilus, which have more or lesss similar characteristics in the young. They all have large umbilical perforations and a similar history in the development of the impressed zone.

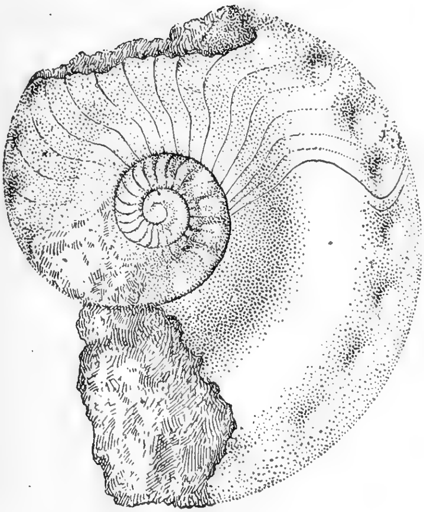

Fig. 16.

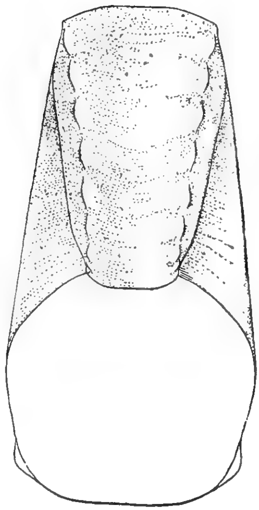

Fig. 17.

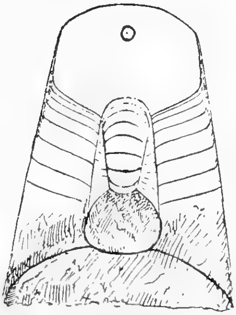

Fig. 18.

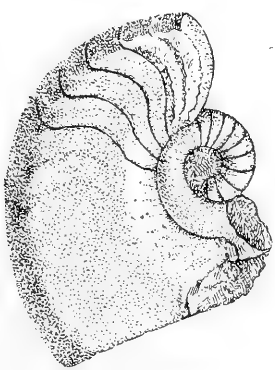

Fig. 19.

Metacoceras cavatiformis.

(*Hyatt.*)

Figs. 16–19 give the adult and general aspect, and Fig. 32, Pl. x, shows the beginning of the contact furrow. This begins only after contact with the apex and in strict correlation with the rounded immature form of the metanepionic and the temnocheilan or tetragonal trapezoidal form assumed by the paranepionic volution. The sutures have ventral and dorsal saddles throughout the metanepionic, but in the paranepionic become straighter on the venter or with a faint lobe, and a similar change takes place in the dorsal sutures. The dorsal lobe is more easily perceptible after contact and becomes deeper with the increase in depth and breadth of the contact furrow and seems to be correlated in development with that modification, although it appears before this furrow is formed.

Tainoceras.

This genus has similar young to those of Metacoceras and probably has a similar history.

Centroceras.

This genus, described in *Genera of Fossil Cephalopods*, possesses a typically quadragonal whorl in the adult stage of the less involute forms, but has a digonal whorl in the nepionic stage, and this becomes similar to that of Temnocheilus, that is trapezoidal in outline and furnished with tubercles in the neanic stage. The contact furrow is faintly marked in some forms like *Centroceras* (*Cyrt.*) *tetragonum*, sp. Vern.,* but it is a mere narrow band on the dorsum.

It is obvious in this genus that the impressed zone exists only in the later stages and after the whorls come into contact. Hall describes a slight impressed zone in *Centroceras* (*Discites*) *ammonis*, sp. Hall† and shows the living chamber complete and nearly one-half of a volution in length.

It is likely that Hall's *Gyroceras Stebos*‡ may prove to belong to genus *Centroceras* (*Gyroceras*) *Ohioense*, sp. Meek,§ is a very large shell of the Corniferous fauna of Ohio which has the form of whorl and single outer row of tubercles of this genus.

* *Trans. Geol. Soc. London*, vi, Pl. xxx.

† *Pal. N. Y.*, v, Suppl., Pt. ii, Pl. cxxv.

‡ *Ibid.*, Pl. cxxvi.

§ *Pal. of Ohio*, i, p. 230, Pl. xxii.

Coelogasteroceras.

This genus was described in my "Carboniferous Cephalopods," second paper, *Fourth Ann. Rep. Geol. Texas.*

Coelogasteroceras canaliculatum of the Carboniferous has an umbilical perforation of considerable size, but the history of the impressed zone is similar to that of Anomaloceras. One section was obtained shown in Fig. 33, Pl. x. This cut across the metanepionic as it was changing in form on its passage into the paranepionic substage and shows the dorsum becoming flattened and an outline transitional to the full nephritic outline of the paranepionic, which is drawn below at a plane which passed through this substage just before the apex was reached. In making this section, the apex was seen and passed through by grinding.

The size and shape of the umbilical perforation in this species does not justify the assumption that the dorsal furrow could have resulted from the abrupt bending of the volution at the gyroceran bend. The curvature of the first whorl is gradual; the expansion of the volution laterally and ventro-dorsally is not remarkable. The diameter of the umbilical perforation was four millimetres in one specimen and in the section figured it was somewhat less at the same points. The increase by growth was also approximately the same in both of these fossils.

Unfortunately the absence of a dorsal furrow on the dorsum of the metanepionic substage was not demonstrable with unquestionable certainty in either of these specimens, but it seemed to be entire and gibbous in both as given in the figure.

The shell is apparently smooth in the nepionic stage, although this may have been in part due to the condition of preservation. It is obvious that there are no lateral furrows or ridges as in Coloceras at any stage. Faint transverse folds were observed in the neanic stage of one specimen, and the abdomen and lateral zones become flattened at the same time. A hollow, central, ventral zone appears in the anephebic substage and persists throughout the ephebic stage.

The sutures are nearly straight in the nepionic, and then acquire a slight ventral lobe in the neanic stage; this deepens in correlation with the ventral hollow zone in the ephebic stage, and the lateral lobes and saddles on the umbilical shoulders also become more marked in this stage.

The siphuncle is propioventran in the paranepionic and very large; in subsequent stages it is somewhat nearer the centre and continues to be large.

Discoceratidæ.

This family includes some genera formerly associated under the Tainoceratidæ and others not heretofore noticed in my classification.

Although it is a provisional and heterogeneous group in some respects, the genera are alike in being more or less heavily ribbed, and in having open apertures so far as known. This association also brings together forms having a tendency to develop into more or less turbinate coils.

The genera are as follows: Peismoceras, Systrophoceras, Trochoceras, Mitroceras, Lower Silurian; Plectoceras and Discoceras, Quebec faunas to Upper Silurian.

Plectoceras.

This genus was described in *Genera of Fossil Cephalopods*, page 268, by the author to include the costated forms similar to Discoceras, but having the siphuncle ventrad of the centre.

The type was *Plectoceras* (*Naut.*) *Jason*, sp. Billings. The mode of coiling may be quite close and regular, with perhaps a slight impressed zone or flattened dorsum, or the coil may be open, and sometimes it is very irregular. In several specimens of *Jason* the first whorls may touch, the ephebic volution may be open and free and yet the extremity of the living chamber again come in contact. The umbilical perforation is large and the impressed zone is absent until the whorls come into contact and it is invariably absent in gerontic whorls.

The species are as follows:

PLECTOCERAS JASON, sp. Billings (*Canadian Nat.*, iv, p. 164).

Type in Museum of Geological Survey at Ottawa. It occurs in the Calciferous of the Mingan Islands and there are similar forms in the same horizon in Newfoundland.

PLECTOCERAS OBSCURUM, n. s.

This species occurs in the Black River fauna in New York and is quite commonly mistaken for the young of *Eurystomites undatus*, but it has an open gyroceran spiral, the siphuncle is nearer the venter and the costæ are more highly developed and more prominent, and have a distinct character from those of that species.

PLECTOCERAS BICKMOREANUS, sp. Whitfield (*Bull. Am. Mus.*, New York).

This species of the Niagara fauna has an open gyroceran whorl, and in the gerontic stage the last whorl is free and in some specimens completely straightened out and lituitean in aspect.

*Peismoceras,** n. g.

Under this name I propose to separate such costated forms as those described by Barrande as Trochoceras, but which differ from true Trochoceras and Discoceras in the development of the form, outline of the apertures, position of the siphuncle and so on.

Peismoceras (*Troch.*) *angulatum*, *optatum*, *placidum*, *disjunctum*, sp. Barrande and others agree in having plain rims to the apertures without deep sinuses, except, of course, the ventral sinus.

The siphuncles are ventrad of the centre, the whorls oval in section, the volutions are barely in contact or open, the apices are very large and the umbilical perforations excessively open and large, and there is no impressed zone at any stage.

Discoceras.

The type of this genus was described and figured by Eichwald under the name of *Clymenia antiquissima*, but was subsequently considered as a distinct genus by Barrande.†

The genus has been subsequently recognized by Schröder and Remelé, but it has by both these authors been used for the smooth forms, having a quadragonal section to the whorl and dorsal siphuncle, as well as for the costated shells.

The neanic stage of all the smooth shells of allied species having the siphuncle dorsal and, therefore, formerly included under the same name, has decided costations with the same aspect and contour as in the adult of *Disc. antiquissimum.* Similar species having costations throughout life cannot be included in the same genus with those that have them only in the neanic and earlier

**Πεῖσμα*, a cable.

†*Syst. Sil. de la Boheme*, ii, p. 177.

stages of growth. The large number and great variety of form of these smooth species, while still maintaining this difference of the later stages of growth, shows that this separation indicates a natural distinction, and I have therefore placed all under the generic name of Schroederoceras, to commemorate that author's distinguished services in this field of inquiry.

DISCOCERAS ANTIQUISSIMUM.

CLYMENIA ANTIQUISSIMA, Eichw. (*Urwelt Russl.*, ii, Pl. iii, Figs. 16, 17).

This is a peculiar species represented in the collection in the Museum of Comparative Zoölogy by a specimen from Porsgrund, in Norway. It is heavily costated, as in the figure given by Eichwald, and these costations are deeply impressed upon the cast throughout the earlier stages and in the ephebic stage. They degenerate only in the gerontic stage.

The abdomen is broader than the dorsum and the sides convex and evenly rounded. The costæ are very prominent and sharply defined, as in the original figure. The sutures, as far as these could be seen, appeared to be similar. The size was also similar and the last whorl in close contact, as in Eichwald's figure of this species.

The specimen described had reached the anagerontic stage, the costæ having disappeared, or, at any rate, ceased to be reflected on the cast near the end of the last whorl, whereas in all previous stages, except probably the earliest nepionic, they are almost equally prominent on both the cast and the shell.

The siphuncle is subdorsan at all the stages observed from what appeared to be the second to the third and fourth whorls. It is quite large, especially on the second whorl.

The neanic whorl is digonal and heavily costated. The ephebic and gerontic whorls are depressed ovals, the abdomens broader than the dorsi. The section of the gerontic volution had ventro-dorsal diameters 25 mm. and transverse 35 mm., without the shell. The whole diameter of this specimen was about 110 mm.

DISCOCERAS GRAFTONENSE.

LITUITES GRAFTONENSIS, M. et W. (*Proc. Acad. Philadelphia*, 1870).

LITUITES GRAFTONENSIS, M. et W. (*Geol. Ill.*, iii, vi).

LITUITES MULTICOSTATUS, Whitfield (*Geol. Wisconsin*, Pl. xx, Fig. 7).
TROCHOLITES MULTICOSTATUS, Whiteaves (*Geol. Canada, Pal. Foss.*, iii, Pt. i, Pl. vi, Fig. 1). Pl. viii, Figs. 21–23.

This interesting species of the Niagara fauna is given here in order to show the young neanic stage which was preserved in relief attached to the centre of a mould of the older whorls, Figs. 22, 23, Pl. viii. The close connection of Discoceras and Trocholites is demonstrated by this drawing. In fact, if separated at this age, the young would have to be placed in that genus. Fig. 21 shows the cast of a perfect mould of another specimen of the same species which has reached the ephebic stage.

Whether this had a dorsal furrow in the umbilical perforation could not be determined. The perforation is certainly very small. Whiteaves' figure shows that the siphuncle is subdorsan in the ephebic stage as it is in the neanic stage described above.

Systrophoceras,* n. g.

This genus includes the remarkable series of costated trochoceran and gyroceran forms described by Barrande in his *Systeme Silurien*, which have the whorls either very slightly in contact, or not touching at any stage, and are devoid of an impressed zone.

Systrophoceras (*Troch.*) *arietinum*, *rapax* and *pingue*, sp. Barrande, have a depressed subtrigonal or subkidney-shaped outline to the whorl with the siphuncle dorsad of the centre, and in many characters are distinct from the others cited below under the name of Peismoceras. These species may have been close-coiled in their younger stages.

Trochoceras.

Barrande described this genus in 1848,† and in the same publication later gave a list of the species ‡ in which the characteristic form, *Trochoceras Davidsoni*, was mentioned first, and this consequently is his type. Hall described the same genus under the same name, but without knowledge of Barrande's work in the Paleontology of New York,§ but his types are both quite distinct, and do not belong to any genus yet described from Bohemia.

* *Σύστροφος*, rolled up.
† *Haidinger's Berichte*, iii, p. 266, 1847.
‡ *Ibid.*, iv, 1848.
§ Vol. ii, 1852, p. 336.

Thus, although both Barrande and Hall have courteously acknowledged each other, and have mutually joined names as authority for this genus calling it Trochoceras, Barrande and Hall, the Trochoceras of the former is not the same as that of the latter, and the name of one or the other or both must be dropped.

I have therefore retained Trochoceras Barrande, and propose for Hall's remarkable forms, *Trochoceras Gebhardi* and *turbinatum*, the new name of Mitroceras* with Mitroceras (*Troch.*) *Gebhardi*, sp. Hall, Pl. lxxvii and lxxvii*a* as the type.

It must not be supposed that all forms of Nautiloids having the turbinate spiral are devoid of impressed zones. There are some species that do have this characteristic, but it is invariably slight, and occupies necessarily a position on the sides rather than on the dorsum of the whorls.

Lituitidæ.

Recent investigations have shown that this group, instead of including about all of the unrolled, shell-covered Cephalopoda of the Paleozoic, must be limited to certain well-defined homogeneous series with peculiar characteristics.

My observations lead me to think that Lituites is a degenerate form of Cyclolituites, a view similar to that of Holm and Schröder, who regard this genus as the radical of the Lituitidæ corresponding to the younger stages of true Lituites.

The genera included in this family form a degenerating series which may have evolved from Cyclolituites, or some form that this most closely represents, becoming specialized by reduction of the spiral and simplification or loss of correlative characters during growth of the whorl, lessening curvature of the annuli and lines of growth and in the outlines of the apertures, until finally, in the extreme forms of Rhynchorthoceras, the whole shell is straight or orthoceran, except during the earliest stage, the nepionic, and in that it is not a perfect coil.

This process takes place through the disappearance in the earlier stages of the progressive characters of Cyclolituites and the gradual replacement of these by characteristics that first appear in the paragerontic stages of such species as *Ang. præcurrens*. That is to say, Rhynchorthoceras has from a comparatively early stage the ven-

* From *Μίτρα*, a girdle, but also used for "turban," in which sense it is here quoted.

tral and dorsal crests and lateral sinuses in its lines of growth that are first observable in the degenerative stages of the ontogeny o allied and more complicated shells (*Ang. præcurrens*), it includes in other words some species at least that are purely phyloparagerontic.

No genus of this family, except Cyclolituites, has an impressed zone, the transverse section being round or more usually a compressed oval ellipse. The most obvious external characteristic, which fails of being distinctive only in some species of Angelinoceras, and in them in the ephebic stage only, is the forward curvature of the lines of growth and costæ on the sides and the prominent paired ventrolateral crests and corresponding lateral sinuses.

The shell varies from that of Cyclolituites with whorls touching until a late ephebic stage, only a part of the living chamber being free, through forms like Lituites with a portion of the camerated whorl and the whole of the living chamber free and straight, to Rhynchorthoceran forms which have uncoiled whorls.

The apertures vary, but possess in Lituites, Ancistroceras and Cyclolituites, prominent ventro-lateral crests and deep ventral sinuses.

The siphuncle is large and subcentral, central or just above the centre and in the young approximates to the dorsum. It is, so far as known, ellipochoanoidal and microchoanitic, *i. e.*, composed of short funnels that are directed towards the apex and having porous walls between the funnels and the next septum.

All of these forms known to me occur in the Orthoceran and Varginatus limestones of Northern Europe and Niagara limestones and Quebec faunas in this country. They seem to be absent from more southern faunas of the same stages.

Foord doubts the appearance of true Lituites in the rocks of Great Britain, and I think he could have positively denied their appearance there since *Lit. ibex.*, sp. Sowerby, certainly has none of the usual characteristics of any of this family.

Trochoceras speciosum, Blake* has most extraordinary costæ turned forwards as in the Lituitidæ, but the siphuncle is ventral and the description is inadequate, and at variance with the figure so that one cannot arrive at any definite conclusion.

* *Brit. Ceph.*, Pl. xiv, Figs. 12–15.

Cyclolituites.

This generic name was given by Remelé, who has done more than any other one author to clear up the relations of the different forms of Lituitidæ. The species mentioned by him was *Cyclolituites applanatus*, and to this Holm added a new form, *Cyclolituites lynceus*. His drawings show that *Lituites Lynnensis*, Kjerulf,* is a species of this genus. The drawing made by Barrande of this last is defective in representing the umbilical perforation as too large. Kjerulf's drawing gives this much smaller. It also gives the lines of growth as bending apically on the first volution and first half of the second volution. They then change to the peculiar forward bend of the Lituidæ, and without doubt the aperture changes at this time also to the outline of the adult, so that this is the anephebic substage. The hyponomic sinus is narrow and deep, and the crests on the abdominal angles, at first blunt in the anephebic stage, become more prominent in the ephebic stage. The sides have lateral sinuses and probably the dorsum is occupied by a crest. Only the last quarter of the outer volution is free. Schröder doubts whether this is a distinct genus, thinking that it may prove to be the young of true Lituites.

CYCLOLITUITES AMERICANUS.

Loc., Gargamelle Cove, Newfoundland.

This species has a quadragonal whorl with somewhat flattened lateral zones. The abdomen is also depressed, but with a slightly gibbous central zone and linear ventral channels on either side, the abdominal angles appearing, in consequence, as lateral ventral ridges. The lines of growth show that the usual hyponomic sinus was present in the aperture, with sharp, narrow crests on the abdominal angles and broad lateral sinuses on the sides. The lines of growth on the venter are crossed by a secondary system due to the impression of the dorsal lines of an outer whorl, which has been broken off in this specimen. These show that the aperture has a prominent median dorsal crest and that the coiling was close, as in other species of this genus.

The sutures seen through the thin shell are nearly straight at first, then in the ephebic stage become flexed with very slight lateral lobes and ventral saddles. There are probably slight flex-

* *Vivies i Christiania*, p. 14, 1865.

ures or lobes to correspond with the ventral channels, but these were very indistinct through the shell.

The siphuncle is of medium size and ventro-centren in the middle of the volution actually seen, and at its termination in what seemed to be the septal floor it was centren.

The original specimen is a nearly completed whorl, 36 or 37 mm. in diameter, and if prolonged and restored to a point opposite the dorsal marks described above it must have been, when complete, about 74 or 75 mm. in diameter.

The dark blue color of the last septum of the fragment described indicated that it might have been the floor of the living chamber, and if so, that living chamber must have been over three-quarters of a volution in length. Every observer, however, knows that this inference is open to great doubt because of the frequent invasion of the matrix into septal chambers through accidental breaks in the shells. Pseudo-septa were observed in this specimen. So far as could be seen the involution simply covered the abdomen, and the contact furrow, although not perceptible on the first part of the whorl described, was evidently present later. This is very interesting, because this furrow is not persistent upon the uncoiled whorls in any species or form of Lituites yet described and seems to have no hold at all upon the organization.

Lituites.

This generic name has been applied to the majority of forms that have the last part of the last whorl or the living chamber free. This general application of the name is so erroneous that it hardly needs discussion. It is, as stated above in this paper, a common tendency of the growth of the whorls in degenerative shells of the Nautiloids throughout the Paleozoic and of the similar forms of Ammonoids during each geologic period, and also a common tendency of the extreme senile or paragerontic substage in the ontogeny of all shells of both orders whenever they attain the extreme limits of their existence. Later authors, especially Remelé, Nötling, Dewitz and Holm, have recognized this fact in some way, either directly or by limiting the generic application of the name Lituites, or by separating the genera Ancistroceras, etc., from Lituites. Remelé was the first to demonstrate the divisibility of the Lituitidæ into different genera, Boll's previous effort in this direction being unsystematic and subsequently repudiated by himself.

Nötling* shows conclusively that there are two groups usually included in Lituites that differ in their lines of growth and apertures, etc. The true Lituites have, according to Nötling, four principal sinuses, deep ventral and dorsal and shallow lateral sinuses. Schröder has criticised this statement, making out five sinuses and five crests in the apertures and lines of growth. Nötling's† statement is substantially the same so far as the larger sinuses and crests are concerned, but Schröder pointed out that the dorsal sinus was subdivided by a central crest into two smaller sinuses. The correct way of describing the sinus of the inner side, judging by the growth and development, is to regard it as the dorsal sinus, and the dividing crest and minor sinuses being developed later as minor or subsidiary dorsal crest and sinuses.

Holm‡ has confirmed this view and, with the fine materials at his command, has figured the dorsal sinus spreading at the base and divided by a slight reëntrant crest, which is also reflected in the lines of growth on that side of the living chamber, while the ventral sinus is deeper and narrower and undivided. These facts increase the differences of the aperture between Lituites and Ancistroceras, and at the same time the slight median crest in the aperture and lines of growth on the dorsum of Lituites makes the affinity with Cycloceras and Ancistroceras clearer than it would otherwise be. The crest and sinuses are also very much more pronounced in Lituites, and the enrolled portion of the whorl is continued longer and is more closely coiled, the whorls being in contact for between three and four volutions. Holm's figures of *Lit. lituus* show that on the early part of the straight whorl the lines of growth are entirely different from the later parts of the same whorl. The outlines have a slight, shallow dorsal sinus, the median dorsal crest not having yet been developed. The same peculiarity is observable in Nötling's figure on a part of the shell preserved and show the lines of growth at about the same stage of growth, and also upon Lossen's figure of the same species. There are also decisive costations on the coiled whorls, which are similar in both of these figures. These in the younger substages are bent apically towards the venter and forwards towards the dorsum, and have not the more complex curves of the older stage.

* "Beitr. z. Kennt. d. Ceph. a. Silurg. d. Prov. Ost-Preussen," *Jahrb. d. k. Preuss. Geol. Landesanst. u. Bergak.*, 1883, p. 126 *et seq.*, and *Zeitsch. Deutsch. Geol. Gesell.*, 1882.

† "Untersuch. u. Sil. Ceph.," *Pal. Abt.*, Dames et Keyser, v, heft iv, p. 44.

‡ *Aftryck. Geol. Fören. Stockholm Förhandl.*, xiii, 1891.

It is plain that the coiled young represents the nepionic and neanic stages and that the aperture must have differed essentially in these stages and perhaps may have been open or else more like that of Cyclolituites.

Nötling also demonstrates in his paper in the *Zeitschrift* that the earlier stages had compressed whorls, the abdomen broader than the dorsum, and also that the siphuncle was nearer the dorsum in the youngest stage observed, and gradually departed from this towards the centre, becoming dorsocentren in the ephebic or outstretched whorl. In old age it again changes its position and tends towards the dorsal side. Nötling has also shown that the siphuncle was ellipochoanoidal, consisting of short funnels and the usual porous sheaths, or that which corresponds to this part in the siphuncles of other forms. The structure of the siphuncle in the younger stages was, however, not described or figured. A list of the species according to Nötling is as follows: *L. lituus*, De Montfort; *L. perfectus*, Wahlenberg; to this Holm added, *L. Tornquisti*, Holm, and gave very instructive figures of the two species already known. *L. discors*, Holm, has a broad dorsal crest in the lines of growth and aperture and is here referred to Ancistroceras, and *L. applanatus* Remelé.

Angelinoceras, n. g.

There are several species usually referred to Lituites which can neither be included in this genus nor in Ancistroceras or Holmiceras. These have open coils in the young, and the usual lituitean outstretched free whorl in the ephebic and gerontic stages. The only species known to me are those described by Angelin and Lindstrom in their *Fragmenta Silurica*. The lines of growth, and the annuli, during the neanic stage, have curves similar to those of Cyclolituites in *A. latus*, viz., with deep ventral sinuses, crests at the abdominal angles, deep lateral sinuses near the dorsum and dorsal crests. These curves change in the ephebic whorl, becoming less sinuous, but, beyond the fact that they differ very much from those of Ancistroceras or Lituites, they cannot be defined with accuracy from the figures given.

The increase by growth is more rapid than in Lituites and less rapid than in Ancistroceras, in *A. latus* and in *A. anguinus* it is very slow throughout life. The ephebic whorl is extended with the usual lituitean curve and closely resembles in aspect, but not in the lines of growth, *Holmiceras præcurrens*, sp. Holm. In *A. anguinum*, however, it remains attenuated. The coiled portion of the shell has about three whorls coiled, and their attenuated proportions and compressed form approximates more closely to those of Lituites than to those of Ancistroceras. The close coiling in Ang. sp. *indet.* (as figured by Angelin) of the nepionic stage shows also more affinity for Lituites than for Ancistroceras. The figures of *Lit. lituus* given by the same authors show also essential differences from those of the true *Lit. lituus*, as figured by Lossen and Nötling. The coiled whorls are not in contact, not so compressed, free from the large fold-like costations of that species and have the characteristic lines of growth bending forward and with prominent ventrolateral crests near the apex of the whorl if correctly figured. Taken altogether, the characteristics of the species of this genus show a series of forms standing apparently between Lituites and Ancistroceras.

Ancistroceras.

The name of Strombolituites was substituted by Remelé.* Boll had originally used the name Ancistroceras in connection with *A. undulatum*, the species which must be considered the type of the genus, but had subsequently abondoned its use,† and this and his insufficient diagnosis was supposed by Remelé to justify the suppression of his name. Boll's type, however, being a good species and a distinct genus, his name must stand in spite of his own desire to suppress it and his defective description. Nötling has also demonstrated that *undulatum* has a closed spiral for one and one-half whorls (said by him to be about two whorls). This is compressed elliptical in the nepionic, and becomes more or less quadragonal near the end of the spiral, assuming very quickly the circular form after this.

Remelé's paper deals also with Lituites and he really divides the group of Lituitidæ into three genera, since he endeavors to limit the name of Ancistroceras to the forms which he subsequently described as Rhynchorthoceras.

The genus Ancistroceras differs from Lituites, according to Nötling, in having only three sinuses, a ventral and two lateral sinuses in the lines of growth and aperture, the dorsum being occupied by a broad low crest. Schröder, in the paper quoted above,

* *Zeitsch. geol. Gesells.*, 1881, Pl. clxxxvii, "Strombolituites," etc.

† *Arch. d. Verds. Freunde d. Naturg. Mecklenburg*, xi.

asserts that lines of growth in Lituites and Ancistroceras are similar and certainly this appears to be in part true. There are distinct inflections indicating the probable presence of five crests and five sinuses as this author states. These are perfectly well shown in *Anc. Torelli*, as figured by Remelé, and in his *Anc.* (*Stromb.*) *Bolli*. But in all of these there are other characters not found in Lituites or in other genera of this family which separate these fossils as a distinct group in my opinion of generic value.

While the lines of growth are similar, they show that differences must have existed in the form of the crests and sinuses on the dorsal side of the aperture corresponding to the slight development of the median minor crest and paired minor sinuses on the dorsal side. In fact when one describes the curves of the dorsal lines of growth as indicating a dorsal crest in place of a lobe, he is coming nearer to the actual aspect than when he correctly classifies the outlines as a broad sinus subdivided by a minor crest and secondary sinuses. In other words, the great dorsal sinus of Lituites has reached the disappearance point in this genus during the ephebic stage but has not entirely vanished except perhaps in some species. It, also, as is well known, is a much larger, broader form, spreading out rapidly in the outstretched or free part of the whorl. It is also plain that the enrolled part or young shell of Ancistroceras has fewer and less closely coiled whorls than in Lituites. Thus *A. Torelli*, as figured by Remelé, has only one to one-half volutions enrolled and these do not touch although closely approximate. In fact the young of Ancistroceras are only coiled during the nepionic stage, and perhaps ananeanic substage, and the figures show much larger, stouter whorls even at the apex than in Lituites. The figures of Remelé of *A. Torelli* and of Nötling of *A. undulatum* are very careful studies, and exhibit the changes in development of the lines and annuli. These have in the neanic stage subacute, narrow crests, lateral sinuses rising to prominent ventro-lateral crests and between these on the venter is a deep, broad median sinus, thus resembling those of Cyclolituites. The paraneanic substage is present on the early part of the outstretched whorl in *Torelli* and *undulatum*.

The siphuncle is also much larger in this genus than in Lituites. The study of the pseudo-septa by Holm led him to observe the siphuncle in *A. undulatum* and *Torelli* and his description is as follows:* "Der siphonen scheint mir wenigstens auf der einen oder

* *Paleontol. Abh.*, Dames u. Kayser, iii, hft. i, "Organiz. Silur. Ceph.," 1885, Pl. xxi.

der anderen Seite, keine eigene, festere, verkalkte Hulle gehabt zu haben.'' If the siphuncle were holochoanoidal, it would have as thick and might have thicker walls than the septa themselves.

A list of the species is as follows, as given by Nötling: *A. undulatum*, Boll.; *Torelli*, Rem.; *Barrandei*, DeWitz.; *Bolli*, Rem. To these Nötling has also added *Cryt. Odini*, Eichwald (*Lethea Rossica*, Pl. xxvi, Fig. 14*a–b*), and he thinks this may be identical with *undulatum*.

Ancistroceras (?) *Dyeri*, n. s., is a large fragment quite different from any European species, having the sutures with slight broad ventral lobes, slight saddles at the abdominal angles, lateral lobes, saddles at the umbilical shoulders, and apparently narrow dorsal lobes.

The fragment is that of a rapidly enlarging arcuate whorl, subquadragonal in section, the lateral zones slightly convergent outwards, the dorsum broader than the venter.

The siphuncle is ventrocentren.

The lines of growth seen on the living chamber had the characteristic ventral sinus, slight crests on the abdominal angles, slight lateral sinuses, broad low crests on the umbilical shoulders and internally faint minor dorsal sinuses apparently rising to an equally faint median dorsal saddle.

It has characteristics which appear to be intermediate between Ancistroceras and Rhyncorthoceras. This fossil is from the Niagara Group near Chicago, Ill., Dyer collection, Mus. of Comp. Zoölogy, and is worth describing in this connection, although until it can be studied in the young and figured it is hardly safe to refer it to this genus. It has been named *Cyrtoceras amplicorne*, Hall, and closely resembles that species, but the section is more decidedly quadragonal, the sides and venter flatter and the transverse diameter broader.

Rhyncorthoceras.

The designation Rhyncoceras has also been used by Remelé and others, but Rhyncorthoceras was used first, and should be exclusively employed. Rhyncoceras is not an equivalent, and there cannot be two names for one genus.

Remelé's description of this genus is perfectly clear and satisfactory. It is in my opinion another grade in morphic degeneration of the Lituitidæ, and is directly in line with and supplementary to the modifications of Lituites and Ancistroceras. It is completely uncoiled in the young, and the tip or apex has not even the open coiling of Ancistroceras, but is really an open or cyrtoceran curve.

The annuli of the shell are also simpler in curvature and according to Remelé they have low broad dorsal and ventral crests and corresponding low broad lateral lobes. These phylogerontic curves appear to be acquired in the early ephebic stages, and therefore appear earlier in the ontogeny than in Ancistroceras.

The siphuncle is large and may be either dorso-centren, or about centren, and in *R. Beyrichea* is said by Remelé to be nearer to the venter than to the dorsum or ventrocentren.

The list of species given by Remelé* is as follows: *R. Beyrichia, Zaddachi, Oelandicum, damesi, tenuistriatum.*

Rhynchorthoceras (*?*) *dubium*. In the Dyer collection, Museum Comparative Zoölogy, there is a fragment that shows this genus probably occurs in the Niagara group of Indiana, but the younger stages are wanting and it cannot be surely placed here until these are known. The first part of the free volution has the usual bands of growth with hyponomic sinus, these lines inclining orad and without inflections or with hardly perceptible lateral sinuses to the dorsum where they unite in low, broad saddles.

There are also three inconspicuous low, broad costæ on this part of the shell. The form is a slightly compressed ellipse, the siphuncle large, ventrocentren, the sutures have ventral and dorsal saddles and lateral lobes. The growth bands lose their inclination in the older part of this volution, becoming straighter on the sides and the hypomic sinus almost disappears. This last characteristic seems to place these fossils in this genus.

Holmiceras, n. g.

Lituites præcurrens sp., Holm, has open, discoidal whorls, like those of *Angelinoceras latum*, and closely resembles this species in form and proportions, both of the enrolled and outstretched whorls, but the lines of growth and annulations are very distinct. It has the four major sinuses in the lines of growth, as in Lituites, but the median dorsal crest is absent. The aspect shows the presence of another genus in this family and the sutures are also different from those of Lituites, having distinct ventral and dorsal lobes in the ephebic stage, with low, broad, almost straight, lateral saddles.

* *Zeitsch. Deutsch. Geol. Gesell.*, xxxiv, 1882.

The figure by Holm, p. 763, shows conclusively that the sutures in the nepionic stage are straight, Trocholites like, and quite distinct from those of the later stages. The narrow annuli cross the whorl during the ephebic stage or first part of the free whorl, with the true Ancistroceran curves, namely, with shallow ventral sinus between two low, narrow ventro-lateral crests, broad, shallow lateral sinuses and a very slight but perceptible dorsal sinus not divided by a crest, as in Lituites.

These change in the gerontic stage, the ventral and dorsal sinuses being replaced by low, broad crests, the lateral sinuses alone remaining. This stage repeats exactly the degenerate characters of the curves in the lines of growth of the ephebic stage of Rhyncorthoceras and show, together with other facts, that we are dealing with a degenerating series. The siphuncle is dorsad of the centre in the ephebic stage, but it is nearer the centre than in Lituites.

This genus does not seem to stand in the line of modifications leading from Lituites to Ancistroceras, nor in that leading from Lituites to Rhyncorthoceras.

Ophidioceratidæ.

The apertures and costated whorls of Ophidioceras have been supposed by several authors to show that it belonged in the family of the Lituitidæ. The apertures are, however, distinct, having only three large sinuses and a corresponding number of crests and the costations and lines of growth have not the peculiar forward bending lateral curves of the Lituitidæ. The ornamentation of the younger stages and the form of the nepionic stage is so widely different that no close comparisons can be made with the young of Cyclolituites, the closest coiled form of the Lituitidæ.

This genus was formerly supposed by the author to belong in the same group with Ascoceras and Glossoceras, which had similar apertures, but recent investigations have shown that these genera are widely separated in structure.

Ophidioceras.

This genus, fully described by Barrande, becomes very interesting in the history of the impressed zone on account of its highly ornamented and costated whorls and the peculiar, excentric character of the free whorl and the aperture with deep, narrow hyponomic sinus, lateral crests and dorsal crests bending inwards and contracting the opening. It is also of interest in this connection as showing how narrow and comma-shaped the umbilical perforation may be without affecting the form of the dorsum, and especially with regard to the history of the degeneration of the impressed zone on the dorsum of the free whorl and living chamber.

Ophidioceras.

OPHIDIOCERAS RUDENS.

OPHIDIOCERAS BARRANDE (*Syst. Sil.*, Pl. xlv); Pl. viii, Figs. 29–35.
Loc. Bohemia.

This species has a flattened comma-shaped umbilical perforation and, although the increase in size is rapid, it is not excessive in the lateral diameters as compared with the ventro-dorsal from the ananepionic substage to the paranepionic. The result is a volution which curves evenly about the core of the perforation and preserves the rounded dorsum and the general aspect of the section without great modification throughout the nepionic stage. The cicatrix is well-marked, as shown in Fig. 30, and the ananepionic substage has an elongated ventro-dorsal and short transverse diameter.

In the metanepionic substage the whorl becomes broader on the venter than on the dorsum, and in the paranepionic the dorsum spreads, becoming broader, but does not quite equal the venter in breadth. In the ananeanic substage the longitudinal ridges become more prominent and more easily observable and the costations also appear.

The contact furrow begins as soon as contact is complete and is at once deep and definitely defined, as a hollow fitting over the ananepionic tip, and it completely covers in this substage. The contact takes place on the dorsal side of the ananepionic substage and the furrow is deeper at this point in proportion to the whorls than it is at any subsequent age.

There were two specimens showing the nepionic stages of this species under observation, the one drawn and this one. Both exhibit the peculiar globular form of the apex, and the well-defined ana- and metanepionic substages, which can be quite closely compared with those of *Nautilus pompilius*, and they have similar constrictions to the first two constrictions depicted in Henry Brook's drawings on Pl. i of this paper.

The dorsum of the whorl becomes at the same time broader and the whorl alters in shape to an approximately kidney-shaped outline with the ventro-dorsal, shorter than the transverse diameter. After this age the increase of growth proceeds more slowly. In the meta-neanic substage, the costæ and longitudinal ridges become well developed, but the venter remains rounded and the lines of growth show a deep, broad hyponomic sinus and lateral crests, and the aperture at this stage must have been very distinct from that of the next substage.

In the paraneanic substage the central ventral zone appears at first as a broad band, in low relief, arising obviously from the elevated edges of the narrow hyponomic sinus, which begins to appear at this age. In the anephebic stage, at the beginning of the third volution, this acquires its specific prominence and characters. The metephebic stage is introduced by the subsequent moulding of the dorsum over this broad carination which modifies the outline of the contact furrow in section, and gives it the peculiar central dorsal face and narrow lateral dorsal faces as peculiar to this genus as are the ventral modifications which give rise to them.*

The sutures do not seem to be much modified after the nepionic stage is passed by. The cæcum, if a spot observed on the broken apex of one specimen is correctly translated, is subventran or nearly so in the first or metanepionic septum and the siphuncle is about the same position relatively or propioventran in the paranepionic substage as observed in two specimens and given in one of these, Fig. 30, Pl. viii, and then changes slowly to centroventran in the anephebic substage. The living chamber is very long, being, if the excentric free part were applied to the coil, almost one volution in length. It is, as has been described by Barrande, present in small (young?) shells, but I doubt its existence, as well as that of the peculiar ophidioceran aperture, before the substage in which the ventral zone appears.

The free whorl in this genus is specially interesting, because even in large shells the impressed zone is preserved on the dorsum in a very significant way. It is well known that most of the shells, if not all of this genus, have the lituitean bend, that is to say, the free living chamber, after it becomes free and excentric, bends suddenly ventrally, as in Fig. 27, Pl. viii, making the last part of the living

* This is usually called a keel or carina, but it is a modification of a different kind and sometimes has keels upon its borders.

chamber straight on the dorsum and producing a slight curvature in reverse of the spiral on the venter. In Ophidioceras this is accompanied by the outgrowth of a transverse dorsal spur which divides this region into two distinct parts, as shown in the same figure. The inner part of the living chamber, Figs. 32, 35, has the central dorsal face and lateral dorsal faces derived from the closely coiled whorls. These parts and the whole zone disappear as they approach the dorsal spur, Figs. 32, 34. On the outer side of this spur the impressed zone reappears, but it is the primitive form of this which reappears and is perpetuated, the dorsal faces of the ephebic impressed zone are not reconstructed, Figs. 32, 33. The spur is not a prolonged costation; it occurs indifferently between two costations or as the continuation of a costation, and is obviously independent in its origin and construction.

These facts show that there is some constantly recurring peculiarity in the growth of these shells which causes the outgrowth of the dorsal spur, and this outgrowth temporarily interrupts the construction of the impressed zone. Notwithstanding this interruption, the latter has even in the largest shells made such an impression on the organism or become so fixed in the organization that, as soon as the outgrowth stops, the impressed zone reappears. The spur either directly obliterates the ephebic characters of this zone, the dorsal faces, or else fills the space which transitional characters would have occupied, so that when the zone comes in beyond the spur it is evenly rounded as in the neanic stage. It is, however, shallower and nearer the aperture it, in part or almost entirely, disappears. The spur always occurs as a divide between the excentric spiral and the reversed curve which begins beyond it, and has some obvious connection with this change in the mode of building the shell, as is shown in Fig. 29, Pl. viii.

The sutures occupying the nepionic whorl are six in number and very wide apart from the first to the fourth.* The fifth and sixth show approximation and the seventh is about the normal distance. The growth of the shell in the nepionic substages and in the ananeanic substage, to which the fourth, fifth and sixth sutures belong, must have been very much more rapid than subsequently. They

*The great size and depth of the apical air chamber is very remarkable. It is not satisfactorily settled in my mind that there is not at least one septum nearer the apex than that which is here counted as the first, but even in well-preserved specimens this has not been observed.

have ventral and dorsal saddles until the contact furrow is formed, and then probably a ventral lobe is always generated.

Barrande's figure of this species, Pl. xlv, Fig. 21, gives similar observations upon a different specimen. When the median ventral zone appears, the broad ventral saddle becomes narrowed to the width of this zone and the lateral lobes are proportionately broadened out.

Ophidioceras tener.

Ophidioceras tener, Barrande (*Syst. Sil.*, Pl. xlv); Pl. viii, Figs. 24 and 25.

Loc., Bohemia.

The specimen of this species, Figs. 24 and 25, gives the peculiar and very large ananepionic substage of this species, and in the side view the two marked constrictions indicating the same changes of form as are described in *Ophidioceras rudens*, but subsequently there is a marked bulging of the sides, in what has been termed in other forms the metanepionic substage, beyond the second constriction. If the first septum occurs where it is figured, the metanepionic substage must be placed in the Ophidioceran forms later than in other forms like *Nautilus pompilius*, which have the first septum nearer to the apex, and the ananepionic substage must be considered as greatly prolonged. Although the specimen had a perfect surface on the side depicted of the nepionic stage, it is possible that there may have been other septa* between this and the apex, but of so fragile a nature that they were not preserved. The surface of this cast is iron pyrite. There are also six septa occupying the nepionic stage of this specimen.

There was a minute circular mark on the apex, indicating the position of the cæcum to be propioventran, but this was not absolutely certain. In the second septum the siphuncle was extracentroventran and in the neanic stage it attained a centroventran position. The subsequent stages observed were similar to those of *Ophidioceras rudens* except that the peculiar flattened ventral zone of this species was introduced later than in that species, as described and figured by Barrande.

The primitive rounded outline of the impressed zone was maintained longer in this species than in *Ophidioceras rudens*.

* See *Ophid. tessellatum.*

Ophidioceras tessallatum.

Ophidioceras tessallatum, Barrande (*Syst. Sil.*, Pl. xlv); Pl. viii, Figs. 26–28.

Loc., Bohemia.

The specimen, Fig. 28, Pl. viii, showed the metanepionic substage with the usual two septa and long apical chamber, but internal to the first septum there was on the venter internal dark lines, indicating a subventran siphuncle. This was cut off by another dark line which may possibly have been the fragmentary remains of a septum. Nevertheless there was no positive proof of this and the question must still be left open. The usual circular mark occurs, indicating the cœcal termination on the worn apex in a subventran position. In the second septum the siphuncle is extracentroventran.

The formation of the ventral zone began earlier in this species than in *Ophidioceras rudens*. The flattening of the abdomen began even in the paranepionic substage and in the ananeanic substage the formation of the zone was well advanced. The development of the costæ seemed also to be accelerated in some specimens.

Fig. 27, Pl. viii, shows the contact furrow as it first appears when crossing the apex. Fig. 27 shows that the umbilical perforation is larger in this species than the others described here, since the first whorl does not meet the ananepionic substage on the dorsal side but strikes it on the surface of the apex, ventrad of the centre. The contact furrow is consequently not at first so deep as in other species, unless this characteristic is variable.

Rutoceratidæ.

This family consists of a number of genera which are interesting in connection with the history of the impressed zone only in so far as they show that this peculiarity is correlated with close coiling, or, in other words, is due to contact.

Thus, Zitteloceras, Halloceras, Rutoceras, Kophinoceras and Strophiceras as a rule do not have the whorls in contact and do not have an impressed zone. The shell in most of these is a rough imbricated structure with ridges or nodes arising from the greater or less permanency of the frilled projections of the apertures. These genera, found in the Silurian and Devonian, were described in my *Genera of Fossil Cephalopods*, p. 284, and associated with others of the Silurian Adelphoceras and Triplooceras, which also had rows of large nodes but were true nautilian shells and had contact furrows.

The genus, Coelogasteroceras (Solenoceras), described in my "Carboniferous Cephalopods," second paper, p. 447, was there removed from the Rutoceratidæ and placed with Coloceras under the name of Coloceratidæ, an error corrected in this paper.

I also included in this family the Triassic genus Phloioceras, having nautilian shells and a deep impressed zone, with *Phloioceras (Naut.) gemmatum*, sp. Mojsisovics, as the type and also with Pleuronautilus, of Mojsisovics.

I am strongly inclined to the opinion that the resemblances of these Triassic shells to Rutoceras are superficial, but having no specimens at my command I cannot make comparisons.

Adelphoceras.

This genus was described by Barrande in his *Systéme Silurien*, and *Adelphoceras Bohemicum* the type, is a large shell with a highly contracted dumbbell-shaped aperture set in the dorso-ventral diameter or vertically. The outline in section is depressed kidney shaped, with a shallow impressed zone, which is probably not present before the whorls come in contact, or at any rate is very slight at a late stage of growth, according to Barrande's figures.

This species has a large subventran siphuncle and there are three rows of tubercles on either side, and it is obviously closely related to Triplooceras, but is remote from Hercoceras, as is demonstrated by the aperture form ornaments and lines of growth.*

Triplooceras.

This genus, described in *Genera of Fossil Cephalopods*, is obviously closely related to Adelphoceras, having three rows of tubercles on either side, but the form is more highly developed, being a depressed oval and the coiling closer with a deeper contact zone and the ornaments disappear much earlier on the shell. It is obviously a grade more progressive than Adelphoceras, but in the same genetic group.

Besides *Triplooceras (Naut.) inspiratum*, sp. Barrande, Pl. "461," there is *Triplooceras (Troch.) reliquum*, sp. Barrande, Pl.

* Barrande's *Adelphoceras secundum* is here referred to Hercoceras.

"493," which has also the characteristic form and markings of this genus. This last has no contact furrow, according to Barrande's Fig. 7, even in a late neanic substage, although there is a distinct contact furrow in the ephebic stage according to his figure of the full-grown shell.

Melonoceratidæ.

Under this title, in *Genera of Fossil Cephalopods*, I included a number of genera having special interest in this connection. The impressed zone is not present in Melonoceras, which is an arcuate form, and in most species of Oonoceras.

Cranoceras, containing the only apparently arcuate form possessing a dorsal furrow, belongs to this family and appears to be allied to the more closely coiled nautilian forms Nedyceras. All of these forms have subtrigonal whorls, with siphuncle ventrad of the centre. The resemblance of Estonioceras and Remeléceras have led me to place them also under the same family name.

Estonioceras.

This genus was described by Nötling,* and separated from Lituites, which it only remotely resembles in having some of the volutions free.

Schröder has more fully described the genus† than any other author, and given all the European species with great care, but has, in my opinion, included in it some forms with quadragonal whorls and siphuncles in different positions which should be separated as Remelé has done under the name of Facilituites.

Estonioceras has a nepionic stage with a large umbilical perforation like that of other species of the same phylum. The apex itself, the ananepionic substage, is remarkably large and grows with extreme rapidity in its transverse diameters, showing the tendency to form a broad, digonal whorl, and is cap-shaped when seen from the side as in Trocholites and Ophidioceras and very large in all its diameters. The sutures of the meta- and paranepionic substages throughout the greater part of the first whorl, as seen in the specimen Fig. 13, Pl. vii, and in Schröder's figure of apex of *Estonioceras imperfectum*, Pl. iv, Fig. 5, a–b, reproduced here on Pl. vii, Figs. 20

* *Op. cit., Jahrb. d. könig.-preus. geol. Landesan. u. Bergak.*, 1882.

† "Ueber Sil. Ceph.," *Pal. Abh.*, Dames et Kayser, v, hft. 4.

and 21, have saddles on the venter with perhaps very slight ventral lobes on either side of this, saddles at the lateral angles and faint dorsal saddles. Schröder also describes the same substages in *Estonioceras perforatum* and the sutures of the first whorl, but his descriptive nomenclature is not clear and the text is consequently not perfectly intelligible. Apparently the first whorl has broad ventral saddles and nearly straight dorsal sutures with sometimes very slight dorsal saddles. He states very distinctly, however, when the whorls touch, at or near the end of the first whorl, that a decided change takes place, the dorsal sutures acquiring well-marked dorsal lobes. He also clearly states that in the uncoiled volutions this dorsal lobe, although it persists, loses in height and breadth.

In his descriptions of *Lituites Muellaurëi*, of Dewitz, he makes these statements clearer by saying that the dorsal and ventral saddles possessed by the adult of this species are similar to the sutures of the young species of *Estoniceras perforatum* and *imperfectum*, which have sutures with ventral and dorsal saddles as figured by him only on the venter of *Estoniceras imperfectum*. There is also a shallow lobe developed in the middle of the dorsal saddle in *Estoniceras perforatum*, which persists even in the gerontic stage. After the lateral angles disappear in the ephebic stage, the saddles and lobes are less prominent and become almost straight in the more rounded volutions of the gerontic stage, but the approximate return of the same outlines as are found in the paranepionic substage is plainly visible, Figs. 17 and 18, Pl. vii.

The lines of growth show a broad hyponomic sinus and lateral crests which increase in prominence towards the dorsum, but directly in the centre of that side there is a crest and on either side of this shallow dorsal sinuses. There is, however, a dorsal sinus which persists in the gerontic stage in the lines of growth of a specimen figured by Schröder of *Estonioceras heros*.*

The aperture is wide in the ephebic stage, but evidently contracts with the whorl in extreme age, as shown in Schröder's figure of *Estonioceras imperfectum*, Pl. iii, Fig. 2, b, and in the figures of *Estonioceras biangulatum* in this paper, Pl. vii, and sometimes the ventro-dorsal diameter may become longer than the transverse in the paragerontic substage. This is, in part, a return to the early proportions, since Schröder describes the apex of his *Estonioceras*

* *Op. cit.* Pl. v.

perforatum as having an apical chamber in which the breadth but little exceeds the ventro-dorsal diameter and doubtless at the apex itself in the ananepionic substage, as in most Nautiloids, the ventro-dorsal diameter exceeds the transverse.

The coiling is so loose that the umbilical perforation is of very large diameter, and the impressed zone, generated only after contact, is very slight even on the second whorl and does not persist after the whorls separate. The dorsum is, however, affected to a limited extent on the free whorl in some species as shown in Schröder's admirable figures. These figures give one great satisfaction, their accuracy, size and detail being full of information.

The whorls touch during the neanic stage only in some species, *Estonioceras ariense,* but in others they may continue in contact probably throughout the ephebic or a large part of that stage, *Eston. perforatum* and *imperfectum.*

The lateral angles become rounded in the ephebic stage, but there is no tendency to form lateral zones or to flatten the abdomen as in Falcilituites. The whorls simply become rounded, depressed ovals and in the paragerontic stage the length of the transverse diameters decrease.

The siphuncle is fully described by Schröder in *Estonioceras imperfectum,* and it is plainly ellipochoanoidal in the ephebic stage. What it may be in the young has not been determined. The funnels are very short and the connecting walls thin and long. The position is subventran in the young, tending more towards the centre and becoming extracentroventran in some species with the advance of age. In the paranepionic substage it may again return to a position nearer the venter.

The species described by Schröder are as follows:

Estonioceras perforatum, Schröder; *Estonioceras* (*Lit.*) *lamellosum,* sp. His. *Discoceras lamellosum* as figured by Angelin et Lindstrom seems quite distinct with closer coiled whorls and deeper impressed zone, too deep in fact for a species of this genus, whereas Hisinger's figure in the *Lethea suecica* is a true Estonioceras. Nevertheless Schröder asserts that both figures were made from the same "individual." *Estonioceras* (*Lit.*) *heros,* sp. Remelé; *ariense,* sp. Schmidt; (*Lit.*) *imperfectum,* sp. Quenstedt.

Estonioceras muellaueri and Schröder's *Estonioceras decheni* have been referred to the genus Falcilituites of Remelé in this paper.

Estonioceras perforatum, Schröder (*op. cit.*, Pl. xxvi); Pl. vii, Figs. 9–12.

Loc., Reval.

The specimen, Fig. 10, Pl. vii, shows the dorsum of the paranepionic volution with the shell of the dorsum preserved. The dorsal crest and dorsal sinuses of the lines of growth and in part the sutures are visible. After this was drawn a part of the shell was removed, exposing the dorsal sutures which are given in Fig. 12, Pl. vii. These show the presence of a dorsal lobe as described above with faint saddles, the remains of the younger dorsal saddle, on either side of this. The ventral sutures have saddles at this stage as may be seen by the outline of the whorl, but these were not seen, although the ventral lobes on either side are plainly visible in the side view of the paranepionic volution in Fig. 11. In the metaneanic substage the dorsal lobe broadens and deepens in correlation with the widening and deepening of the contact furrow, and the lateral lobes appear then almost like saddles on the sides as in Fig. 11 above in the outline of the only septum visible at this age in this specimen. They are, however, still really slight aborad inflections or lobes. There is no true annular lobe at any stage.

Fig. 9, Pl. vii, reproduced from Schröder's figures of *Estonioceras perforatum*, shows that in this species in at least some varieties the neanic stage probably does not acquire a contact furrow until it strikes the metanepionic substage.

The specimen figured is in collection of Mus. Comp. Zoölogy.

Estonioceras biangulatum, n. sp. Pl. vii, Figs. 13–19.

Loc., Breslau.

The figures of this species show the large umbilical perforation and digonal whorl of the paranepionic substage and neanic stages seen from the side in the centre of Fig. 13, Pl. vii, and then from the front with part of the outer whorl between the broken lines and also the terminal part of the free whorl removed in Fig. 15. The portion removed belongs to the ephebic stage, which in this species has a digonal section. The lateral angles do not show rounding and the lateral diameters continue to increase steadily and rapidly until the anagerontic substage begins as the whorl becomes free. Then a decisive decrease is noticeable in both of these characteristics. In this specimen the transverse diameter through the middle of the free volution without the shell, Fig. 17 and 18, was 42 mm., the ventro-dorsal .30 mm. at the termination of the same, the fragment of the living chamber also devoid of shell was transversely about 40 mm., while the dorso-ventral had increased to 32 mm. This and the point of view of Fig. 18 gives the aspect of a more considerable diminution in the lateral diameters than actually took place. The sectional view of this end shows true proportions in Fig. 19, Pl. vii.

The section, Fig. 15, gives the neanic whorl at the inner break in the side view, Fig. 13, and this shows how very small and slight the zone of involution is in this species. It broadens slightly with age, but immediately disappears in the free part of the whorl, as it does also in most species of this genus.

The lines of growth are given on the dorsum of the metagerontic substage in Fig. 17, and these do not differ materially from those of the nepionic stage in *Estonioceras perforatum*. The lines of growth could not be observed on the dorsum of the earlier stages of growth, but it is probable that in the stages in which the whorls are in contact that the dorsal crest is narrow and occupies the area of the impressed zone.

The sutures in the paranepionic substage have ventral saddles with very slight ventral lobes on either side, saddles at the lateral angles and apparently lateral lobes. Three sutures of this substage were followed on the dorsum to the centre and no central inflections could be seen. This was somewhere about the sixth or eighth septum, as nearly as could be ascertained, and the suture formed a very shallow lobe across the dorsum, but this would ordinarily be described as straight. These, in other words, are closely similar and of about the same age as the complete dorsal sutures of *Estonioceras imperfectum* given in Fig. 21, Pl. vii, and probably about the same age as the dorsal sutures of *Estonioceras perforatum* given in Fig. 12, Pl. vii. In the ephebic stage broad lobes appear on the venter, reaching to the saddles at the lateral angles. The septum, Fig. 15*a*, Pl. vii, given to show the contact furrow, also shows that a faint narrow dorsal lobe coextensive with this furrow is produced by contact. In the paragerontic substage, as shown on the last three sutures of Fig. 18, the broad ventral lobe is replaced by faint saddles with very faintly marked lobes on either side and the saddles of the lateral angles in consequence of the rounding of these angles have become lateral saddles. The lateral lobes appear only very faintly or are absent on the under side or dorsum. The dorsal lobe is not, however, affected to the same extent by senile degeneration, and persists, although narrower in proportion in the centre of the suture, as may be seen in Fig. 17, Pl. vii.

The siphuncle is propioventran in all the stages observed from the ephebic to the anagerontic.

Remeléceras,* n. g.

This genus, known at present only by one species, is closely allied as regards aspect and the late appearance of a contact furrow to Estonioceras. It differs in having a much deeper furrow, a nephritic instead of a digonal or depressed elliptical form of whorl and in the dorsal sutures and apparently also in the extraordinary form of annular muscle.

REMELÉCERAS IMPRESSUM. Pl. viii, Figs. 1–8.

Loc. (?)

This extraordinary form is described and figured in this memoir on account of its interesting connection with the history of the impressed zone, notwithstanding the absence of any information with regard to the locality. The side view, Fig. 1, Pl. viii, shows the sutures, which are similar to those of Estonioceras, and the impression of what appears to be the annular muscle at the base of the living chamber is very distinct. This may be seen on the dorsal side, Fig. 3, where the lower line has a deeper and broader depression in the cast reaching across the contact furrow. These two lines of depression depart from each other widely on the ventral side, Fig. 2, the outer one forming a broad saddle. They of course correspond to raised ridges on the inner surface of the shell of the living chamber and may have been due to abnormal action in the secretions along the upper and lower borders of the annular muscle.

The depth of the contact furrow in the full-grown shell near the end of the incomplete living chamber was somewhat greater than is given in Fig. 4, but only a shade deeper, and is also slightly deeper than this beyond the base of this living chamber on the septate part of the volution. In younger stages, shown successively in Figs. 5–7, with their accompanying sections, Figs. 6–8, this furrow diminishes in depth and breadth and almost disappears

*Dedicated to Remelé, well known for his original observations on fossil Cephalopods.

on the third fragment. This shows that it did not begin to exist in this shell until late in the neanic stage and the younger nepionic stage must have been similar to that of Estonioceras.

It is also interesting and suggestive to note that the depth and development of the dorsal lobe correlates exactly with the depth and breadth of the contact furrow. The lateral asymmetry in the dorsal lobes of the sutures is another fact to be noted in this specimen.

The central whorls existed in this specimen, but were completely concealed by the matrix. A section was made of these, but they exhibited no structures.

The siphuncle was not visible.

This cast reminds the observer more closely of *Estonioceras* (?) *lamellosum*, as figured by Angelin and Lindström, than any other form, but according to Schröder this last is a true estonioceran form with only a slight contact furrow.

Nædyceras.

This genus was described by the author in *Genera of Fossil Cephalopods*, p. 281. It includes a large number of species with subtrigonal whorls, the dorsum much broader than the venter, which is elevated and usually subangular. The siphuncle is subventran and quite large.

The sutures have ventral saddles, lateral lobes and the dorsum may have a slight lobe or be nearly straight. The genus is of interest in this connection because, although completely coiled and the whorls in contact in several forms and although the whorl approximates to the nephritic outline, it never has an impressed zone. This is easily accounted for when one examines the figure of *Nædyceras vestustum*, Barrande, Pl. "35." This shell shows that, although close-coiled, the rate of growth is slow and the umbilical perforation very large, so that there is no pressure of one whorl upon another.

The genus has a number of forms in the Devonian, which also show similar peculiarities whether they are similar or more open in their coiling than *vestustum*, or have the turbinate mode of growth, which last is not unusual.

The shells are all smooth.

Cranoceras.

This genus was described in *Genera of Fossil Cephalopods*, p. 281, for a series of cyrtoceran forms having in the Silurian representatives like *Cranoceras* (*Cyrt.*) *hospitale*, sp. Barrande, Pl. "151;" *nigrum*, Pl. "127," and *Turnus*, Pl. "483" and "484."

The whorls are subtrigonal with the dorsum, much wider than the venter, which is apt to be elevated and subangulated. The young, until they are quite large, are compressed elliptical in section, with the ventro-dorsal diameter longer than the transverse, then expanding more rapidly they become more depressed and take on the subtrigonal outline, the dorsum broader than the venter, which in some species changes subsequently into the nephritic with a slight impressed zone, Fig. 43, Pl. viii.

The sutures have ventral saddles, slight lateral lobes and slight broad dorsal lobes, but in some species may be approximately straight and in the young stages are of this character in most forms. Considering the size of the shells the septa are remarkably close and numerous, and only slightly concave.

The siphuncle is propioventran and apt to be filled with radiating deposits. The Silurian forms do not have the nephritic outline and also have no impressed zone at any stage, judging from the large shell of *Cranoceras turnus*, which, although it has a nautilian-like form in the large fragment described by Barrande, probably did not coil very closely.

The Devonian forms are, however, more interesting in connection with the history of the impressed zone. These can be included under the names of *Cranoceras* (*Cyrt.*) *depressum* and *Cranoceras* (*Cyrt.*) *lineatum.*

In the Museum of Comparative Zoölogy, in the Schulze collection from Pelm near Gerolstein, in the Eifel, there is a specimen of *Cranoceras lineatum* 159 mm. in length along the median lateral line, transverse diameter of smaller end 45 mm., abdominodorsal 41 mm., and diameters of larger end 109 mm. and 85 mm. This is evidently a quick-growing and very large specimen, but showing no signs of having been coiled. It has, however, near the larger end on the incurved dorsal side a very faint impressed zone given in the outline, Fig. 43, Pl. viii, traced from the specimen. Some specimens do not exhibit this depression, but most of this species do have similar depressions and some of these are so nearly straight and the angle of growth so convergent that it becomes difficult, perhaps impossible, to attribute the existence of this zone to contact and pressure of a coiled whorl, unless it was acquired by inheritance through some unknown closely coiled forms.

None of these specimens have the double impressed zone figured in *Cranoceras* (*Cyrtoceras*) *depressum*, by D'Archiac et De Verneuil,* but I have studied some fragments of this species showing the same peculiarity. The two latero-dorsal impressions or faces and the central gibbous dorsal face give an outline similar to that of the young of the *Trocholites canadense*, given in Fig. 24, Pl. iv, of this paper. The history of the appearance of this modification in this large adult whorl, arising as it does from the direct modification of the younger rounded dorsum† without being preceded by the formation of an impressed zone is, however, entirely distinct from that which occurs in the paranepionic substage of Trocholites. In several genera of Carboniferous nautiloids (ex. Asymptoceras, Apheleceras) similar faces appear on the dorsum, but the central, gibbous dorsal face is fitted into the hollow flute or ventral zone of the next inner whorl and is obviously a result of close-coiling and adaptation of the plastic dorsum of the growing external volutions to the ventral modifications of the inner volution.

In Solenocheilus of the Carboniferous, however, the whorl has a rounded venter and yet notwithstanding this a gibbous dorsal face and dorso-lateral concave faces or furrows are formed independently. In *Cranoceras depressum* the origin of the gibbous dorsal face and latero-dorsal faces or furrows appears also, so far as the facts go, to have been entirely independent of any correlation with the ventral surface, which is rounded and gibbous. These characteristics do not seem to have had a mechanical origin in any of the shells, so far examined, which have the dorsal side free or comparatively free from contact.

A very large and remarkable specimen in the Schulze collection, Mus. of Comp. Zoölogy, shows a very short living chamber, which has an aperture very broad transversely and with a nephritic outline and apparently very broad and well-marked impressed zone. This species is not a variety of *lineatum*, but a distinct species precisely similar to D'Archiac and De Verneuil's figures of *Phragmoceras subventricosum*, but the siphuncle is ventral.

* *Geol. Trans. London*, 2d ser., vi, Pl. xxix.

† This is also figured by Roemer, *Harzgeb. Paleontogr.*, iii, Pl. vi, in a young specimen.

It is questionable, however, even in this form, whether there was anything more than a flattened dorsal side on the septate part of the whorl, since this is the aspect of the perfect side, the left side of this specimen, the right dorsal side and part of centre being crushed in by pressure. A second specimen of smaller size shows the peculiar dorsal aspect of *Cranoceras depressum*, but so faintly that the gibbous face and flutings are hardly perceptible.

I have been, of course, struck by the resemblance of these shells to the young of the nautilian forms of the Mesozoic, but there is still closer resemblance in the general aspect of species of Uranoceras and the closely set septa of the species of Cranoceras, and their contracted apertures show that it is not safe to consider them as radical forms.

They resemble the young of some species of the Nephritidæ, but this family has a peculiar ornamentation in young shells and is a closed generic series having apparently its own slender radical forms in the Devonian and possibly even its own arcuate radicals in this period.

Nephritidæ.

This family name is given to cover a series of genera having heavily ridged shells in the young, and for the most part in adults, with whorls having considerable resemblance in general outline and sutures to the true Nautilidæ, with which I formerly associated them.

Sphyradoceras, described in my *Genera of Fossil Cephalopods*, page 298, contains the remote radicals of the group and this genus has arcuate and trochoceran forms. They are of value in this connection only in so far as they show that the impressed zone, as a rule, is not present when shells are not in close contact.

Uranoceras has a number of large stout shells with solid, nautilian-looking whorls which are, however, never, so far as I have seen, in sufficiently close contact to produce a contact furrow. These forms are interesting, however, because the dorsum is always slightly flattened and has the aspect common to the nepionic stage of nautilian shells, so that one continually expects to find a specimen with a dorsal furrow. I have, however, not yet found an example of this kind, although the whorls are often so close as to touch each other. The type is *Uranoceras* (*Cyrt.?*) *uranum*, sp. Barrande, in the Silurian, but most of the species occur in the Devonian.

My references, in *Genera of Fossil Cephalopods,* to some Carboniferous nautiloids as probably members of this genus were erroneous. Barrandeoceras has been referred to above as belonging to the Tarphyceratidæ.

Pselioceras, mentioned also in my *Genera of Fossil Cephalopods,* as another member of this family, may possibly be a genus of Rineceratidæ, but it does not belong here.

The family of the true Nautilidæ have been properly limited farther on to Mesozoic genera.

*Rhadinoceras,** n. g.

The species here noticed under this name were formerly included in the genus Nephriticeras. They have compressed elliptical or almost rounded whorls, growing more slowly than in Nephriticeras, have the impressed zone only in the later stages of growth and are transitional between gyroceran forms and Nephriticeras.

RHADINOCERAS CORNULUM.
NAUTILUS CORNULUS, Hall (*Pal. N. Y.*, v. Pt. ii, Pl. lx).

Hall's figure shows the nepionic and neanic stages of this shell, and there is a slight contact furrow.

The form of the whorl in section is almost circular, not changing much throughout the nepionic stage.

The sutures are similar to those of Nephriticeras, with slight ventral and dorsal lobes and rather narrow lateral lobes.

The siphuncle, according to Hall, is dorsad of the centre.

The shell has only fine striæ and fine longitudinal ridges.

Having studied the original of this species in Prof. Hall's collections, I can confirm his observation and state that this is obviously a close-coiled nautilian form with a slight contact furrow produced after the whorls come into contact in the ananeanic substage, but not existing previously.

The umbilical perforation was very large, and young shells show that Rhadinoceras contains transitional forms between Nephriticeras and some cyrtoceran ancestor. In other words, these two genera were not derived from any coiled nautilian form of the Devonian or Silurian, but are progressive modifications of some closely allied arcuate form. This conclusion is sustained also by the existence of a peculiar cyrtoceran form associated with these

*'Ῥᾱδῐνός, slender.

which may be a survivor of the ancestral genus of this group. I allude to the peculiar arcuate species described by Hall from the Goniatites limestone of Manlius, N. Y., under the name of *Cyrtoceras liratum.* Hall recognized the affinity of this shell, in the ornamentation and form to species here described as included in Rhadinoceras, and it can be easily observed that the young of *Rhadinoceras cornulum* directly repeats the characters of his *Cyrtoceras liratum.*

RHADINOCERAS HYATTI.

NAUTILUS HYATTI, Hall (*Pal. N. Y.*, v, Pt. ii, Pl. cxxvi).

This species, so far as figured by Hall and so far as known to me from the observation of Prof. Hall's collection, is even less closely coiled than *Rhadinoceras cornulum.*

The early stages figured by Hall show no dorsal furrow and the form is similar to that of *cornulum*, but it is a depressed ellipse in the nepionic stage, increasing more rapidly by growth in its transverse diameters than in *cornulum.* The affinity of this species with the nepionic stage of Nephriticeras is indicated not only by the form of the whorl, which is identical, but by the presence of coarser longitudinal ridges, and by the sutures.

Whether the whorls of this species were ever in close contact is doubtful, on account of the absence of more complete specimens and the want of a contact furrow on the fragments, so far as known to me.

But the single fragment figured by Hall, and examined by me, was not old enough to settle this question, and I am inclined to the opinion that it will be found to be a true nautilian shell.

Nephriticeras.

This genus, described by the author in *Genera of Cossil Cephalopods*, p. 300, formerly included the transitional species separated above under the name of Rhadinoceras.

These shells are all unquestionably nautilian.

The early part of the nepionic, probably metanepionic substage, is similar in transverse section and ornaments to the full-grown shells of Rhadinoceras, but the paranepionic volution becomes speedily depressed and subtrigonal, the dorsum broad and much flattened, the abdomen elevated and narrower than the dorsum.

The siphuncle is dorsad of the centre.

The sutures have ventral and dorsal lobes and lateral lobes in the ephebic stage, but in the earlier stage there are ventral saddles.

NEPHRITICERAS LIRATUM.
NAUTILUS LIRATUS, sp. Hall (*Pal. N. Y.*, v. Pt. ii, Pl. lvii and Pl. lx).

This species in the metanepionic substage is distinctly annulated and also has broad longitudinal ridges, as shown in Hall's figures on Pl. lx. These ridges disappear together with the annulations on the abdomen of the paranepionic volution, but persist longer on the dorsum, and in some specimens they are very large flutes on the sides even in the neanic, as is shown in Hall's Fig. 3, Pl. lvii.

In the neanic stage the form of the volution changes from subtrigonal to a broad depressed oval.

No impressed zone has been observed, but this may be due to the age of the shells so far observed, none of which as figured, nor so far as I have seen, exceeded one volution.

NEPHRITICERAS JUVENIS.
NAUTILUS LIRATUS, var. JUVENIS, Hall (*Pal. N. Y.*, v, Pt. ii, Pl. lvi, Figs. 5, 6).

This shell, described as a variety of *liratus* by Hall, is obviously distinct. The form changes more rapidly than in *liratus* and, in the fragment of the nepionic volution figured by Hall, it may also be seen that the longitudinal ridges are much smaller than in *liratus*, more like those of the young of *Nephriticeras bucinum*. It differs from the last in having no impressed zone at the same age.

It is highly probable than an impressed zone appeared in a later stage than has yet been described.

NEPHRITICERAS SUBLIRATUM.
NAUTILUS SUBLIRATUM, sp. Hall (*Pal. N. Y.*, v, Pt. ii, Pl. lvii).

This species has similar changes of form to those of *liratum*, but it is altogether a broader whorled species and acquires the nephritic outline at an earlier stage of growth, and probably has in perfect specimens a smaller umbilical perforation.

There are no longitudinal ridges on the ventral side in the original specimen, which was in the neanic stage of development, but these are large and persistent on the dorsum as in *Nephriticeras liratum*. In Hall's figures the sutures have been confused with the lines of growth and the dorsal sutures are not correctly given. The dorsal lobes exactly coincide with the impressed zone in Fig. 6 of his plate. This figure shows the last part of the paranepionic volution in section below and the ananeanic with the impressed zone above this. The smoothness of the impressed zone in Hall's Fig. 6 of this species shows that the longitudinal ridges were obliterated as they are in other forms by the pressure of the growing whorl, and that this zone is probably due to contact and did not occur on the free side of the volution in the umbilical perforation. I use the general term "impressed zone," because, although my notes and Hall's observations and the figures all seem to warrant the statement that this zone in this species is a contact furrow, I have not been able to revise and confirm these observations.

NEPHRITICERAS BUCINUM.

NAUTILUS BUCINUS, Hall (*Pal. N. Y.*, v, Pt. ii, Pl. lx).

The paranepionic volution is shown in Hall's Fig. 1, Pl. lx, with a convex dorsum, and in Pl. cvii, Figs. 2 and 3, it is again shown with the siphuncle dorsad of the centre and the outline distinctly subtrigonal. These figures indicate great variability in the time at which the impressed zone appears, since the section in Pl. cvii is very much larger than that of about the same age of Fig. 2, Pl. lx. One is disposed to think that these are perhaps different species. Fig. 2 of Pl. lx gives in front view a section of the paranepionic volution with a distinct but narrow impressed zone marked on the dorsum. This whorl has a nephritic outline and is very different from the subtrigonal outline of a whorl with convex dorsum referred to above, which belongs to an obviously later stage of growth in a larger species.

Having examined these specimens in Prof. Hall's collection some years since, I find in my notes the statement that "no depression (meaning the dorsal furrow) occurs in the centre of any of these shells until the whorls touch, which they do at a late stage of growth." The form changes from a depressed oval in the metanepionic to nephritic more rapidly than in *Nephriticeras subliratum* and the transverse diameters increase faster. The longitudinal ridges are smaller and less prominent than in *Nephriticeras liratum*.

The sutures in the young have ventral and dorsal saddles and only in later stages these are replaced on the dorsum and venter by bread, shallow lobes, but in some specimens the sutures are nearly straight or may retain slight saddles on the venter.

The siphuncle is extracentrodorsan.

NEPHRITICERAS CAVUM.

NAUTILUS CAVUS (*Pal. N. Y.*, v, Pt. ii, Pl. cvi).

The fragment of the neanic stage, figured by Hall, has the nephritic whorl and similar sutures to the full grown of *Nephriticeras bucinum*, but the dorsal lobes are deeper perhaps and more V-shaped. The septa are different in being much more widely separated, but are otherwise similar to those of the later stages in *Nephriticeras bucinum*. I find in my notes that the impressed zone occurs after the dorsal lobes are formed and at an earlier stage than in *bucinum*.

Siphuncle is unknown.

NEPHRITICERAS ACRÆUM.

NAUTILUS ACRÆUS, Hall (*Pal. N. Y.*, v, Suppl., Pl. cix).

The fragment of the neanic stage, figured by Hall, shows the nephritic outline impressed zone and ridges similar to those of the older stages of *Nephriticeras bucinum* occurring at an earlier stage than they do in *Nephriticeras cavum*.*

NEPHRITICERAS MAGISTER.

NAUTILUS MAGISTER, Hall (*Pal. N. Y.*, v, Pls. lxii, cvii, cviii).

The large fossils of this species which I have examined have not afforded me any information with regard to the young, but the nephritic form of the whorl, the impressed zone and large beaded siphuncle dorsad of the centre show that the species belongs in the same genus with *Nephriticeras bucinum*.

This species may have either slight ventral lobes or saddles on the venter.

NEPHRITICERAS MAXIMUM.

NAUTILUS MAXIMUS, Hall (*Pal. N. Y.*, v, Pt. ii, Pls. lxxiii, lxxiv).

This is like *Nephriticeras magister*, known only through large fossils, but the young of the specimen figured by Hall on Pl. lxxiii

* I regret very much that in finishing this paper I have had no opportunity to revisit Prof. Hall's collection and study again his old and new materials. It is not improbable that his fine series of Nephriticeran species may show that the impressed zone was present as a dorsal furrow in the paranepionic substage of some of the more involute and tachygenic shells.

has, according to my notes, and when seen from the side, a general resemblance to *Nephriticeras oriens*.

The sutures and position of the siphuncle and form of whorl places it in this genus.

NEPHRITICERAS ORIENS.

NAUTILUS ORIENS, Hall (*Pal. N. Y.*, v, Pt. ii, Pl. lxi, and Suppl., Pl. cvi).

This species is obviously closely allied to *Nephriticeras magister* and *maximum*. The shell shows coarse longitudinal ridges and striations of growth as in other species of this genus, and the sutures and position and structure of siphuncle also justify its associations with these species in the same genus.

NEPHRITICERAS INELEGANS.

GYROCERAS (NAUT.) INELEGANS, Meek (*Pal. Ohio*, i, Pl. xxi).

This form is closely allied to *magister* and is probably a species of this genus.

Endoceratidæ.

This family was described in my *Genera of Fossil Cephalopods*, and again in "Carboniferous Cephalopods," *Fourth Annual Rep. Geol. Surv. Texas*, p. 465.

The genera are of interest in this paper because of the absence of the impressed zone in the more generalized open-whorled Edaphoceras, its appearance as a contact furrow in Endolobus and its appearance as a dorsal furrow in *Potoceras dubium*. I have placed this last form in this family with much reservation. The young have characteristics similar to those of *Endolobus Avonensis*, but the development is more advanced and decidedly tachygenic.

The absence of a dorsal furrow in the nepionic whorl of so highly specialized and so involute a shell as Ephippioceras is upon the whole rather remarkable and requires confirmation with a better preparation than the one at my command. The highly digonal form of the young has induced me to transfer this genus from the Apsidoceratidæ, under which it appeared in my *Genera of Fossil Cephalopods*, to this family.

Edaphoceras.

This genus was first described by the author in *Genera of Fossil Cephalopods*,* the type being a large Carboniferous species

* *Proc. Bost. Soc. Nat. Hist.*, xxii, 1883, p. 288.

eight inches in diameter described by Meek and Worthen* and fully figured by them. These figures reproduced on Pl. vii, Fig. 22–24, show the generic differences of this species and the forms on the same plate, which are good examples of the genus Estonioceras. Edaphoceras differs in having non-involute whorls without an impressed zone and a more completely digonal outline in transverse section of the full-grown volution.

The sutures have ventral lobes, saddles at the lateral angles and dorsal lobes with slight median saddles if the figure is correct.

The siphuncle is centren in the adult.

Notwithstanding the close resemblance of the type species to *Estonioceras ariense* as figured by Schröder, I doubt whether this Carboniferous type has direct genetic connection with Estonioceras of the Silurian. Until the young are known it will be impracticable to settle this question, but at present the close-coiled shells of *Edaphoceras niotense*, as described by Meek and Worthen, and of *Edaphoceras* (*Naut.*) *hesperis*, Eichwald,† both with siphuncles nearly or exactly centren and neither having an impressed zone and the peculiar form described by Foord‡ as *Solenocheilus caledonicus* which is similar but has a slight impressed zone, all point to a separate phylum from that of Estonioceras.

I do not, however, wish to imply that they did not arise from the same common origin, possibly some form of Eudoceras, but simply that Edaphoceras does not appear to be a direct descendant of Estonioceras.

Endolobus.

This genus was first described in *Genera of Fossil Cephalopods*, and subsequently in the *Second* and *Fourth Ann. Rept. Geol. Surv. of Texas.*

Unluckily I have never been able to study the young of the type *Endolobus spectabilis* of Meek and it may be that none of the species referred to this genus really belong to it.

Endolobus avonensis.

Nautilus avonensis, Dawson (*Geol. of Acadia*, p. 311). Pl. viii, Figs. 36–39.

Loc., Joggins, Nova Scotia.

The ananepionic stage of this species, Fig. 38, Pl. viii, has a trigonal shape and the cicatrix, although necessarily exaggerated in

* *Geol. of Ill.*, v, Pl. xix.

† *Leth Rossica*, Pl. xlv, Fig. 7.

‡ *Cat. Foss. Ceph.*, ii, p. 172, Fig. 30.

the figure, is approximately given. This form is like that of the arcuate forms of genus Tripteroceras in their ephebic stage. The shell was smooth. A paranepionic septum is shown below and in the specimen (Figs. 36–37) a still younger septum was developed after this drawing was made. These have ventral saddles, very faint lateral lobes, and minute shallow dorsal lobes, resembling in shape those of the older stages.

As shown in these drawings, the dorsum of the nepionic stage, which ends with the section just below the apex, is rounded and the impressed zone is a contact furrow beginning in the ananeanic substage only after the whorls touch. This zone deepens rapidly, but is never very broad or deep.

The side view shows the cyrtoceran form of the metanepionic substage and the large size of the umbilical perforation, which is given by a dotted line.

The siphuncle is nearly subventran in the paranepionic substage, but it does not increase proportionately in size and becomes centroventran in the neanic septum as shown above the apex, and ventrocentren in the ephebic stage.

The lateral angles are more acute and the form more perfectly digonal in the neanic and early ephebic stage than in the paranepionic or gerontic stages.

The specimen figured is in Museum of Comparative Zoölogy.

A young specimen of this species from Windsor, N. S., in the Museum at Ottawa, shows the living chamber of the early ephebic stage or paraneanic substage at the end of the second whorl. This is not quite one-half of a volution in length and has a deep, rather narrow hyponomic sinus with large median lateral crests and deep sinuses near the lines of involution.

Lophoceras.

This genus, described in *Fourth Annual Report Geological Survey of Texas,* has a very slight impressed zone in some species and it is clearly dependent upon the contact of the whorls.

*Potoceras.**

POTOCERAS DUBIUM, n. sp. Pl. x, Figs. 15–22.

Loc. (?).

The nepionic stage is shown enlarged in Figs. 16–18, Pl. x, and

* *Πότος*, drinking.

this is in a general way very similar to that of *Endolobus avonense* during the ana- and metanepionic substage, but in the paranepionic a dorsal furrow appears which is not present in Endolobus at the same early age. The longitudinal ridges appear also in this substage, the previous substages being smooth. The umbilical perforation, Fig. 15, shows the very abrupt bend which takes place at the end of the metanepionic substage just before the dorsal furrow appears. This furrow is broad and well defined and cannot be said to be correlative with a nephritic outline. The section of the whorl at this age, Fig. 17, still retains in some measure the trigonal outline of the ana- and metanepionic substages. It has become temnocheilan or trapezoidal through the great broadening of the abdomen, but if no furrow were present it would have to be described as a modified subtrigonal (see Fig. 17 which gives the form correctly). It is in no sense nephritic, although obviously transitional and standing between the preceding digonal and succeeding nephritic outline shown in the ananeanic substage. This substage occupies the last quarter of the first whorl. The broadening out of the furrow, which also increases in depth, although the curvature remains constant, can be observed in this same substage while the volution is still free, also the advent of a purely nephritic outline and a minute annular lobe in the middle of the dorsal lobe. The siphuncle shifts somewhat nearer the centre.

Contact takes place on the ventral side of the ananepionic volution, but the apical end is not free. The dorsal sutures in consequence of the annular lobe have a much spread-out or flattened V shape like those of *Endolobus avonensis* at a later stage and in the contact furrow (see Fig. 37, Pl. viii).

The form of the adult also resembles that species. The sutures have ventral saddles, lateral lobes and dorsal lobes in the ephebic stage and the outline is nephritic. The annular lobe does not increase much in size with advancing age and seems to disappear in this stage. Although the locality of this specimen is unknown, the probable age is Devonian.

Fearing to trust my own conclusions in this instance, and having one valve of a Brachiopod which was detached from the specimen described above, I sent the latter to Mr. Charles Schuchert in the National Museum, Washington, for determination. This gentleman very kindly gave me the benefit of his great special knowledge of this group and returned it to me with some other specimens of a species of Martinia from the Iberger Kalk, Upper Devonian of Grund, Germany, with which he considered the species to be closely related.

Ephippioceras.

Ephippioceras ferratum, Hyatt.
Nautilus ferratum, Owen (*Geol. Kentucky*, iii, Pl. x, Fig. 2).
Figs. 23–26, Pl. x, enlarged 5 diameters.

The nepionic stage is given in Fig. 23, from the side showing the lateral longitudinal ridges of the paranepionic and part of the metanepionic substage. These ridges are more acute on the venter and wider apart and blunter on the sides. The form in section of the metanepionic is digonal, and that of the paranepionic substage has a more elevated venter and flatter dorsum. There was no dorsal furrow in the paranepionic substage, so far as could be ascertained, but the condition of the specimen left this fact open to doubt.

It is interesting to note that the form and characters of the young of this very aberrant form seem to indicate affinity with the Eudoceratidæ.

The peculiar ridge-like mesal division of the septa, which correlate with the prominent ventral and dorsal saddles of this genus, are not present in the nepionic stage. The imperfect condition of this fossil did not enable me to make detailed observations upon the young farther than in the stage figured.

Trigonoceratidæ.

This family includes the close-coiled nautilian forms Coelonautilus, Stroboceras, Apheleceras, Subclymenia and Diorugoceras. The young of all of these genera, except possibly Diorugoceras, which I have not seen and which is also very involute, have a similar history. They are rounded in the nepionic stage and have an impressed zone only late in life, if they have it at all. Usually the form is similar to that given in Figs. 29 and 30, Pl. x, of *Apheleceras mutabile* (sp. D'Orb.), Hyatt.

This species shows in the young that the genus has been but recently derived from an arcuate type. The apex in the ananepionic and part of the metanepionic substage is free and the whorls barely touch at first. The corrugated shell of the nepionic and neanic stages show also the same primitive characters and the resemblances of these younger stages to the loosely coiled gyroceran form of Trigonoceras are closely parallel. If the adults were not known they would be referred necessarily to that genus.

The group is of importance in the history of the impressed zone since it shows in its most specialized and highly involute members that a contact furrow may appear even in a form of whorl that has naturally a gibbous dorsum and concave abdomen.

Fig. 2, Pl. xii, of *Diorugoceras* (*Naut.*) *planidorsatum* (sp. Portlock), Hyatt shows the peculiar character of the contact furrow in these forms when it occurs.

It is probable that the early neanic stage has a gibbous dorsum fitting into the hollow abdomen and that the involution is acquired rapidly in the later substages of the neanic stage, but not having seen specimens of the young I cannot state this as a fact.

Triboloceratidæ.

The figures of *Thoracoceras puzosianum* of Pl. ix show a shell which in form is a slightly depressed oval and both in this respect and in the fluted ornamentation approximates to the nepionic stage of *Thoracoceras canaliculatum* and other subspinous forms of the same genus. This last species has also a similar form, and by comparing this with the young of the loosely coiled, gyroceran forms on the same plate, Figs. 14 and 15 of Triboloceras, it will be seen how closely they resemble them. Triboloceras in turn grades into the nautilian form of the same family, *Vestinautilus Konincki*, Figs. 5–13. The figures show the development of this form through a nepionic stage which is at first similar to *T. puzosianum*, then becomes similar in ornamentation to *T. canaliculatum* and then passing into the neanic stage these primitive characters are replaced by the peculiar acquired ornamentation and whorls having the hollow, central, ventral and lateral ventral zones of this family and smooth, gibbous, umbilical zones with broad, fluted, lateral faces. The subspinous ornamentation persists in this form on the ridges throughout the ephebic stage. In the gerontic stage these progressive characters disappear and with them the fluted faces and zones also tend to extinction and in the paragerontic stage do actually give way to a rounded form without salient angles. This last is not figured, but the tendencies towards extinction of the ornaments, etc., may be seen in the anagerontic substage delineated in Figs. 5 and 6.

Vestinautilus Konincki leads into such forms as *Vestinautilus pinguis,* Figs. 16–19, which has the ridged characters, etc., confined to the nepionic stage, which is somewhat abbreviated. The subspinous characteristics are also crowded back and replaced earlier by gerontic modifications similar to those which occur only in the senile stage of *V. Konincki.* Thus these degenerative changes are shown to occur in what is properly the parephebic substage of *V. pinguis.* The history of the impressed zone accords with that of the other characters and may be seen in the figures to have been introduced as an acquired character dependent upon close coiling. It is not present in Triboloceras nor in the nepionic or ananeanic substages of the nautilian forms. It appears only after contact, and in other words is a contact furrow and its characteristics are determined wholly by the moulding of the dorsum on the peculiar ventral surfaces which are encountered during growth.

COLOCERAS GLOBATUM.
NAUTILUS GLOBATUS, De Koninck (*Calc. Carbon.*, Pl. xxxi).
Pl. x, Figs. 1–14.

The development of this species was partially described in my "Carboniferous Cephalopods," second paper, *Fourth Ann. Rept. Geol. Surv. Texas,* p. 447–451, but no figures were given and the genus Coloceras was then erroneously referred to the same genetic series as Coelogasteroceras. More extended study of both of these forms has shown me that the latter belongs to a distinct series. *Coloceras globatum* has the peculiar lateral flutes and characteristics of the Triboloceratidæ in the nepionic and neanic stages, and the hollow ventral zone of the paranepionic substage, which led me to suppose that it belonged to the same genetic series as Coelogasteroceras, may be accounted for equally well when *C. globatum* is referred to the Triboloceratidæ. Figs. 5 and 6, Pl. ix, of *Vestinautilus Konincki* show that the broad, hollow, ventral zone of the ephebic stage becomes narrow and the abdomen is gibbous on either side of it in the anagerontic substage of this form.

The similarity of the ventral hollow zone of the young of *C. globatum* may be accounted for, if it is supposed to be an accelerated phylogerontic character. The only difficulty in the way of this assumption is the preëxistence of the lateral flutes in the neanic stage. I have, however, frequently seen similar examples of the unequal acceleration of characters and this is probably another of this class. At any rate the ornamentation, form and lateral flutes all plainly point to the same genetic stock as Koninickioceras, whereas in Coelogasteroceras* there are no lateral flutes or faces and a very distinct and more primitive shell, especially in the nepionic stage, as may be seen in the section, Fig. 33 of Pl. x.

The figures of *Coloceras globatum* on Pl. x give the history of the dorsal furrow. They show also that considerable variation exists in the form of the ananepionic substage and it may be that Figs. 10–12 belong to a different species from those that show a flatter and more trigonal outline in the early stages. The umbilical perforation, however, remains about the same in all the specimens. This is of good size and there is no abrupt curve at the beginning of the paranepionic substage which would account for the genesis of the nepionic furrow in the dorsum of the specimen in Figs. 10–12, which is perfect in its proportions and markings. In the specimens given, 1 and 2 and 7, there is a more abrupt curve at this point and more sudden appearance of this zone, but the passage of the form into the nephritic outline is gradual even in these specimens. The first suture in Fig. 10 obviously belongs to the first living chamber of the metanepionic substage, while the second and third are paranepionic, although the second is still within the limits of the metanepionic volution, *i. e.*, built in that part before the dorsal furrow appeared. The third suture is indented by the furrow. The ananepionic substage is at first smooth except for horizontal and inconspicuous growth striæ, then becomes longitudinally ridged, Fig. 7.

The changes of form in this substage, which can be divided into three parts, are well marked in these drawings. There is first the age of the cicatrix with a form which is a very elongated trigonal and quite distinct in every way from the next; then the age in which the broad trigonal form appears, but the surface of the shell is still smooth, and lastly the digonal, longitudinally ridged age passing into the metanepionic and often bounded by a slight constriction. The metanepionic, Fig. 6, has an elliptical form with longitudinal ridges intersected by the edges of the growth bands. In this the digonal outline tends to disappear, although sometimes it is maintained more or less by the early appearance of the prominent, broad lateral ridge. This ridge, however, usually appears later, as shown in section, Fig. 3, and is characteristic of the species.

*I have provisionally referred Coelogasteroceras to the family of the Hercoceratidæ.

The dorsum becomes flattened in the latter part of the metanepionic substage and other transitions to the nephritic outline are obvious in the gradual spreading out of the transverse diameters.

The dorsal furrow appears as described above sometimes when the bend is abrupt and sometimes when it is gradual; in other words, it is obviously not correlated with the size or shape of the umbilical perforation nor dependent upon the curvature of the volution. It appears always in the same place at or about the third suture and when the nephritic outline is assumed at the beginning of the paranepionic substage. But it will be observed in section Fig. 4, that the outline, which has been very carefully drawn, is not remarkable for being very broad in proportion, nor does the study of this specimen give any grounds for supposing that the dorsal furrow could be considered a necessary condition of the mode of growth. The curvature is about the same during the remainder of the first volution, but the zone broadens with growth and development of the nephritic outline, as may be seen in Figs. 2, 11, 13, 14 and Sec. 3. This zone has longitudinal ridges, but these are much finer than those of the sides and abdomen.

The neanic stage begins when the longitudinal ridges and central zone disappear on the venter. The ridges persist on the dorsal side, but disappear in what is probably the paraneanic substage, leaving the heavy lateral ridge and its accompanying flutes. The neanic stage is therefore phyloanagerontic.

The ephebic stage is perfectly smooth and phyloparagerontic in aspect.

The action of tachygenesis upon degenerative characters is thus clearly apparent throughout the neanic and ephebic stages in this interesting species. This fact is entirely in accord with the principles of Bioplastology as explained above with regard to the action of this law upon retrogressive characters.*

Rineceratidæ.

The figures of Pl. ix show that this family has characteristics closely resembling the arcuate forms of Thoracoceras which are repeated in the ananepionic substage. Rineceras, however, never has a hollow ventral central zone but remains gibbous on the abdomen throughout life.

This characteristic also serves to distinguish the nautilian mem-

*See pp. 373, 415, 417.

bers of the same family when compared with the closely allied forms of the Triboloceratidæ, all of which have a hollow central ventral zone at some stage.

Lispoceras sulciferum, Fig. 24, shows the nepionic stage and ananeanic substage with form and characteristics approximately repeating those of Rineceras, and these resemblances are considerably closer than the figures would lead one to suppose. I did not notice until too late to replace them that these figures were not so complete as I had thought them to be.

The greatest development of the impressed zone in this family occurs in the compressed lenticular form of Phacoceras, Figs. 26, 27, and although Fig. 27 is not entirely satisfactory in the young, as given by DeKoninck, it seems to demonstrate together with his description that the nepionic stage had a section which would place it either in this family or in some other with fluted whorls and a gibbous abdomen. None of these genera have any species so far known which have a dorsal furrow, the impressed zone being strictly a contact furrow as in the Triboloceratidæ.

The genus Pselioceras of the Dyas is perhaps a member of this family, but I have strong doubts whether it does not belong to an independent family phylum in spite of the general similarity to other genera of Rineceratidæ. It is of some interest here because the umbilical perforation is very large, and it adds one more illustration to the many already noticed of shells having primitive forms and primitive modes of coiling in the young, which have the impressed zone only in the shape of a contact furrow. There is a slight contact furrow generated after the whorls touch in *Pselioceras ophioneum*, sp. Waagen.

Thrincoceras.

I mention this genus of the Rineceratidæ especially because I wish to correct here a curious mistake that has inadvertently occurred in my drawing of *Thrincoceras kentuckiense*, p. 432, *Fourth Annual Report of the Geological Survey of Texas.* The section Fig. 13 shows a furrow on the free dorsum of the nepionic volution. A careful reëxamination shows that this does not exist. There is a mark due to erosion which occurs at the point previously examined, but this is not present on other parts of the same volution.

The history of the impressed zone in this species does not differ from that of the same character in other genera of the same family of which the best known form is *Discitoceras* (*Naut.*) *discors*, sp. McCoy. All species have large umbilical perforations, the nepionic stage has no dorsal furrow and there is only a contact furrow generated in later stages.

Koninckioceratidæ.

The genera Koninckioceras and Domatoceras have been examined and these have no impressed zone until after contact.

Solenocheilidæ.

In Aipoceras, the arcuate form of this family, there is no impressed zone, and in Oncodoceras, some of which last are gyroceran, no impressed zone has been observed. In Asymptoceras, although the forms are all close coiled, this zone is only faintly indicated in some species, and when it is better defined it occurs late in the ontogeny, and then only as a contact furrow. The same remarks apply also to species of Solenocheilus. In the description of Cranoceras this genus was referred to as comparable with *Cranoceras depressum* in the peculiar configuration of the dorsum.

There are however, differences which show that this resemblance is not very close or significant. In *Solenocheilus Springeri*, for example, the gibbous dorsum and latero-dorsal flutes and heavy ridges on the umbilical shoulders appear before the contact furrow, but this comes into existence as soon as the whorls touch and modifies the dorsum in proportion to the amount of involution. The latero-dorsal flutes also are dependant upon the extent and size of the ridges or keels on umbilical shoulders and are not as in Cranoceras primitive inflections of the dorsal surface.

Incerta Sedes.

The new genera Peripetoceras of the (Permian) Dyas and Syringoceras of the Trias together with Mojsisovics genus Pleuronautilus of the Trias have been given together here as a matter of convenience, although it is by no means certain that they belong to the same family.

*Peripetoceras,** n. g.

This genus has been instituted for a single species described below, which cannot be placed with any other species.

* *Περιπετής*, clasped around.

PERIPETOCERAS FRIESLEBENI, Geinitz (Leonh. et Bronn, *Jahrb.*, 1841, Pl. xi, Fig. 1). Figs. 1–3, Pl. xi.

Loc., Tunstall Hill, England, Dyas.

This shell has a metanepionic substage with a subangular abdomen and siphuncle propiodorsan. The umbilical perforation is small and a dorsal furrow appears in the paranepionic substage. The apex, as shown in Fig. 1, Pl. xi, is narrow and compressed; the metanepionic, Figs. 2 and 3, broadens on the dorsum but remains rounded; the dorsal furrow at its first appearance, just beyond the gyroceran bend in the paranepionic, is deeper, as shown in Fig. 3, than it is subsequently when opposite the largest diameter of the umbilical perforation, Fig. 2, and the whorl changes at the same time from digonal to trapezoidal or temnocheilan-like. The siphuncle, however, remains propiodorsan.

The neanic substage has a nephritic outline and in the ephebic stage the volution becomes subquadrate with a flattened abdomen.

The living chamber is somewhat over one-fourth of a volution in length, with broad, shallow, hyponomic sinus, broad, low, lateral crests and sinuses on the umbilical zones.

The siphuncle continues to be propiodorsan in position.

The sutures have broad, ventral and dorsal lobes and lateral lobes. There are annular lobes in older stages according to Geinitz. I could find none in the early ephebic stage of the single specimen from Tunstall Hill, which showed a perfect septum, but they may be present in later substages.

*Syringoceras,** n. g.

This genus has been framed for Triassic species like the type, *Syringoceras granulosostriatus,* which have a tubular, nepionic volution with the siphuncle subventran. The early nepionic shell is also ornamented with very closely set transverse ridges, but it has no longitudinal ridges until a comparatively late stage. This nepionic ornamentation is like that of the genus Hercoceras at the same age. The impressed zone is present only after contact and is not deep.

The genus includes the group of *Nautilus Barrandei* of Mojsisovics, the equivalent of *Nautilus linearis,* Laube, and *S.* (*Naut.*) *evolutum,* sp. Mojsisovics.

Syringoceras (*Naut.*) *granulosostriatus* and *linearis,* stated by

* Σύριγξ, a tube.

Mojsisovics to be the same as *Acis Munst*, have been figured on Pl. xi, Figs. 4–8, to show that the impressed zone is present only after contact in these Triassic species, which have good-sized umbilical perforations and a cylindrical first whorl.

Pleuronautilus.

This genus was described by Mojsisovics to include a number of costated nautilian shells of the Trias, having in one section of this genus shells with the nepionic stage marked by transverse bands and in the species copied from Mojsisovics, Pl. xii, Fig. 3, the umbilical perforation is very large.

In correlation with this the apex is free and the generic characters appear late in the neanic stage.

This shell appears at first to be an extraordinary exception to the rule that generalized forms, with large umbilical perforations, slow growth of the dorso-ventral diameters and more or less cylindrical first volutions, always have a gibbous dorsum in the nepionic stage. Mojsisovics' figure, copied here, Pl. xii, Figs. 4 and 5, and in his description, has a dorsal furrow in the paranepionic substage. In order to confirm or refute such an important observation I wrote a letter of inquiry to Dr. Edmund Mojsisovics von Mojsvar and have received in return the following courteous reply, which shows clearly that the species cannot be quoted as exceptional in the opinion of this eminent authority. I quote below both my translation and the original letter:

"Die Impression auf der intern Seite des (auf Taf. iv, Fig. 3, meiner Hallstätter Cephalopoden) zu *Pleuronautilus superbus* gestellten Fragmenten kann nicht durch eine Verdrückung erklärt werden, sondern nun als eine thatsächlich der Schale sukommende Eigenschaft betrachtet werden. Ich halte es aber jetzt für wahrscheinlich, dass dieses Fragment trotz seiner grossen Uebereinstimmung mit dem ersten Umgange von *Pleuronautilus superbus* nicht zu dieser Art, sondern zu einer andern neuen Art gestellt und nicht als erster Umgang betrachtet werden darf. Ich neige vielmehr jetzt der Ansicht zu, dass die Impression auf der concaven Seite von weggebrochenen innern Umgängen herrühren dürfte."

"The impression upon the inner side of the fragment (Pl. iv, Fig. 3 (?) of my *Hallstätter Cephalopods*), referred to *Pleuronautilus superbus*, cannot be explained as due to compression, but must be regarded as an actual characteristic belonging to the shell. I now, however, consider it probable that this fragment, in spite of its great similarity to the first volution of *Pleuronautilus superbus*, should not be placed with this species, nor regarded as a first whorl, but as another new species. I incline much more at present to the view that the impression (the author's dorsal furrow) upon the concave side might have originated from a whorl now broken away."

Nautilidæ.

Without attempting at present to limit the chronologic distribution of this family, it is necessary in this connection to make some remarks with reference to my observations on the general affinities of the genera described in this paper, which are all Mesozoic.

Digonioceras is obviously the most primitive type yet found in the Mesozoic, and the most primitive or most generalized species is *Digonioceras excavatum*, as figured by D'Orbigny. The broad first whorl of this species is persistent in adults and so also is the slight amount of the involution and the discoidal character of the coil. The digonal and approximately nephritic outline of the young in the paranepionic is succeeded by a subtrigonal outline in the adult.

This is substantially paralleled by the development of the species of Cenoceras, Cymatoceras, Eutrephoceras and Nautilus.

All of these are apt in their nepionic substages to bring out the nephritic, and in the paranepionic the subtrigonal form of whorl with a broad dorsum, converging lateral zones and more or less subacute or elevated venter. This occurs even when the nephritic outline or some other is assumed in the later stages.

There is, therefore, in all of these genera some direct reference to the form of the ephebic stage of Digonioceras.

This fact is of great importance in connection with the assumption made in this memoir, that after the Trias the survivors of the Nautiloids are all nautilian shells and bear the marks of their descent from close-coiled ancestors and are not directly connectible with straight or arcuate types as the nautilian shells of the Paleozoic often are.

Digonioceras, n. g.

Digonioceras excavatum, was described in my *Genera of Fossil Cephalopods*, as a member of the genus Endolobus surviving in the

Jura, but the observations on the young given in this paper show that these forms are not so closely related as I then supposed.

The species differ from any species of Endolobus in the form of the young and in having the annular lobe and dorsal furrow developed earlier and in not having any large nodular tubercles. The form of the whorl in section is, however, similiar in adults of Digonioceras and also the aperture. The umbilical perforation is larger than usual in other allied genera of the same period and the involution is apt to be less in the older substages, leaving the umbilici open.

D'Orbigny's figure copied on Pl. xi, Figs. 13, 14, shows that a dorsal furrow was present in the paranepionic substage* and there is a similar furrow at the same age in *Digonioceras rotundum*, the type of this genus.

DIGONIOCERAS, sp. (?)

The species from Balingen, Middle Lias, Figs. 19–21, Pl. xi, shows a form similar to *Digonioceras excavatum*. The metanepionic outline in this has no dorsal furrow, as shown in the corrected section, Fig. 21, but the suture has an annular lobe. The dorsal furrow begins on the dorsum at the second septum of this fragment, which was probably the fourth or fifth of the complete shell.

DIGONIOCERAS ROTUNDUM, n. s.

This has affinities with *excavatus*, but the large fine young specimen, Figs. 6–11, Pl. xii, show that the shell was specifically distinct. It is obviously from the Oolite, but the locality is not known. Figs. 6 and 7 show the neanic stage and Fig. 8 the nepionic. The involution is not greater than it is in *D. excavatum* and the form is very similar in the paranepionic. The whorl, however, is really nephritic in the ananeanic substage, and has already assumed an outline in section quite distinct from that of *Digonioceras excavatum*. This last-named species retains throughout life, if correctly figured by D'Orbigny, the same form as the paranepionic volution of *D. rotundum* shown in Fig. 8. The outer whorl in Fig. 7 should be a little broader in proportion and more completely nephritic. There is a slight trace or linear depression near the median line on the abdomen, but this may be an individual character, and not important to the diagnosis of the species.

*This species, at first referred to the Lias, was subsequently in this author's Prodrome placed in the Inferior Oolite.

Cenoceras.

This genus was described in my *Genera of Fossil Cephalopods* to include a number of the Nautili of the Trias and Jura which should be separated. I propose now to limit the genus to those forms which, like *Cenoceras intermedium*, as figured by D'Orbigny, have trigonal ananepionic substages with subquadragonal metanepionic volutions and a dorsal furrow in the nepionic stage. The ephebic stage is also more or less quadragonal, with the dorso-ventral longer than the transverse diameters and the lateral zones convergent. The umbilical shoulders are prominent and the umbilical zones broad and at right angles to the plane of the coil. The sutures have ventral and dorsal saddles only in the first and second septa. The annular lobe and dorsal lobe are apt to develop very early, in some species certainly in the third septum. The siphuncle is near the centre in the first septum and subsequently varies from dorsad to ventrad of centre, but is never near either the venter or the dorsum. The ornamentation has both longitudinal ridges and transverse bands, but the former may or may not be present in adults.

CENOCERAS INTERMEDIUM.
NAUTILUS INTERMEDIUS, Sow. (?) (*Min. Conch.*, Pl. 125).
NAUTILUS INTERMEDIUS, D'Orb. (*Terr. Jurass.*, Pl. 27).
Loc., Balingen, Middle Lias.
Pl. xi, Figs. 15–18.

I feel considerable doubt whether Figs. 17 and 18 are really the young of *C. intermedius* and the name is taken solely on D'Orbigny's authority. It has, however, a peculiar compressed form and obviously a large umbilical perforation in the ananepionic and a subquadrate outline in the metanepionic, with siphuncle ventrocentren as in most specimens of this species. The ana- and metanepionic substages have no dorsal furrow.

Figs. 15 and 16 show the paranepionic and ananeanic substage of a specimen with the siphuncle dorsocentren, evidently an unusual position, since several other specimens of nearly the same age have it ventrocentren and in adults it is still nearer the venter. The whorl is tetragonal in the paranepionic, with well-marked ventral, lateral and dorsal lobes in the sutures and annular lobes. The dorsal furrow is also well developed and the umbilical perforation, restored with a dotted line in Fig. 15, must have been quite large.

There seems to have been no close bending of this whorl sufficient to cause the formation of a dorsal furrow in this shell.

The ananeanic volution given in section, Fig. 16, is too rounded, the lateral zones in this specimen are quite flat and convergent as in adults, and the abdomen is also flattened. The zone of contact is marked by a shaded space in Fig. 16 and is deep and well marked off from the dorsal furrow above in the same figure.

CENOCERAS LINEATUM.
NAUTILUS LINEATUS, Sow. (*Min. Conch.*, Pl. 141).
NAUTILUS LINEATUS, D'Orb. (*Terr. Jurass.*, Pl. xxxi).
Loc., Bayeux, Inf. Oolite.
Pl. xi, Figs. 22–27 and 28–31.

The ananepionic and metanepionic substages and part of the paranepionic are shown in Figs. 24–27, and also the cicatrix and general form and shell ornaments, which last are continued in the adults of several species of this genus.

The umbilical perforation is small and comma-like, contact taking place on the dorsum of the ananepionic volution. A well-developed dorsal furrow is present in the paranepionic but not in the metanepionic, as shown in Figs. 26, 22 and 23. There are annular lobes in the nepionic stage, but these disappear in the paraneanic substage.

Figs. 28–31 are so similar to the early stage of this species that I have referred them to it, although this was identified by Quenstedt as *Nautilus aratus*, Schlot.

CENOCERAS ARATUM.
NAUTILUS ARATUS, Schlot.
Loc., Suabia, Middle Lias.
Pl. xi, Figs. 32–35.

The specimen shown in Figs. 32–35 was figured first in my *Embryology of Fossil Cephalopods*, is one of Saemann's originals and although quite perfect in some respects has no shell.

It is a cast in iron of the interior and shows the characteristics figured very distinctly. The early beginning of the annular lobe in the third suture and that of the dorsal furrow in the metanepionic between the third and fourth sutures is very interesting in view of the fact that this shell had a comparatively large umbilical perforation and the curvature of the first whorl is so uniform that its early origin cannot reasonably be attributed to that as a cause. The furrow deepens immediately and affects the outline of the fourth suture. A slight dorsal lobe appears in the suture of the third septum at the same time with the annular lobe, and is better given in Fig. 33 than in Fig. 34. The flattening of the dorsum is apparent in the second suture, and, so far as I could see after repeated observations, my former figure in *Embryology of Cephalopods* was erroneous in placing an annular lobe in this suture. This species shows highly accelerated development in all of its characteristics and this acceleration is obviously genetic and independent of the size of the umbilical perforation, which is very large considering the fact that it is a Jurassic species.

I have also examined another less perfect specimen of this species having a considerable part of the shell preserved, but the first and second apical chambers were lost. The external shell of the umbilical zones had longitudinal ridges as well as external parts of the lateral zones and the venter in the paranepionic substage. The form of the whorl in section near the ends of the paranepionic substage remains about the same, except that the venter becomes slightly broader and flatter. The umbilical perforation is not quite so large and the gyroceran bend is more abrupt in this specimen, but otherwise it is exactly similar to the first described specimen. It is in Museum of Boston Society of Natural History.

CENOCERAS CLAUSUM.

NAUTILUS CLAUSUS, D'Orb. (*Terr. Jurass.*, Pl. xxxiii).
Loc., St. Vigor, near Bayeux, Inf. Oolite.
Pl. xii, Figs. 12–15.

This species has a small umbilical perforation. The form and general aspect are very similar to those of other compressed shells of this genus, but the shell in the paranepionic substage has peculiarly well-marked and broad growth bands with interrupted longitudinal ridges. The ana- and metanepionic volutions are shown in Figs. 13–15 and have a rounded dorsum, the dorsal furrow appears in the paranepionic at the gyroceran bend and deepens rapidly as the shell grows around the perforation. The amount of involution is probably about the same as in *Cenoceras granulosus*, which it also resembles in general aspect as well as in ornamentation.

Cenoceras granulosum.

Nautilus granulosus, D'Orb. (*Terr. Jurass.*, Pl. xxxv).

Loc., Chatillon, France, Oxfordian.

Pl. xi, Figs. 36–39, and Fig. 31, Pl. xii.

In this species, which is well characterized by its compressed form and tubercular ornamentation, the compressed form is present even in the nepionic stage. Figs. 37 and 38 show that the umbilical perforation is of medium size. Contact takes place on or near the dorsal edge of the cicatrix on the apex, as shown in Fig. 31, Pl. xii. The citatrix is plainly visible in several specimens of this species and it is also obvious that in none of them does the dorsal furrow appear until after the gyroceran bend begins. The dorsum of the metanepionic substage remains rounded and gibbous until the bending begins and then it becomes flattened and immediately hollow, showing the commencement of the dorsal furrow as in Figs. 36 and 37, and this continues to deepen and broaden throughout the paranepionic, as is shown in Figs. 38 and 39.

Cymatoceras.

This genus, described in *Genera of Fossil Cephalopods,* had for its type *Cymatoceras* (*Naut.*) *pseudoelegans*, sp. D'Orb., which is found in the Necomian together with *Cymatoceras neocomiense*. Both of these have costæ which pass entirely across the venter. In the type species these appear very late in the ontogeny in the ephebic stage, whereas in *neocomiense* and other species the costations appear earlier in the ananeanic substage. The sutures have slight ventral lobes or saddles with deep lateral and dorsal lobes. There are annular lobes at a very early age in some species.

Cymatoceras elegans (?).

Nautilus elegans (?) Sow. (*Min. Conch.*, Pl. cxvi).

Nautilus elegans (?) D'Orb. (*Terr. Jurass.*, Pl. xix).

Loc., Texas, Cretaceous.

Pl. xii, Figs. 16–21.

This species is represented by a number of specimens of the young, but these do not break apart well and have to be cut and viewed, as a rule, in sections.

The large size of the apical chamber is noticeable, and the great distance apart of the first sutures indicates the rapid growth of the young shell. This fact is very interesting since here we also find a high degree of acceleration in other characters. Thus the dorsal furrow appears in the ananepionic substage at a considerable distance from the gyroceran bend and continues after this, as shown in Fig. 20, along the dorsum and is continuous with that of the paranepionic.

The costations appear in the neanic stage.

CYMATOCERAS DESLONCHAMPSIANUM.

NAUTILUS DESLONCHAMPSIANUS, D'Orb. (*Terr. Jurass.*, Pl. xx).

Loc., Rouen, France, Cretaceous.

Pl. xii, Figs. 22–27.

This species, which is represented by several good specimens of the young, has very nearly the same ontogeny as *Cymatoceras elegans*, except, of course, in the specific characteristics and the position of the siphuncle. This last is propiodorsan in the metanepionic instead of being propioventran as in *C. elegans* (?). The sutures of the early epembryonic stages differ from those figured by Branco for the same species, but this may be owing to the fact that we have really observed different species. The dorsal furrow appears as in *Cymatoceras elegans* in the metanepionic at the second septum, as in Fig. 24, and is continued in the paranepionic substage.

CYMATOCERAS SIMPLEX (?).

NAUTILUS SIMPLEX, Sow. (*Min. Conch.*, Pl. 122).

Loc., England, Cretaceous.

Pl. xii, Fig. 28.

This single specimen differs somewhat from the specimens of *Cymatoceras deslonchampsianus* and may be more distinct in the adult, but I do not feel sure of the fact that it is a different species.

It has been figured in this connection because it shows that the dorsal furrow is present in this shell both in the metanepionic and paranepionic substages.

CYMATOCERAS RADIATUM.

NAUTILUS RADIATUS, Sow. (*Min. Conch.*, Pl. 356).

NAUTILUS RADIATUS, D'Orb. (*Terr. Jurass.*, Pl. xiv).

Loc., Rouen, Cretaceous.

Pl. xii, Figs. 29 and 30, and Pl. xiii, Figs. 1 and 2.

The ananeanic substage is shown in outline in centre of Fig. 30, Pl. xii, and in Fig. 1, Pl. xiii, which is the reverse of that of Fig. 30, but enlarged two diameters. The presence of an annular lobe is noted as it appeared in the specimen, but this part was covered by remnants of the nacreous layer and it was not positively defined. The dorsal furrow began between the first and second septum and is faintly shaded in Fig. 1, Pl. xiii. The dorsal sutures were covered except as far as represented. The side view, Pl. xiii, Fig. 2, shows these sutures, so far as seen, the last two in this figure being the first two of Fig. 29, Pl. xii.

The broad costæ of the genus made their appearance in the ananeanic substage at the same time that the septa approximate and the zone of contact is formed.

It will be observed that the costæ are broader at first than they are in later age even in this figure, showing that growth was more rapid at first as in the development of the septa.

Eutrephoceras,* n. g.

This genus includes these forms like the type *Eutrephoceras Dekayi*, which have globose ananepionic substages, increasing subsequently with great rapidity in all their diameters. The ana- and metanepionic substages are highly tachygenic and these shells have very small, and often hardly perceptible and much flattened, umbilical perforations. The siphuncles are subdorsan from the apex through the nepionic stage in some species, in others this position is not maintained, but the siphuncle is generally in later stages near the dorsum and in the ephebic stages it is dorsad of the centre.

The nepionic stage has longitudinal ridges and transverse bands, the former disappearing in adults which are smooth.

The form of the whorl in section is nephritic from an early age and changes but little throughout life.

The sutures are almost straight, having but slight ventral lobes, broad ventro-lateral saddles, lobes on the umbilical zones and deep lobes in the zone of impression. There are no annular lobes at any stage of development.

* *Ευτρεφής*, clasping around.

Eutrephoceras, Dekayi.

Nautilus, Dekayi. Morton (Synop. Org. Rem., Pl. viii, Fig. 4).

Loc., Dakotah, Cretaceous.

Pl. xiii, Figs. 4–8; Pl. xiv, Fig. 1.

The ananepionic substage in this species is very obtuse and almost saucer shaped, the whorl increases so rapidly in all its diameters. The cicatrix is present on one specimen and is a double depression with a dividing ridge on the cast of the apical chamber. There is a peculiar plate of nacreous matter which may be the equivalent of a similar plate which fills in the apex of the shell in *Nautilus pompilius* or it may be simply a remnant of the apical deposit which has this peculiar form. However this may be, the cæcum is seen through it in one specimen, and in another it can be seen in the same position, although the plate is not visible, the apex being more completely covered by the external shell.

It seems clear that the dark spots observed in these two specimens were due to the presence of the cæcum filled by a dark, sparry deposit and showing through the nacreous layer.* If so this organ is close against the venter of the apical chamber. I was not able to see the youngest septa, but there are evidently very few of them and the one shown in Fig. 4 is probably either the third or fourth septum.

The metanepionic substage is not so smooth as the ananepionic, and although it is difficult to observe without making a section, I am quite sure that there is a faint dorsal furrow present before the gyroceran bend begins. The longitudinal ridges and the transverse bands with the usual crenulated edges begin to be observable in this substage.

The bend which begins the paranepionic substage is very abrupt and almost at right angles to the dorsum of the metanepionic substage and has a deep dorsal furrow. The umbilical perforation is consequently so small and arcuate that it is very difficult to observe. In Fig. 6 the lateral angle of the shell and of the first septum that is built upon the dorsum of the apex has been cut off and shows the opening of the umbilical perforation in part, but has a misleading outline since it is just the reverse in shape of the true internal perforation. It, however, shows that there is a perforation as does also Fig. 4. This shell must grow in these younger substages with

* It can be observed in the apex of *Nautilus pompilius* through the thin shell of the ananepionic substage.

great rapidity upon the venter in order to swing that part around the very sharp curve made by the gyroceran bend.

The paranepionic substage has well-marked longitudinal ridges and transverse bands of growth given in Fig. 6. The latter part of the paranepionic in this species, if this be properly limited by means of the ornamentation, is close coiled. That is to say, it touches dorsum of the ananepionic and envelops it, the involution being almost complete from the very beginning.

The umbilical perforation is, however, not completely closed nor is it subsequently closed by extra growths of shell as in *Nautilus pompilius*. The area of the umbilical zones is marked off at an early age by the smoothness of the shell, the longitudinal ridges being absent on these parts. In some specimens the shell markings are much stronger than in others, but in all they seem to grow more decided until near the end of the metaneanic substage.

The meta- and paranepionic substages have an elevated subangular abdomen not shown in any of the figures, the outline of the section of the whorl is in reality in these early substages depressed subtrigonal similar to the young whorl of Cymatoceras, but less acute, and to that of *Nautilus pompilius*, but more pronounced than in that species on account of the subangularity of the venter; the venter of *Nautilus pompilius* being more rounded in the paranepionic substage.

The ananeanic and metaneanic are blended and probably not separable, but the paraneanic can be distinguished. The former has the siphuncle tending more towards the centre, although in some specimens this alteration is not so great as in others. The transverse bands become broader and their edges have tubercular-like short ridges on a secondary band, which are sometimes well marked off on their apical borders from the sunken younger parts of the same bands of growth. These ridges are always continuous from band to band and over the sunken parts of each band. In the paraneanic substage, as shown in Figs. 7 and 8, these ornaments begin to diminish and finally die out. In Fig. 8 this substage is limited by the retention on one side of a partial constriction or permanent aperture, which, however, is not present in all shells.

In the anephebic stage, also shown in Figs. 7 and 8, orad of the constriction, the shell is very nearly as smooth as it is in the full grown. The form of the whorl remains about the same. The siphuncle has become dorso-centren in position in this shell, in others it may still remain nearer the dorsum, but in most shells it shifts its position somewhat.

In the metephebic stage the shell appears to have been smooth and the whorl is apparently somewhat more depressed or more absolutely nephritic in outline. This distinction is due to the larger size and greater proportionate increase in lateral growth. The dorsal sutures in this substage and probably throughout the ephebic and possibly earlier have not only the broad dorsal lobes in the contact furrow, but narrow and very shallow lobes, which cannot be described as annular lobes, although they resemble these as they appear in the neanic stage of *Endolobus avonensis*, Fig. 38, Pl. viii. They are, however, much shallower. In the centre of these, in the only specimen perfect enough to show this, there were minute linguiform saddles as given in Fig. 1, Pl. xiv. The sutures have to be in perfect condition to observe such markings and this may account for the absence of similar markings upon other nautiloids. The siphuncle may be either ventrocentren, centren or dorsocentren, but it is more commonly dorsocentren.

EUTREPHOCERAS, sp. (?)
Pl. xiii, Fig. 3.
Loc., France, Cretaceous.

This shell is referred to here because it shows clearly the presence of a faint dorsal furrow in the metanepionic substage opposite a corresponding furrow in the paranepionic. The cast of the perforation was preserved in this specimen and it was extremely flat and comma shaped. The whorls are coiling towards the observer so that there can be no doubt that the section of the central volution is metanepionic.

EUTREPHOCERAS FAXOENSE, n. s.
Loc., Faxoe, Denmark, Cretaceous.
Pl. xiii, Figs. 9–12.

This species differs from *Eutrephoceras Dekayi* in the extreme subdorsan position and smaller size of the siphuncle in the nepionic stage, has larger umbilical openings and is also apparently a smaller form. Otherwise it is very close in sutures and form to this species. The umbilical cast is preserved on one side in Fig. 9, and shows the involution to have been considerably less than in *E. Dekayi*. The development is, however, so similar otherwise that no special description is necessary. It must be noted, however, that the shell was absent, so that no comparison of the ornamentation could be made.

EUTREPHOCERAS IMPERIALIS.

NAUTILUS IMPERIALIS, Sow. (*Min. Conch.*, Pl. xiii, Figs. 13–16).

Loc., Isle of Sheppy and Isle of Wight, Tertiary.

Pl. xiii, Figs. 14–16.

In this interesting Tertiary species the siphuncle is subdorsan even in the apical chamber, as is shown in Fig. 14, and it clings to this position throughout the nepionic stage. The form does not seem to differ materially from that of *Eutrephoceras Dekayi.* The umbilical perforation is of about the same form and size, that is to say, it is as small as is practicable to afford room for the shell to turn and has a depressed comma shape. The external umbilici are more open than in *E. Dekayi* and smaller than in *E. Faxoense.* The ornamentation is quite distinct. In the nepionic stage there are longitudinal ridges and transverse bands, but these are never so prominent as in *Dekayi.* In what I suppose is the neanic stage these still persist, but are so fine that their intersecting lines, with minute depression in the checker-board-like spaces between them, give a punctate aspect to the surface when viewed with a cross light.

The specimens from the Isle of Sheppy, supposed to be identical with this species, shows the presence of a dorsal furrow in the opposed dorsi of the meta- and paranepionic volutions, Fig. 16, and the very small size of the perforation.

This species has an annular lobe which has no connection with the subdorsan siphuncle. I could not find any traces of these in the older sutures. The sutures resembled those of *Eutrephoceras Dekayi* except that I could not find any signs of the linguæ-form dorsal saddles in the centre of the dorsal lobes.

Nautilus.

Before beginning the brief notice of this genus, which I propose to give, I desire to return thanks to Henry Brooks, whose observations and drawings have contributed so largely to the interest of this paper. These are also noticed in connection with the figures themselves. I am also deeply indebted to Dr. Charles E. Beecher, of New Haven, who has loaned me a series of beautiful preparations, making a complete series of all of the substages of development in *Nautilus pompilius* and more or less of other species, and also to Dr. R. T. Jackson, for similar material. I hope to use this material more extensively and effectually in the future. In this paper full justice cannot be done to the work of Dr. Beecher or Mr. Brooks.

This generic name, heretofore supposed to include nearly all of the coiled or nautilian forms of Nautiloidea and still used by some conservative paleontologists in this way, is really not applicable to any forms except the living species of nautiloids and possibly some shells in the Tertiary. Even these last cannot be satisfactorily referred to the genus Nautilus until their nepionic substages have been worked out.

The genus Eutrephoceras is a near ally but still distinct in most of its characteristics. The broad outline of all of the epinepionic stages of growth, the general position of the siphuncle, dorsad of the centre, and the distinct sutures of Eutrephoceras separate the species. The minute umbilical perforations and closer coiling of the younger substages of the conch in Eutrephoceras show also that it is the terminal group of some other genetic series than that to which Nautilus probably belongs.

The genus Cymatoceras of the Cretaceous differs in the broad costations as well as in the outline of the nepionic whorl. The sutures of this genus are more like those of Nautilus than the sutures of Eutrephoceras.

The genus Nautilus is obviously still more remote from Cenoceras of the Jura in the sutures of all stages and form of the ananepionic and succeeding nepionic substages, although in the outline of the ephebic whorl and position of the siphuncle there is close approximation. If one excepts the comparison of the ananepionic substage, which is obviously similar to that of *Eutrephoceras Dekayi*, being only more compressed, the nepionic stage and the ananeanic substage are very close in aspect to those of Digonioceras, although the succeeding substages become quite distinct.

I cannot in this memoir give full descriptions of the substages of development which I hope to treat fully in the future. It will suffice to refer to the accurate drawings of Mr. Brooks, given on Pl. i, and to notice the fact that young shells and preparations now in my possession of *Nautilus umbilicatus*, *pompilius* and *macromphalus* show no variations in their characteristics worth noticing here. It is essential, however, to call attention to the statement made elsewhere, that the dorsal furrow begins in *Nautilus umbilicatus, pompilius* and *macromphalus* in the metanepionic or at any rate before the gyroceran bend begins.

The ornamentation is similar to that of the young of most other genera of the Mesozoic during the nepionic stage, but the young of Nautilus do not repeat the broad costæ of the epinepionic stages of Cymatoceras. The shell of *Nautilus pompilius* becomes smooth in the ananeanic substage which begins when contact occurs.

The color of the ana- and metanepionic substages are pearly, the outer layer of shell being thin and colorless in these substages. A uniform brown spreads over the exterior in the paranepionic substage. This tends to break up into transverse bands in the ananeanic at the same time that the ornaments begin to disappear.

This breaking up into bands is due to a decided fading out of the coloration which may sometimes seriously affect the stripes themselves. In the metaneanic, sometimes after the coloration has for a brief space been reduced, the bright, broad, brown stripes of the adult appear upon a white ground.

The form of the outline of the whorl changes in the ananeanic, the sides and venter becoming flattened and being less involute, the whorl repeats approximately the ephebic whorl of *Nautilus umbilicatus*. To speak more accurately, it would at this time be identical with any species that might have an ephebic form exactly intermediate between *Nautilus umbilicatus* and *pompilius*, since the involution of the latter is at all stages somewhat greater than that of the former species at the same age. In the paranepionic the animal begins to deposit calcareous matter along the lines of involution in the umbilical zones and thus spreads more towards the centre and increases the involution. This process really begins with the metaneanic and is often marked by a permanent constriction beyond which the transverse lines of growth become coarser than they are in the ananeanic substage.

In the anephebic substage, the closing of the umbilici by the spreading inwards of the calcarous deposits of the umbilical zones begins and is carried out fully in the metephebic substage, the umbilici being completely covered up and obliterated. In the parephebic substage the brown coloration disappears, leaving the surface white. No degenerative modifications other than this loss of color and occasional approximation of two last septa have been observed in any shells that have come under my observation, and, therefore, I have thought this change probably belonged to the later ephebic and not to the true gerontic stage.

These facts show clearly that in this genus the least involute of existing species, *Nautilus umbilicatus*, is the most primitive and has characteristics repeated more or less in the young of the more involute *Nautilus pompilius*. This observation is of great importance in this paper, since it confirms the opinion that genetic groups of Nautiloids and Ammonoids are series of parallel morphic modifications, in the evolution of which the shells progressed from less closely coiled and less involute to more closely coiled and more involute shells.

Dr. Beecher has called my attention in his preparation of *Nautilus macromphalus* to a very important fact in connection with the bioplastology of the Nautiloids, viz., that there are indications in the ontogeny of this species of degenerative changes which have also taken a parallel course to those observed in other genera and families; in other words, that it is more closely coiled and more involute in the nepionic stage than later in life.

The nepionic stage of this species differs in form from that of *Nautilus pompilius*, but the most marked distinction lies in the abrupt bending of the shell in building the gyroceran curve. This consists partly in the formation of thick extensions of the shell along the lines of involution. These are similar to the testaceous umbilical extensions occurring in the same situation in *Nautilus umbilicatus*, but begin later in the ontogeny of that species, and also similar to those occurring in the young of *N. pompilius* earlier than in *umbilicatus*, but later than in the ontogeny of *macromphalus*. All of these facts and also the form of the young of *macromphalus* can only be accounted for by assuming that it is probably a descendant of *Nautilus pompilius*, which exhibits an accelerated development of earlier nepionic substages and then in the ephebic stage becomes less involute.

I shall try to put these propositions in future papers into convincing form with illustrations, but it is easy to verify them with any good specimen of *N. macromphalus* since the internal whorls are visible in every case.

These observations confirm in the most unexpected manner the generalization deduced from fossil shells, that in progressive series, evolution is towards closer coiling of the shell and in retrogressive series the direction of evolution is towards uncoiling.

Aturidæ.

In my second paper on "Carboniferous Cephalopods," *Geological Survey of Texas, Fourth Annual Report*, p. 389, I pointed out the fact that the genera Enclimatoceras of the Mesozoic, Hercoglossa of the Cretaceous and Aturia of the Tertiary formed a distinct group by themselves.

These genera have ventral saddles, deep lateral lobes and lateral saddles of so highly specialized outlines that the sutures resemble those of some of the Clymeninæ. The forms are compressed and as a rule deeply involute. Unfortunately I have been unable to get the ananepionic substages of Enclimatoceras or Hercoglossa.

It is, however, fortunate that the involute character of the young in these genera and close coiling of adults in the entire group makes it highly probable that the young when investigated will not be likely to contradict the conclusions obtained from the study of Aturia.

Through the kindness of the Directors of the National Museum and Geological Survey and Dr. W. H. Dall and Mr. T. W. Stanton, I received a number of sections of *Enclimatoceras Ulrichi*, from Prairie Creek, Wilcox county, Alabama, and Zell county, Texas, Tertiary, but not one of these had a centre perfect enough to be of any use.

Aturia.

This genus, first described by Bronn, has long been admitted and is easily recognized by the aid of the peculiar sutures and siphuncle.

Aturia Morrissi, Michellotii.

Loc., Baldasseres, Tertiary.

Pl. xiii, Figs. 17–19.

The ananepionic substage in this species is very globose and the growth of the apex is certainly very rapid in all its diameters. This rapid increase is, however, not sustained in the transverse diameters of the metanepionic and succeeding stages. The gyroceran bend is so abrupt and the coiling is so close at the end of the metanepionic, that I have not yet succeeded in seeing and studying the dorsum of this substage. The opening of the umbilical perforation can be seen in Fig. 19, which is enlarged six diameters, as a black spot at the junction of the sutures and is visible only under a magnifier in the original. The other figures are also enlarged six diameters.

Fig. 19 also shows the first three sutures and the highly accelerated development of the first suture which takes on immediately the peculiar lobes and saddles of the generic group to which this species belongs, and also the great depth of the apical chamber.

ATURIA ZIZAC, Bronn.

Loc., Dax, France, Tertiary.

Pl. xiii, Figs. 20–22.

Figs. 20 and 21 give front and side views of the nepionic and half of the neanic stages enlarged about ten times with the first four sutures.

This species has a globose apex similar to that of Morrissi and the umbilical perforation is also minute. This and the closeness of the coiling is shown and the subdorsan siphuncle are shown in Fig. 22. I have restored the dorsal shell of the ananepionic substage in this specimen. The extraordinary depth of the apical chamber, the lobate character of the suture of the first septum, and the highly tachygenic (accelerated) development of all of the characters of the apex are noticeable in this species as in *Aturia Morrissi.*

Scaphites.

The phylogerontic forms known by this name are of interest in this paper because of the invariably excentric retroversal character of the living chamber and their obviously intermediate station between the more uncoiled phylogerontic genera and such phylogerontic genera as Sphaeroceras and the like which are closer approximations to normal shells and are consequently persistently involute at all stages of development.

The figures of this genus, in consequence of the retroversal bend of the living chamber, do not usually give any data, and although the literature is so abundant I was forced to make what observations I could in finishing up this paper upon the materials immediately in hand. In one fine large specimen of Scaphites from Mingusville, Mont., Coll. Bost. Soc. Nat. History, I was able to excavate the dorsum and found the impressed zone retained even upon the edge of the aperture or rather in the base of the dorsal crest. The aperture had the usual shelf-like constriction figured by Meek and on the dorsal side were two narrow sinuses and a median dorsal crest, the length of which could not be determined.

Mr. Stanton, in his "Colorado Formation,"* shows a similar retention of the impressed zone in *Scaphites ventricosus.*

The gerontic whorl is quite free for some distance, and although the impressed zone sensibly diminishes in depth and breadth towards the aperture it is not obliterated. These two species have comparatively short living chambers, which are free only for a part of their length, and one would naturally expect that the very deep contact furrow of the ephebic and anagerontic substage would persist. The conditions are quite different from those that occur in shells with more extended gerontic stages, like *Scaphites larvæformis*, Meek and Hayden, and in these the paragerontic substage may perhaps have no impressed zone.

I have, however, examined a considerable number of scaphitoid shells from European localities and some of these gave positive information of the persistence of the impressed zone in the lower, inner border of the aperture, although, as in *Scaphites nodosus*, it was sometimes hardly perceptible in the outline of this part.

Helicancylidæ.

This family name serves the purpose of temporarily uniting all phylogerontic species of the Cretaceous in America which have three rows of tubercles on either side. The characteristics are given below under the generic title "Helicancylus."

Helicancylus, Gabb.†

It is probable that genetic connection as shown by the ornamentation existed between cretacic shells of normal involute form like *Acanthoceras Rémondi* of the nodose variety figured by Gabb as having three rows of tubercles and his *Crioceras latus*.‡ This last also has three rows of spines and single costæ, but has an open coil without an impressed zone. There are similar marks of affinity in the species described by the same author as *Helicancylus æquicostatus*, which has also three rows of nodes. The last, however, has the

* *Bull. U. S. Geol. Survey*, Pls. xliv and xlv.

† *Pal. Cal.*, i, Pl. xiii, and ii, Pl. xxv.

‡ *Ibid.*, i, Pl. xv, Fig. 2.

composite mode of development described below in Nostoceras and Emperoceras with a gerontic stage which is a close approximation to Hamulina and Ptychoceras,* and affords evidence that this genus is a phylogerontic form in which the gerontic retroversal last volution replaces the helicoceran. These and other forms appear at any rate to give an approximate solution of the difficult problem of the derivation of such form as Hamites, Hamulina, Ptychoceras and Baculites, and also Turrillites and Helicoceras.

The helicoid spiral appears sandwiched between a phylogerontic nepionic stage in Nostoceras and Emperoceras and a true ontogenetic, gerontic living chamber with a retroversal curvature. This ontogeny shows this spiral to be a special, probably pathologic adaptive mode of development peculiar to the ephebic stage of some of the phylogerontic series, but not necessarily having any corresponding feature in the gerontic stages of any large number of normal formed Ammonitinæ.

This explanation is in accord with the fact that all normal Ammonoids and Nautiloids revolve in the same plane even in the gerontic stage, and enables one to explain the most puzzling of the degenerative forms. Thus there may be, as in *Macroscaphites Ivanii*, shells with retroversal gerontic stages derived directly from normal Ammonitinæ. Some helicoceran forms are also derived directly from similar normal forms, the most wonderful example being the series discovered and accurately described many years since by Quenstedt, who traced helicoceran and crioceran, and even baculites-like shells all back to their proper origin in *Cosmoceras* (*Amm.*) *bifurcatum* of the Jura. Neumayr is constantly alluded to as the person who discovered this important biological fact, whereas the credit is due to Quenstedt, who showed that all such forms in the Jura were probably pathologic derivatives of normal forms. I have examined a considerable number of the species of Turrillites and Helicoceras from European localities, and although the apices of some of these were small enough to have shown at least the beginning of an excentric nepionic or neanic stage, if any had existed I did not succeed in finding any indications of the presence of such forms in the young. It is, however, very strange that the youngest stages are invariably absent even in large series of specimens of the same species, and this suggests that the youngest stage was especially liable to destruction, and might not have been like a normal formed

*See remarks on Ptychoceras.

involute Ammonoid, *i. e.*, it might have been excentric or helicoid. So far as known, however, all European series approximate to normal forms in the young. Here and there also there are diseased individuals, as in the so-called *Turrilites Boblayei* (*Arietidæ*) and *Turrilites Valdani* and *Coynarti* figured by D'Orbigny, and other isolated examples of unsymmetrical shells having helicoid tendencies in the ephebic and even younger stages. It is also fully demonstrated by specimens and drawings that many Turrilites and helicoceran forms do not have a retroversal living chamber in the gerontic stages as in the scaphitoid and ancyloceran-like series traceable to various genera. This may be due to the incompleteness of the specimens heretofore collected and the perishability of the excentric gerontic volution when present. This hardly accounts for those species having contracted living chambers and apertures, the presence of which are almost conclusive in favor of the opinion that they could not have had retroversal gerontic living chambers.

These facts and the tendency of the terminal gerontic volution to return to the mode of revolution in the same plane and to resume the lost bilateral symmetry of the whorl in Emperoceras and Nostoceras show plainly that the helicoid spiral is acquired, adaptive pathologic tendency that may come in anywhere as an intermediate stage in the ontogeny or phylogeny of any degenerative species or series, and is not strictly speaking a normal phylogerontic characteristic.

Another interesting result of the discovery of Helicancylus by Gabb is that Hamulina, Hamites, and probably also the allied Ptychoceras can be definitely characterized as phylogerontic forms of phylogerontic series. The author has previously claimed, with Quenstedt, that this was the only way to account for the Hamites, Ptychoceran and Baculites-like modifications of European forms. American forms with helicoid tendencies, like Helicancylus, having gerontic stages which differ from true Ptychoceras only in the closeness with which the gerontic retroversal bend is made, afford positive evidence in the same direction.

It should be noted in this connection that these remarks do not necessarily imply that Ptychoceras has not a distinct mode of development, an ontogeny of its own and also its own peculiar genetic series as may be seen in the remarks on that genus.

I have had an opportunity to study the gerontic stage of a species of Helicancylus in the Whitney Coll., Mus. of Comp. Zoölogy, which may be new. The gerontic stage is the same as that of *H. æquicostatum*, and is closely bent and like Ptychoceras, although there is no gerontic contact furrow. The costæ are large, single and tuberculated, not alternately entire and tuberculated as in Gabb's species.

Nostoceratidæ.

This is probably a more or less artificial group, but it serves the present purpose of showing the common characteristics of several groups of phylogerontic species. I have united under this name all such distorted forms of the Cretaceous in this country with unsymmetrical spirals in the ephebic stages, more or less prominent costæ and two rows of tubercles on the abdomen. The earliest stages are too little known for any general description to be given, the gerontic stages often have a retroversal living chamber and are tuberculated.

The genera are Nostoceras, Didymoceras, Emperoceras, Exiteloceras.

Quenstedt was the first to call attention to the persistency of styles of ornamentation in series of degenerative shells and to point out that these were indications of affinity that could not be lightly laid aside. A considerable proportion of the phylogerontic species of the Cretaceous in this country have only two rows of tubercles with costations bifurcated at the bases of these tubercles, but I have not been able to find any corresponding ornamented normal form which might be considered their phylogerontic radical.

Helicoceras Stevensoni (Whitfield) is represented among the specimens sent me from Yale Museum by a fine specimen and the youngest part of this specimen indicates a change in the spiral, but the young was not sufficiently defined to enable me to place the species in its proper genus.

I have before me a fragment of a whorl very similar to *Stevensoni* in costæ and tubercles, but of larger size than is usual in that species, and yet this has an irregular contact furrow on the upper side. The irregularity of this furrow may be due to age and the species may have been a true turrilites-like form when younger, or it may indicate that the separation of shells with the helicoceran mode of growth into different genera from true turrilites-like shells with a contact furrow is artificial and not advisable. This fragment reported as found at Colorado City Mineral Springs, and is in Museum of Comparative Zoölogy.

Helicoceras umbilicatum, Meek, *Invertebrate Paleontology*, Pl. xxii, Fig. 5, is probably a close ally of *Stevensoni*, but my information is not satisfactory.

Heteroceras Conradi, as figured by Whiteaves in *Mesozoic Fossils*, i, Pt. ii, Pl. xii, and supposed to be identical with *Ammonoceratites Conradi* of Morton is also a form that is not sufficiently well-known to be referred to its proper genus. The costæ have no tubercles and resemble those of the young of *Nostoceras Stantoni* and *helicinum*. There is also obviously a retroversal gerontic volution shown by Whiteaves in his Fig. 3, and there is apparently no contact furrow, the mode of growth being helicoceran and not turrilitean.

It may be useful in connection with these descriptions of phylogerontic forms to note the fact that there are some series of true ancyloceran forms in this country having shells revolving in symmetrical spirals in the same plane, and not having helicoidal ephebic stages. They are similar to most of the European series, and it is not advisable to name them till proper comparisons can be made.

Ancyloceras percostatum and *Rémondi*, Gabb, described in *Paleontology of California*, are good examples of species having this kind of spiral.

Lindigia.

This genus Karstens,* with *Lindigia helicoceroides* as the type, has (in this small species) linear, untuberculated costæ, a helicoceran spiral in the ephebic stage, and comparatively a very large and long retroversal gerontic volution.

Heteroceras Conradi of Whiteaves may be a species of this genus occurring in North America, but Lindigia has peculiar ventral crests in the costæ of the anagerontic substage that are quite distinct from those figured by Whiteaves in his species.

Helicoceras simplicostatum of Whitfield resembles this species, but it may nevertheless be the parephebic substage of some other tuberculated species which has lost its ephebic tubercles.

Nostoceras,† n. g.

The species of this genus have a close-coiled unsymmetrical shell during the ephebic stage and are true turrilites. There are two

* *Geol. de la Colombie*, Venezuela, etc., Pl. i, 1856.

† *Νόστος*, a return.

rows of ventral tubercles, which become more or less deflected during development towards the lower side (whether this be the left or right side) of the whorls. There is a contact furrow which is maintained as long as the whorls are sufficiently close coiled and then disappears on the free gerontic volution. This volution is excentric and then recurved as in all retroversal living chambers. The nepionic stage is not yet known, but it is obviously quite different from that of the more loosely coiled helicoceran spirals of the genus Emperoceras.

This genus has the two rows of ventral tubercles and general aspect of the shells of Ptychoceras and Emperoceras, described in this paper and these characters contrast decidedly with those of the Helicancylus phylum.

The nepionic and perhaps earlier neanic substages are not known, but there are indications in some specimens of *Nostoceras helicinum* that in the early neanic substages the whorl is not a normal ammonoidal spiral, but an open, whorled, irregular shell of some kind. The specimens I have in hand also show that in both species, *Nostoceras Stantoni* and *Nostoceras helicinum*, the last neanic or earliest ephebic substage has no contact furrow and has single costæ without tubercles. The ephebic stage has tubercles as a rule, and more or less bifurcated costæ, but both may be absent in some shells. The gerontic volution is apt to have tubercles even when they are absent in the ephebic stage.

This genus is of interest in connection with the history of the impressed zone because here, as in other allied forms, this characteristic enters upon a new phase of its history. The nepionic stage being unknown, one cannot state positively that it has a close-coiled shell and a contact furrow, but since this has now been found in so many uncoiled forms, it is legitimate to infer that it was present. In such shells the contact furrow which arises after the degeneration and loss of the nepionic contact furrow is obviously distinct, occupying the side and not the dorsum of the whorl.

The type is *Nostoceras Stantoni*, U. S. National Museum; Loc., Chatfield, Novarro county, Texas.

Nostoceras Stantoni.

Loc., Chatfield, Novarro county, Texas.

This species has several varieties.

Var. retrorsus.

This variety has from five to six complete turrilites-like whorls before the retroversal gerontic stage begins. The apex does not exhibit any indications that the species had an excentric young stage even at the small diameter of 5 mm. in one specimen. There appear to be no tubercles on the earliest whorls examined, probably the neanic stage. Two irregular rows of tubercles are introduced in the ephebic stage with alternating untuberculated costæ. The tuberculated costæ are sometimes bifurcated, and sometimes single. The costæ are closely set, subacute ridges, with concave flutes between them both, arching apically, the flutings broader than the costal ridges, but the surface is otherwise smooth.

The height of the coil is over 40 mm. in the largest specimen, through the ephebic whorls, although the apex is imperfect. In two other specimens this length is much less, although the number of the whorls is about the same. The diameter of this specimen through the parephebic whorl is 34 mm. The height (transverse diameter) of the parephebic substage is 19 mm., the ventro-dorsal diameter about 13 mm. The diameter of the umbilical opening must have been less than 12 mm.

The costæ are wider apart in the last of the ephebic stage, or parephebic substage, and I expected to find that they died out altogether for a certain space, but there was no evidence of this. They, however, appear to be slightly more prominent on the gerontic volution than on the parephebic substage.

The contact furrow begins early, being present on the smallest whorl examined. There is therefore no positive indications that this species had uncoiled or excentric young as in Emperoceras.

In the anagerontic substage the whorl bends downwards or orally in two dextral specimens, and in the metagerontic acquires larger tubercles and coarser costæ, sometimes bifurcated, and bends upwards towards the base of the ephebic volution, forming the retroversal living chamber. The last part of this, or the paragerontic substage, is nearly or quite straight, the bifurcations disappear, leaving the costæ straight, and the tubercles also gradually disappear. The latest senile substage is also nearly if not quite bilaterally symmetrical and strongly contrasts in this respect with all the stages preceding the metagerontic substage. The return to the symmetrical form of whorl really begins in the metagerontic substage. The living chamber has an aperture in one specimen. This is straight across the venter, has slight crests on the sides, and is straight or with very slight crest on the dorsum.

Mr. Stanton has kindly examined the numerous specimens in the National Museum, and estimates that the retroversal chamber in this variety is generally the sixth or seventh volution and also remarks that one specimen is nearly double the size of the largest one mentioned above, and that there are but few that are smaller. The three specimens I have of this variety are dextral, but there are others in the National Museum which are sinistral.

Var. prematurum.

This variety has more closely set costæ and smaller tubercles and the gerontic stage begins earlier, there being, if my estimate is correct, only three or four closely coiled whorls. The last volution is well preserved in the only specimen of this variety that I have and this shows clearly an open aperture, almost straight across the venter, with slight crests on the sides and equally obscure crest on the dorsum. It is, in other words, precisely similar to the aperture of variety *retrorsum*. The specimen here described is sinistral, and is the only one obviously belonging to this variety in the collection of the National Museum.

Var. aberrans.

This variety may have three, four or five closely coiled whorls and considerable variation in the tuberculations, etc., but when the gerontic stage begins, the aspect is distinct. The anagerontic substage does not bend so abruptly as in *retrorsum* or *prematurum* it is more oblique to the axis of the spire and the retroversal metagerontic substage, if it be superadded in this variety, would be more oblique than in var. *prematurum*. One specimen is dextral and the other is sinistral.

Remarks.

This species was discovered by Mr. Stanton in the Ripley beds, where it is associated, as stated by the same gentleman, with a number of other phylogerontic species, such as two species of Ptychoceras, *Turrilites splendens*, Shum., *Nostoceras* (*Turr.*) *helicinum*, Shum., *Helicoceras navarroensis*, Shum., and a variety of other typical Ripley species. Mr. Stanton also informs me that out of 26 specimens in the National Museum, 16 are dextral and 10 are sinistral.

Nostoceras helicinum.

Heteroceras helicinum, Shumard.*

Loc., Chatfield, Novarro county, Texas.

At the diameter of 8 mm. in one of the two specimens before me, there are indications that the young was more loosely coiled, and perhaps more or less excentric in comparison with the later closer-coiled stages. The contact furrow was also obviously absent in these earlier substages. In the other specimen, at diameter of about 9mm., there are similar indications. Nevertheless, I was by no means sure of what these changes indicated, whether a helicoceran, scaphetoid or hamites-like shell. All that can be said is that they show irregularities in the growth of the young not present in the turrillitean volutions of the ephebic stage.

The young, probably in the anephebic substage, has single costæ, each tuberculated on either side of the venter. These become more or less irregularly bifurcated, and with intermediate entire costæ without tubercles, usually one, sometimes two, in each interspace in the metephebic substage. The whole is a flat turbinated coil of not more than four or five whorls with prominent tubercles and costations.

In the anagerontic substage the volution abandons the spiral, the contact furrow disappearing immediately, and the shell grows downwards and outwards, as in the anagerontic substage of *Nostoceras Stantoni*, var. *aberrans*.

The single tuberculated costæ of the young are similar to those of the later stages of *Ancyloceras Jennyi*, Whitf., *Pal. Black Hills*, and some of the helicoceran forms found elsewhere; but the young shells were obviously quite different, being more closely coiled and stouter shells. Specimen in Coll. U. S. Nat. Mus., No. 21103.

Didymoceras,† n. g.

There are a series of forms having loose helicoid spirals, two rows of more or less irregular ventral tubercles and irregularly bifurcated costæ, which also have, or appear to have, a gerontic stage with a retroversal volution, as in Nostoceras. These are all larger shells and are separable by the helicoceran mode of growth in the ephebic stage.

* Received through the kindness of Mr. T. W. Stanton, who identified the species.

†Δίδυμος, double.

Beside the type form, *Didymcoeras nebrascense*, in the Yale University Museum, there are several closely allied species, as follows: *Didymoceras (Het.) cochleatum* and *tortum*, Meek, *Invertebrate Paleontology*, Pl. xxi.

Some of the species described by Whitfield and others from the Black Hills have similar ornamentation and helicoceran whorls, and probably belong to the same series, if not this genus. I refer to *Heteroceras Newtoni*, *Exploration of the Black Hills*, Pl. xv, and its possible gerontic stage, *Ancyloceras tricostatus*, Fig. 7 of same plate. With regard to this form I have, however, doubts arising from its close resemblance to *Nostoceras helicinum*, and these make it necessary to study the young before it can be definitively referred to the same genus with *Nebrascense*.

Didymoceras nebrascense.

Heteroceras nebrascense, Meek (*Invert. Foss.*, Pl. xxii, Fig. 1).
Heteroceras, Whitf. (*Pal. Black Hills*, Pl. xv, Fig. 6).

Loc., Near Buffalo Gap, S. Dakota.

Pl. xiv, Figs.

The young of this species is unknown, but the younger stages of the closely allied cochleatum show that it did not have a contact furrow—at least in the early ephebic substage. The metephebic substage has more or less irregular, obscure tubercles and rather fine, closely set costæ, occasionally bifurcated at the tuberculations. These disappear in the parephebic substage. The geronic volution is retroversal as in Nostoceras. The costæ increase in size and prominence in the anagerontic substage, and also become tuberculated and bifurcated. During the metagerontic snbstage these characters are more developed, and the volution makes a retroversal bend. All of the ornaments are lost, however, in the paragerontic substage, the costæ depressed and finally disappear except on the venter, and the whorl becomes again bilaterally symmetrical. The costæ and lines of growth bend slightly forwards across the venter, then backwards into sinuses on the inner parts of either side and form symmetrical crests across the dorsum. The aperture is preserved in this specimen and shows the same outline.

Mr. T. W. Stanton* in discussing a collection of fossils from Fort Pierre shales, near Boulder, Colo., described substantially the same remarkable characteristics in this species and in *tortum*, and

***Proc. Colorado Scien.* Soc., ii, Pt. iii, 1887.

was the first to state that most of our Western forms of Heteroceras probably had similar irregularities in the development of the last volution.

*Emperoceras,** n. g.

The young are hamites-like, so far as known in the neanic stage and become helicoceran in the ephebic stage. It is not positively known that they have an extended gerontic stage.

EMPEROCERAS BEECHERI.

Loc., Near Buffalo Gap, S. Dakota.

This species has, in the earliest substage, observed probably the metaneanic straight volution with straight costæ, having each two minute tubercles on the venter, and no intermediate untuberculated and single costæ. The section is compressed oval, the dorsum broader than the venter. The siphuncle is certainly in the mesal plane between the rows of ventral tubercles in this substage. The sutures are simple and appear to be symmetrical, or more nearly so than in the succeeding substages.

The paraneanic is introduced when the hamites-like first bend of this specimen is made, and is terminated by a permanent constriction in the elbow of the second bend in both specimens of this species. Bifurcated costæ appear and intermediate untuberculated costæ in this substage.

The next arm, probably the anephebic substage, is bent more or less downwards, but the curvature is distinct from that of the metephebic stage, and the form of volution in section is still a depressed oval, although much more gibbous on the upper than on the lower side. The section is that of a compressed ellipse, the ventrodorsal diameters increasing faster than the transverse.

The intermediate single costæ running uninterruptedly across the venter are more numerous in this substage, occurring from one to three between each bifurcated and tuberculated costation. The bifurcations are not always well marked, but they are more distinct than those given in the drawings, and here and there a costation may be single and have tubercles. This volution begins to twist in the metephebic substage, and the asymmetrical helicoceran form is fully developed in the flattening of the lower side and the increasing gibbosity of the upper side, whether this be right or left, and the tubercles are correspondingly deflected. The siphuncle has

*Ἔμπηρος, deformed.

shifted less, and consequently the upper row of tubercles is brought over the trace made by this organ in the cast of the interior. Great irregularity appears in this substage, the costæ may be bifurcated at the tubercles and between them, or they may run across the venter and be bifurcated at the base of the tubercle of the opposite side. This ornamentation is similar to the fragment figured by Gabb in *Paleontology of California* as *Ammonites Cooperi*, Vol. i, Pl. xiv.

The dorsal crests formed by costæ occupy the somewhat flattened dorsum of the early part of the paraneanic substage, but when the twisting begins these dorsal crests begin to be unsymmetrical also. In other words, the lines of growth and costæ assume the usual direction and aspect of turbinate shells, whether Gasteropoda or Cephalopoda.

The spiral is quite irregular in the anephebic substage, but is more regular in the metephebic and parephebic substages. In the parephebic substage the tubercles disappear in this specimen.

There is a decided contraction of the transverse diameter of the spiral in this substage.

The absence of the tubercles on this substage is similar to the change that takes place in *Nostoceras nebrascense* at the same age and enables one to classify all the substages satisfactorily.

Exiteloceras,* n. g.

After a careful survey of the forms referred to this genus, it has become evident that there is a series having the following characteristics and quite separable from the full-grown stages of any other genus referred to the Nostoceratidæ. They are, however, not so easily separated from the young of Nostoceras if my observations are correct, since the single costæ with two lines of tubercles are found in the young of that genus and of Emperoceras. This, however, is entirely in accord with the system advocated in this and other publications and is in my opinion another argument in favor of distinguishing the group by another name.

The series of forms figured by Meek in his *Invertebrate Paleontology*, Pl. xxi, have a single costæ with two rows of tubercles, each costation being tuberculated. The ephebic stage is helicoceran and the gerontic stage probably has the retroversal living chamber.

* Ἐξίτηλος, becoming extinct.

The species are as follows: *Exiteloceras* (*Heteroceras*) *Cheyennense* and *angulatum*. *Exiteloceras* (*Ancyloceras*) *uncum*, Meek, *Invertebrate Paleontology*, Pl. xxi, is probably a fragment of the gerontic stage of one of these.

Exiteloceras (*Ancyloceras*) *Jennyi*, Whitfield, *Paleontology of the Black Hills*, Pl. xvi, has also similar ornamentation, but the costæ differ somewhat. This form, if the drawing is correct, has a tendency to asymmetry and when older was probably helicoidal.

Ancyloceras lineatus, Gabb, *Paleontology of California*, has also similar costæ, form and tubercles, but this may be a fragment of Ptychoceras.

I have also before me two fragments, one 20 mm. in transverse diameter by 19 mm. ventro-dorsally, the other 17 mm. transversely by 20 mm. ventro-dorsally, which have precisely the costæ and tubercles of *Exiteloceras angulatum*, as figured by Meek, namely, very prominent, subacute single costæ reaching completely round the whorl, each one having two tubercles on the venter with a slight depression on the prominent costation between them. They are fragments of helicoceran whorls and the aspect is altogether distinct from that of any form in other genera. Loc., Elm Fork, Dallas county, Texas. *Hamites Fremonti*, Marcou, *Geology of North America*, p. 36, Pl. i, Fig. 3, is probably a gerontic stage of some species of this group. The anagerontic substage in his figure has single costæ without tubercles, but the metagerontic substage has the retroversal bend and every third costation has two ventral tubercles. All costæ are single and prominent.

Exiteloceras (*Helicoceras*) *pariense*, White, *U. S. Geol. Survey W. 100 Merid.*, Wheeler, Pt. i, *Pal.*, Pl. xix, Fig. 2, is another species of this series which shows by the twist in the costations that it is probably in older stages helicoidal.

Ptychoceratidæ.

I use this family name here provisionally and only in order to make clearer the essential distinctions that seem to exist between the series represented by the genera, Sciponoceras, Ptychoceras and Diptychoceras and other series of genera described in this paper.

The young, so far as known, have slight, smooth shells in the neanic stage, the ephebic stage has the lines of growth and costæ inclined forwards in passing over the sides and venter and probably corresponding apertures like those of Baculites, but with less prominent rostra or ventral crests. As the gerontic stage begins the aperture changes in outline and the shell bends with a sharp curve and forms a gerontic perforation, which is long and narrow. A gerontic dorsal furrow appears in this bend and beyond it a gerontic contact furrow also appears. In Sciponoceras the gerontic stage has not been fully observed and in Diptychoceras these gerontic characters begin to appear in the ephebic stage.

The family characters are therefore simply the straight mode of growth and the changes in the aperture and also probably the tendency observed in all species of Ptychoceras to lose the rostrum in old age. This can be seen in the backward or aborad inclination of the costæ on the gerontic arm as compared with the forward curves of the same in the ephebic stage on the opposite parts of the first arm.

*Sciponoceras.**

This form apparently completes the series of which Ptychoceras and Diptychoceras are obviously members. In comparing these two last and in studying their development and comparing them also with the young of Emperoceras I was struck by the peculiar form of rostrum or low, broad, ventral crest indicated by the lines of growth in the ephebic stage and the irregularities of the constrictions indicating apertures especially at the gerontic bends. The apertures of the ephebic stage may have had considerable resemblances to the apertures of species of Baculites in the ephebic stage, but when old age approaches the modifications attending the tendency to bend in Ptychoceras are entirely distinct and the apertures altogether different.

These facts are nicely shown in D'Orbigny's figures of the type of this genus, *Sciponoceras* (*Baculites*) *baculoides*, Terrains *Crétacés*, Pl. cxxxviii. This shell at first appears to represent the ephebic and younger stages of a species of Ptychoceras, but on more closely examining the drawing, if this be correct, it can be seen that it is an outgrown or aged specimen having a gerontic stage of its own. This is indicated by the partial disappearance of the costæ near the terminal aperture, which is also just beginning to make the first gerontic bend and has an entirely different outline from the constrictions figured below on the cast of the same specimens.

* *Σκίπων*, a staff.

The extremely attenuated and much elongated cone of this species is also altogether different from that of Ptychoceras.

Another very interesting line of investigation is suggested also by these studies. The resemblances of this shell and the full-grown and senile stages of Baculites are indications either of affinity or very close morphic parallelism. I am personally inclined towards the latter opinion since Baculites itself seems to me to be a composite of the extreme phylogerontic forms of several different genetic series.

Ptychoceras.

This genus is interesting here on account of its relations to the gerontic stage of Helicancylus and also because of the presence of a secondary development of the impressed zone, which appears during the gerontic stage of the ontogeny of most of the species now referred to this genus. This last character and the close angular bending of the straight limbs of the whorl, separate the species wherever they occur. It is very likely that eventually this and Baculites will be split into distinct series and shown to belong to a number of different genera, but just now, with the exception of Sciponoceras, this is not desirable.

The American fossils I have seen all have the two rows of ventral tubercles and are not similar to the Helicancylus phylum in their ornamentation. They are much more like the young of *Emperoceras Beecheri* in the singleness and tuberculation of each one of the costæ.

PTYCHOCERAS CRASSUM, Whitfield.
Loc., Near Boulder, Colo., Cretaceous.
Pl. xiv, Figs. 18–21.

Fragments of this species kindly loaned me by Mr. T. W. Stanton and identified by him show the following significant facts in the history of the impressed zone. The ephebic stage, which is I think the latter part of the straight arm with closely set tuberculated costæ inclined orally, is of the usual rounded form in section. The venter between the two rows of ventral tubercles is narrower than the dorsum, which is somewhat flattened but still entirely gibbous, the ventro-dorsal and transverse diameters are nearly equal near the bend. As the bend is made a decided enlargement of the ventro-dorsal diameters occurs and the costæ after this become more widely separated and are inclined apically and the sides flatter. This difference in the inclination of the ribs shows that the slight crest in the lines of growth and probably apertures of the ephebic stage have been lost in the gerontic stage.

The dorsum as the bend is made becomes flattened and when this is completed it is a distinct furrow which cannot be called a dorsal furrow or a contact furrow. The true dorsal furrow, if it occurred at all in this form, must have been between the protoconch and the apex, the true contact furrow probably did occur in the nepionic stage which has not yet been seen.

This furrow then which occurs in the bend before the contact of the gerontic volution or arm takes place is probably a gerontic dorsal furrow. The lines of growth in this furrow are bent forwards into a slight but well-defined crest in two of the specimens examined and the costations were wholly absent. The umbilical perforation which occurs here is not very small and it occurs between two straight volutions and is the reverse morphically of the nepionic perforations; thus it also is a gerontic perforation and not an umbilical perforation, a degenerative and not a progressive character. The length of this perforation was 4 mm. more or less in three specimens; the vertical diameter was very much less but was not measurable.

Just before contact takes place one costation crosses the dorsum with a forward bend or crest in two specimens. Close to it, but at the contact, in another specimen, there occurs a costation which is the reverse of this, having a sinus which marks the beginning of the gerontic contact furrow. This furrow in the only fragment showing the dorsum in older parts of the gerontic stage obliterates the costæ. The lines of growth were nowhere visible in this contact furrow, so that, whether this side had crests or sinuses in the apertures, could not be observed.

PTYCHOCERAS TEXANUM, Shum.*

Loc., Chatfield, Texas.

Three fragments of this species, sent like others through the kindness of Mr. T. W. Stanton, show peculiarities with reference to the gerontic contact furrow and gerontic dorsal furrow, resembling essentially those described for *Ptychoceras crassum*, but in this

*Identified by Mr. T. W. Stanton. See Shum., *Proc. Bost. Soc. Nat. Hist.*, viii, p. 190.

small fossil the gerontic umbilical perforation is much larger and wider in proportion.

One in fact begins to find the same difficulties in the application of the purely mechanical theory of the origin of the gerontic dorsal furrow here that was mentioned in accounting for the origin of the dorsal furrow in the nepionic stages of the close-coiled Nautiloids. My opportunities and materials do not permit me to discuss the subject intelligently but merely to note the facts.

One fragment of a volution or an arm, apparently of this species and identical in every way with the other two of the same lot in ornamentation and form, has, however, a gibbous dorsum.

It is either not a Ptychoceras or it is the paragerontic substage of this species after it has passed the age in which the gerontic contact furrow is present, or else, as I have suspected from the examination of other species, any species of Ptychoceras may have modifications that would place it in the genus Hamulina, *i. e.*, some specimens may not be closely appressed in the gerontic stage and may not have the gerontic contact furrow.

*Diptychoceras.**

The single species described by Gabb as *Diptychoceras lævis* is of interest in this connection as a further modification of Ptychoceras.

It has in its ephebic stage a straight arm occupying the same position with relation to the younger or first straight arm as that of the gerontic arm of Ptychoceras. That this is the ephebic stage is shown not only by the presence beyond it of the third straight arm, but also by the presence on the second arm of costæ that incline orally in passing on to the venter.

The gerontic characteristics of Ptychoceras are therefore only in part, not as a whole, carried back into the ephebic stage of Diptychoceras. The gerontic stage or third arm in the ontogeny of the shells of this species is similar to that of Ptychoceras and this has its own gerontic characters. The tendency to the peculiar mode of growth first found in the gerontic stage of Ptychoceras, the closely appressed retroversal straight limb is, however, inherited in the ephebic stage of Diptychoceras.

It would be interesting to follow out the history of the impressed zone in the gerontic stages of shells of this species, but I have no

*Gabb, *Pal. Cal.*, ii, p. 143.

materials. Gabb states that both the second and third arms envelop more or less the preceding, and they must therefore have contact furrows in both stages.

VI. Summary.

The importance of the impressed zone can be made apparent better by discussing the correlative facts of the morphology than by any other means.

When one considers the mode of growth of the young of any one of the straight or primitive arcuate forms of Nautiloids, the prominent fact is the bilateral symmetry of the cone and the asymmetry of the ventral and dorsal sides as in *Spyroceras* (?) *crotalum*, Figs. 10–12, p. 361, and the young of other forms, p. 360. It is obvious from these drawings and other observations that this asymmetry is due to the more rapid growth of the ventral as contrasted with the dorsal side. This is shown by the greater breadth of the bands of growth and the intervals between the sutures that are greater on that side. Subsequently in the ontogeny of the straight forms, in Endoceras, Orthoceras, the growth becomes more nearly equal and in many forms is practically equal and the shell is built out in nearly straight lines. The angles of the curves made by the dorsal and ventral sides near the apex are on this account entirely distinct from each other, the venter departing from the end of the cicatrix at a much wider angle than the dorsum, which is much less inclined and soon tends to assume an almost straight line.

The two sides, venter and dorsum, tend therefore to become less divergent after the nepionic stage is passed, but they nevertheless continue as long as the cone increases in the ventro-dorsal diameters to grow in more or less divergent directions during the neanic and ephebic stages except in the living chambers of certain species. In these the diameters become shortened towards the aperture and the sides converge more or less either in the lateral or ventro-dorsal diameters or in all diameters. This occurs in some species only in the gerontic stage, but in others it may occur at any stage after the nepionic.

In all shell-covered cephalopods, so far as known, the nepionic shells have open apertures and all four sides are continually divergent in these younger substages of development. The asymmetry of the apex of the conch in all arcuate and coiled forms is also very strongly marked and there is an obvious correlation between the close coiling of the young, the size of the umbilical perforation and the rate of increase of the outer or ventral side. Thus in shells with large umbilical perforations, the first whorl increased slowly and was more nearly equal on the ventral and dorsal sides than in those with small perforations in which the outer sides or ventral increased much faster than the inner. This is shown by the lines of growth whenever they are observable and by the distance apart of the sutures, both of these being much more widely separated on the venter than on the dorsum, and also by the extremely long and gibbous outline of the venter as compared with that of the dorsum.

One can readily illustrate this by drawing a circle with lines radiating from the centre and then roughly projecting upon this background the figure of any of the species given, allowing the centre of the radii to coincide with the centre of the umbilical perforation. It can then be easily seen, that as the whorl grows, if the umbilical perforation be small, the outer side has necessarily in keeping pace with the inner to describe a much larger arc in proportion than it does when the umbilical perforation is larger. This necessarily follows because the two sides, starting from a given place in the plot of the radii, are more nearly parallel in proportion as the perforation is larger. Thus in shells with small perforations the increase of the ventro-dorsal diameters of the body is often much in excess of all other diameters and this preponderance in highly involute shells may be continued until near the end of the gerontic stage. The proportional increase in breadth of the growth bands of the venter as compared with those of the dorsum is a corollary of this proposition, or in other words the bands on the outer convex side necessarily have quicker growth than those of the dorsum, being built out farther in the same periods of time.

The ananepionic substage, as a rule, has the lines of growth straight or with ventral crests broader in the median line than at any other part, but in the metanepionic or early paranepionic at latest the hyponomic sinus is introduced. While the bands of growth still remain broader on the venter in spite of this depression on that side, there is after this stage a constant lagging behind of the central ventral surface due to the presence of the hyponome.

Among Ammonoidea this is not the case except in the more generalized Goniatitinæ.* The higher Goniatitinæ and almost all shells of the remaining suborders of this order have a rostrum on the venter. Shells having this peculiar structure, due to the absence of a hyponome, continue to increase or broaden out the bands of growth after the rostrum is introduced into the ontogeny, producing often long-pointed or palmate growths. This is certainly independent of the spiral mode of growth and has no effect upon it, since the rostrum is very well developed in forms like Baculites, having phylogerontic straight whorl, and it may be entirely absent in the gerontic stage of Ptychoceras and in forms with lateral lappets to the apertures as in some Scaphites and other genera which are more closely coiled.

Taking into consideration all of such facts there still remains a certain obvious and necessary relation between the ratios of growth of the bands on the outer and inner sides of a coiled shell which has been described above, and which is a mechanical necessity of growth in a spiral.

It is also true, as a rule, that the lateral diameters increase faster in shells with small umbilical perforations than in those with large open centres. But this seems to be merely a function of the quicker growth and general accompaniment of the early age of such types and to have direct exceptions that do not enable us to bring it under any uniform law. Thus Estonioceras is a type with large umbilical perforations and slow-growing ventral bands of deposition, but the lateral diameters increase fast as in the young of some forms like *Estonioceras imperfectum*, Figs. 20 and 21, Pl. vii.

In nearly all shells there is a noticeable tendency to decrease the lateral diameters in the later nepionic and neanic stages, and is obviously due to Minot's law of growth, which is noticed in the Introduction, p. 381.

Among Nautiloids it is observed in Trocholites as a generic character occurring in the neanic stage and is in these species and in the nepionic stage of Ammonoidea an absolute decrease so well marked that in the former the apex and in the latter the protoconch are not covered and can be seen beyond the outer volution, this being the usual aspect in a ventral view of a Goniatite or the young of Ammonitinæ.

A similar decrease occurs in other forms of Nautiloids than

* See Introduction, p. 355.

Trocholites,* but is usually less and occurs later and more slowly and it is not an absolute decrease. That is to say the outer whorl never falls off so much in the ratio growth as to become actually smaller than the inner volution in any of its diameters until the gerontic stage. In this stage the falling off in the rate of increase by growth may and sometimes does accomplish this result on the last part of the outer whorl.

A description of the parallelism of different genetic series and the constant and often repeated tendency that these exhibit to evolve a series of similar forms has been given in the Introduction. This tendency produces straight, arcuate, loosely coiled and close coiled, and finally involute shells in each group, however distinct they may be in structure.

The tendency to bend towards the side opposite the hyponome is almost universal in all shell-covered Cephalopods. There are a few arcuate species that bend towards the hyponome like Barrande's *Cyrtoceras nitidum*, but many even of his group of the so-called "endogastrica" have, like his *Cyrt. Murchisonia* and *Cyrt. neutrum*, the hyponome and therefore the true venter on the outer or convex side. There is only one genetic series or genus, as a whole, that appears to contradict this statement. All of the species of the true Phragmoceras except one, *P. perversum*, Barrande, bend towards the ventral side and about all have the siphuncle and also, of course, the azygos sinus of the hyponome in the aperture and the corresponding sinuses in lines of growth on the same side. The shells of this genus are much compressed and the apertures are very much elongated and present a unique aspect. They are contracted along the central parts and the hyponome or motor organ is removed as far as possible from that part of the aperture which must have given opportunity for the external extension of the arms. This fact, however, is counterbalanced by the aperture of *P. perversum*, this being an extreme case of differentiation and removal as widely as possible of the hyponomic and brachial sinuses of the apertures and yet the shell is bent towards the dorsum and the siphuncle is ventral. Many species of Gomphoceras (Acleistoceras) are bent ventrally, whereas others with similar apertures and characteristics are bent dorsally. So far, therefore, as the characters of the apertures go, it is not possible to state that the bending is inva-

*This peculiarity has led some authors to suppose that Trocholites had a protoconch like that of the Ammonoidea.

riably towards the dorsum, but that this is the general tendency of arcuate forms is obvious.

When it comes to the evolution of coiled forms the problem is different. Among these last, including also the loosely coiled or gyroceran, there is so far as known no exception to the rule that all such shells are bent dorsally from the earliest substages of the conch.

I have assumed in other papers that coiling among Gasteropoda could be accounted for by the unequal growth caused by the weight of the shell when carried above the foot and the facts appear to justify this conclusion in so far as that class is concerned. The presence of the hyponome on the ventral side in Cephalopoda would of itself account for the tipping of the shell towards the opposite or dorsal side both when the animal was crawling and swimming. This would leave the ventral edge of the mantle free to deposit calcareous matter undisturbed by pressure, whereas the dorsal edge would be more subject to disturbance and to shocks from compression which might interfere with the work of excretion. It is reasonable to suggest such a mechanical explanation both for the general tendency to bending and coiling and also for the dorsal direction.

If it were possible to account for the exceptions observed, as in the tendency of Phragmoceras towards the venter, by means of exceptional habits or structures, this suggestion would have more force, but unfortunately this cannot be done, at least at present. It is obvious, however, that there is some directive cause which acts upon every genetic series in greater or less proportion, giving to each evolving series the same tendency to produce in succession the straight, arcuate,* and then the coiled forms in different degrees of intensity and that most of these have coiled in a dorsal direction away from the hyponome or organ of locomotion.

The position of the siphuncle with reference to the mode of coiling need not be discussed, since it obviously has no general relations, except that it is always, except in turbinate forms, Trochoceras, Turrilites, etc., and in abnormal forms, like some species

* Even in large and some small species and specimens of Baculites there is an arcuate tendency. D'Orbigny figures this in *B. incurvatus*, *Terr. Crétac.*, Pl. cxxxix, and Mr. Stanton has put together a very large specimen of Baculites in Nat. Mus. having a curve like Cyrtoceras. This is some five feet long, straight or nearly so in the younger part and arcuate in the older stage.

This specimen is from the Ripley Formation, Texas.

of Psiloceras and one of Anomaloceras and in pathologic individuals, always in or approximate to the mesal plane. There is, however, a fact to be noted. In the Endoceratidæ and Actinoceratidæ it is always in direct connection with the cicatrix. In other forms not having an endosiphuncle* this connection is not strictly maintained, and while it is often situated over the area of the cicatrix, it may be, as in *Eutrophoceras Dekayi*, near the shell but not over the cicatrix, or as in Hercoceras, Fig. 13, Pl. viii, at some distance from the apex. There is upon the whole, however, a distinct tendency towards location in the mesal plane and centren or ventrad of the centre, those having a subdorsan siphuncle like some species of Eutrephoceras and Aturia being exceptional. In most forms, even those having siphuncle subdorsan in the second septum, it is nearer the venter in the first septum; marked examples of this are the *Eutrephoceras Dekayi* of the Cretacic, Fig. 4, Pl. xiii, and several species of Schroederoceras, or else it tends towards the centre, as in *Trocholites canadensis*, Figs. 39 and 40, Pl. v. It is also to be observed that in the adults of most forms of Nautiloids the siphuncle is centren or ventrad of the centre, that is on the same side with the hyponome. This tendency is more general among arcuate and coiled Nautiloidea than among straight forms, which as a rule have the siphuncle centren,† and finally in the Ammonoidea the subventran position is universal.

Whatever may be the cause of the general tendency of each genetic series to evolve along parallel lines of modification so far as the tendency towards coiling is concerned, it is obvious that it is not dependent upon time, climate or any special differences of structure. The bending takes place in every series even in the Piloceras with a huge siphuncle filled with calcareous matter and there is no positive proof that they may not have had coiled forms which belong to the same genetic series although none have been found. Arcuate and coiled shells are also found in every period, and under every condition of climate so far as geographic distribution is concerned.

It has been assumed in the Introduction that differences of habit could be used to account for these general tendencies producing

* See Introduction, p. 412.

† The exceptions to this rule are very interesting. They include the radical type Diphragmoceras, the Endoceratidæ and the remarkable genus Bathmoceras. All of these have the siphuncle in most examples ventrad of the centre and in many of them it is subventran.

parallelisms in the evolution of different and diverging genetic series. Thus the Belemonoids and Sepoids, both preëminently swimming types* and with organizations obviously derived from an Orthoceran radical, have straight internal shells.

There is an obvious correlation between coiling of the shell and the habit of crawling. Thus all univalve crawling mollusca have this general tendency. Among Gasteropoda, this is well known and those shells which degenerate and tend to loose the spiral mode of growth and become irregularly straightened out in these older stages of growth, are forms which become attached or lead sedentary lives, *i. e.*, Vermetus attached late in life and Magilus buried in coral. The most significant case, however, is that of Fissurella, which has a coiled shell in the nepionic stage and becomes similar to Patella, a depressed, straight cone in the neanic and ephebic stages, the habitat being like that of Patella and the approximate forms of Haliotis and others, comparatively sedentary upon littoral rock ledges.

A habit of crawling could be considered as sufficiently general in application and sufficiently persistent in an organization like that of the Nautiloids and Ammonoids, which are covered by shell and possess only the hyponome as a motor organ to affect entire orders and continue constant through time and geologic changes in the majority of forms.

With such a habit the tendency to become more exclusively crawling and to depend upon that mode of life, might, as has been explained in the introduction, produce in each series the same tendency, but it seems impracticable, so far as my experience goes, to find any other cause sufficiently general and likely to be undisturbed by geologic and climatic changes.

It is certainly not inherent in the organism to coil up. If the converse be assumed one must account for the continuance and persistence of the absolutely straight Orthoceras from the earliest times to the Trias and why these were unaltered and did not become arcuate or coiled as a whole. Inherent tendencies must, if the term has any meaning at all, work out their own evolution to some degree. They must sensibly affect the organization in all series having a common embryo unless held back or kept in abeyance by interfering causes. It is difficult to imagine any interfering cause acting so constantly through long geologic periods that it could

* See Introduction, p. 356.

hold in abeyance the inherent tendency to become coiled in the genus Orthoceras. This is more obvious when one considers that this trunk form is perpetually giving rise to branches that show the tendency to coil up. In assuming that habit is the cause as determined by the law explained in the Introduction, p. 367, the greatest difficulty seems to disappear. As long as the shells could maintain themselves in the station they have been forced into, or had chosen, just so long would they maintain the form suitable for their habits or surroundings and they would change only in proportion as they changed their stations. Thus the main line might continue as long as it existed to hold the same form while its branches seeking new habitats and novel modes of life would change in directions determined by those. Whatever the causes may be, the fact is obvious, that the tendency towards becoming arcuate and coiled is general in the descendants of straight shells and not confined to any special series or time.

That it is an acquired character seems also to be a reasonable conclusion. An acquired character is one that is introduced into the life of the individual and is not present in the embryo before the tissues become differentiated into germ plasm and somato plasm. It is impossible to disprove or prove that a characteristic is acquired or genetic unless it can be followed back to its origin. Until this is done one cannot assert positively that it was not potentially existent in the embryo and became apparent at the proper time in the ontogeny in accordance with genetic law.

The law of acceleration can be true only upon condition that there are such things as acquired characteristics introduced in epembryonic stages. The examples given above in support of this law are all instances of acquired characters introduced late in the ontogeny and gradually forced back to younger and younger stages in successive generations, or species, or genera. This law is based upon the assumption that such characteristics exist and it is also supposed to show the mode in which they are inherited.

It is not necessary for me here to deal with any of these facts, except the tendency towards coiling among shell-covered Cephalopods. This tendency is manifested in the conch alone of the Nautiloidea, that is, in the epembryonic stages, and we can follow it as described above, both in the phylogeny and ontogeny, progressing with equal steps. That is to say, the more generalized of each genetic series show in their ontogeny that they were derived from the more loosely coiled, and the more specialized show that they were derived from forms which were tightly coiled. In other words, the tendency to closer and closer coiling gains in the organization of the different genetic series, and is manifested more intensely in the young of more specialized forms and makes them coil more quickly and closer. In general, it is also easily seen that after the trunk forms die out in the Trias, as explained in the Introduction, page 370, and it is not possible for any new genetic series to be given off from these, this tendency has greater force. In the Jura and Cretaceous the shells are exclusively nautilian, and even the nautilian shells with very large perforations, common even in the Triassic, have entirely disappeared.

In the shells shown on Pl. xi–xiii there is not one that has a really large umbilical perforation and a free cyrtoceran apex, such as is seen in so many of the Silurian, Devonian, Carboniferous, and even in some Triassic shells. All of these transitional forms disappear with the trunk forms, and the same fact is true of the Ammonoidea. The transitional forms disappear in the Devonian at the same time with Bactrites, the radical straight form of this order. With regard to special series, it becomes more difficult to show agreement between chronology and bioplastology on account of the deficiencies in the records of collected forms and the general tendency of radical species to persist and be found either on exactly the same level with their descendants or even to outlive them and be present in later faunas.

In studying the coiling of nautilian shells one is struck by the fact that the ana- and the metanepionic substages are comparatively straight. They are not really straight, as has been explained above, but their comparatively straight aspect, in contrast with the succeeding stages of development, is noticeable.

At the end of the metanepionic substage the curvature is apt to be suddenly altered, bending more rapidly inward. This is what I have called the gyroceran bend, because it is the first indication that the shell is a true nautilian form. If one compares the length of the ana- and metanepionic substages in the different plates beginning with Pl. iv and ending with Pl. xiii, it will be seen that there is a notable decrease in the comparative length of these two substages when the umbilical perforations become very small, and the same is true of the species of the Calciferous and Silurian, which have small umbilical perforations, as shown on Pl. iv–vi.

In many shells with very large perforations the curvature is often uniform, and there is no sudden alteration in the direction of coiling of the first whorl, as in several Carboniferous forms and the remarkable shell *Pleunautilus superbus*, Pl. xii. The same is true of the coiling of all gyroceran forms in their ephebic and earlier stages. The coiling is more uniform than that of more specialized and more closely coiled shells. This, and the presence of smaller umbilical perforations in the same genetic series, is easily accounted for if we admit that the tendency to become closer coiled is genetic, and that in accordance with the law of tachygenesis it affects the growth of the young earlier in the more specialized and later-occurring forms, thus shortening up the ana- and metanepionic substages.

The elliptical outline in section, the universal rotundity of the dorsum in the ana- and metanepionic substages and the sutures, serve to reinforce the assumption that these substages derive their characteristics, so far as form is concerned, from arcuate or straight ancestors. This is in general the adult characters of most species of groups having orthoceran or cyrtoceran forms, and in none, except Cranoceras of the Devonian, has any signs of a dorsal furrow been found. The ornamentation of these substages, and usually the paranepionic, in part or as a whole, also points distinctly to some straight or arcuate ancestor. The ananepionic substage is universally smooth or with only a few longitudinal ridges, but the metanepionic varies more. The form and markings in Vestinautilus, Pl. ix, point distinctly to a similarly ornamented arcuate ancestor, and the gradual shortening up of the younger substages is also shown by the figures on this plate and the explanations.

The outline of the first volution changes abruptly at or immediately after the beginning of the gyroceran bend, that is, at the beginning of the paranepionic substage in most nautilian shells. The dorsum is apt to become flatter in species having large umbilical perforations, and in those with small perforations, this tendency is intensified and the dorsum is apt to become concave, the dorsal furrow making its appearance. The sutures of the ana- and metanepionic substages are apt to have ventral and dorsal saddles, whereas a dorsal lobe very often appears in the paranepionic, ex., Barrandeoceras. This dorsal lobe is still more plainly marked when the dorsal furrow is present in the paranepionic volution.

The flattening or broadening out of the dorsum, which occurs in a great many forms in the paranepionic, is paralleled by the similar tendencies occurring in shells that have the whorls contiguous. This is the first effect of contact, and the formation of a lobe in the sutures also very commonly accompanies slight contacts. Nevertheless, dorsal lobes in the sutures and the flattening of the dorsal side may occur in cyrtoceran and gyroceran coils of species that appear to be transitional, from more primitive uncoiled to the close coiled nautilian forms, as in *Barrandeoceras Sternbergi*, Pl. xiv, and other examples, such as *Aphetoceras boreale*, Pl. v.

These characteristics obviously exist under different conditions on the free whorls of primitive shells and the similar whorls of the young of nautilian shells than they do on whorls which are in contact. In order to make these distinctions clear, I have named the dorsal hollow zone that appears before or independently of contact, *the dorsal furrow*, and that which occurs after that, *the contact furrow*, both being considered part of the same feature, the compressed zone.

Before proceeding further it is necessary to study the origin and history of the impressed zone, and to define it more clearly than has been done in the preceding pages.

In the first place, as already stated, it does not exist in any of the trunk or radical forms, except Cranoceras. Its first appearance, so far as the morphology is concerned, is in nautilian forms after contact, and this occurs constantly in different genetic series. In fact the definition of a nautilian shell is based upon the possession of a contact furrow.

If we regard any genetic series by itself we can often see that the impressed zone is purely a contact furrow. Thus, in the Estonioceras, it is absent in the umbilical perforation on the dorsum of the nepionic stage and it is slight and present only in the contact stages, being soon lost upon the free part, or gerontic stage of the coil. In other species of some other groups the same thing occurs either completely or partially: Eurystomites, Pl. v; Tarphyceras, Pl. vi; Schroederoceras, Pl. vii, and so on.

In transitional species with large umbilical perforations, the dorsal furrow is not present in any specimen, although many have been examined and recorded. In the major number of nautilian forms, in the Silurian, Devonian and Carboniferous and quite a number of Triassic species, the umbilical perforations are large and there are no dorsal furrows. In many of these species the looseness of the coiling is shown by the free apex and the slight development and late incoming of the contact furrow.

It is, of course, as has been stated above, practically impossible in many series to get sufficient evidence to establish the agreement of chronology with bioplastology. But there are here and there series that show such an agreement, and give approximately complete and positive evidence in favor of the descent of nautilian from arcuate forms. But even if this agreement occurred in a smaller number of series than it actually does, the evidence from the morphology alone would be sufficient. It is not possible to explain why the apex of the transitional forms with large umbilical perforations is so often free, or the existence of the larger umbilical perforations themselves, or, in fact, any of the peculiarities of the nepionic stage, which resemble those of radical forms, except on the assumption that they have been derived from these same straight or arcuate radicals through direct genetic connection. Thus, although the chronological record may coincide with the bioplastology only in a few series, these few become positive evidence of the highest value, that confirms the inferences drawn from the testimony of the bioplastology and outweighs any amount of negative evidence derived from the incompleteness of the record.

With these remarks, we can now pass on to the consideration of the history of the impressed zone, and its mode of origin and apparent history in different series.

There are a number of orthoceran and arcuate forms that may be cited as the radicals of the Tarphyceratidæ.

These, like the history of the transitions into Aphetoceras, are almost complete, since in this last genus the curvature in the young, until a late stage, is so slight that one is not absolutely certain whether to consider that such a fragment as is figured on Pl. v, Figs. 15–17, is really a part of a gyroceran shell or a fragment of a cyrtoceran form that never coils. The position of the siphuncle, section of the whorl and sutures make the young of these forms genetically identical with the adults of such forms as *Aphetoceras Americanum*, and on the other hand the full-grown characters and large gyroceran coils, are closer in some species than in others and the genus passes by insensible gradations into the more closely coiled nautilian genus, Pycnoceras.

This last has the large umbilical perforation and almost cylindrical first whorl, slight contact furrow of an ordinary transitional form, but otherwise the nepionic stage resembles the adults of Aphetoceras in its section and position of siphuncle and sutures.

The gap between Pycnoceras and the next member of this series, Tarphyceras, is wide and one or more genera are needed to fill up the interval.

In all of the genera mentioned above, except Tarphyceras, there is no dorsal furrow, the zone of impression is produced by contact, and the umbilical perforations are large.

In Tarphyceras, however, although in form, sutures and position of siphuncle the genus is closely allied to Aphetoceras, the young are altogether distinct.

As depicted on Pl. iv, the young have very small umbilical perforations, the whorls broaden out by growth rapidly, and after a short, straight or only slightly curved apical part is built in the ana- and metanepionic substages, the broadening volution makes a sudden and very abrupt gyroceran bend towards the apex. This is very sudden and the umbilical perforation is flat or comma-shaped.

It might of course be shown, if other intermediate shells were found, that the mechanical effects of this sudden bending did not produce the dorsal furrow, but that this is an adequate mechanical cause can reasonably be claimed by those who oppose the view that it is due to heredity.

It has already been shown that the outer side or venter tends to grow faster than the inner, and if this reaches a point in its ratio of growth that far exceeds that of the inner side, it is obvious that it must act upon that side as a force that bends or tends to make it more arcuate in proportion to this excess of growth or rapidity of increase. The outer side being free would be apt to retain its genetic form, and the inner side or dorsum would be greatly influenced or moulded by the pressure to which it was subjected. Thus it can be assumed that in case of a sudden bending, as in Tarphyceras, the venter would maintain its rounded outline and forcing the dorsum inward as it grew would tend to make it assume the arcuate form or bend inwards in a crease or dorsal furrow in the paranepionic volution conforming more or less with the shape of the dorsum of the metanepionic volution.

There are some reasons why this explanation is not wholly satisfactory. In the first place, if this be the case, why did not the whorl of the paranepionic completely close the umbilical perforation and plaster the dorsal shell layers against the dorsum of the metanepionic substage? This is partly answered by the fact that the tendency to shell building on that side would prevent this until a small umbilical perforation was formed and also by the fact that in many shells the whorl of the paranepionic actually does plaster itself on to the dorsum of the metanepionic and the umbilical perforation is reduced to a very small aperture. It is, however, absolutely essential to call in the aid of heredity, otherwise the tendency to shell building in the dorsum of the nepionic stage cannot be considered sufficient to prevent the entire obliteration of the umbilical perforation. The shell on the dorsum of the older stages is in great measure absent in most nautilian shells, but there is no such difference in gyroceran or cyrtoceran forms or in loose coiled gyroceran form with the whorls touching, nor yet in nautilian form with very faint contact furrows. The tendency to build thick shell on the dorsum of the nepionic whorl, while still free, is therefore one that can only have been derived from shells having free dorsal sides and this tendency is obviously strong enough to stiffen that side and prevent the entire closing of the umbilical perforation.

In the second place there are a number of Cretaceous, Tertiary and recent Nautiloids having accelerated development of the dorsal furrow, and in these the furrow appears on both sides of the comma-shaped umbilical perforations. It is perfectly plain in these that no bending of the whorl could account for the result and that it is in no sense due to a moulding of one whorl upon another. The outlines of the dorsum of the paranepionic substage in these species does not coincide with those opposed to it; they are the reverse of each other.

Nevertheless it is practicable, as has been said above, to appeal to the curvature of the paranepionic volution at the gyroceran bend as a possible mechanical cause for the incoming of the dorsal furrow on the distal part of the curve so long as the curve is sufficiently abrupt to produce it, or so long as the absence of ancestral forms does not enable us to trace the origin of this character back to a contact furrow and account for its presence in the earlier stages of species like those of the genus Tarphyceras by the action of the law of acceleration.

I have consequently thought it safer for the sake of argument to concede that the dorsal furrow of Tarphyceras was perhaps present in the paranepionic because of mechanical and not through genetic causes.

In the Trocholitidæ the straight and arcuate forms are not yet known nor are the nautilian forms quite satisfactory.

The dorsal side of *Litoceras insolens*, which has a comparatively large umbilical perforation, has not yet been studied in the paranepionic substage, and although it seems very likely that it is gibbous and without a dorsal furrow, this cannot be stated positively. In Trocholitoceras and Trocholites, the umbilical perforations are very small and have dorsal furrows on the paranepionic after the gyroceran bend has been passed by.

The same argument can be framed for their appearance that was used for the Tarphyceratidæ, viz., that the weight of evidence is in favor of the mechanical generation of the dorsal furrow in the paranepionic. There is also one fact possibly of some importance in this connection. In the specimen of *Trocholites canadensis*, in section Figs. 39 and 40, Pl. vi, it can be seen that the inner part of the dorsal furrow, where it first appears, is a single, broad furrow. As it becomes more distant from the gyroceran bend, however, it becomes divided into two smaller furrows by the rising of a central gibbous face.

It might be assumed that the development of this central gibbous face was due to heredity, this being the expression of a tendency to return to the rounded dorsum of radical types as soon as the pressure due to the abrupt bending was removed.

Precisely similar furrows and a median gibbous face occur, however, on the dorsum of Cranoceras. The curvature of this form and all of its characteristics indicate that the bending of the cone could not have been the mechanical agent which caused a single dorsal furrow and the appearance of the two dorsal furrows and the central gibbous face complicates the problem and seems to make it insoluble on a purely mechanical basis. I have called this a gibbous face, but in reality it is not a "face" at all in the sense in which that term is here used. It is a modification of the primitive rounded dorsum and is really a "zone" or secondary modification. In Trocholites it arises as a modification of the dorsal furrow, and is therefore a true "face." It is possible that with advance of knowledge this distinction may be more important than it seems now, and may enable us to explain the exceptional characteristics of Cranoceras.

Before it could be safely assumed that mechanical causes generated the single or double dorsal furrows of *Trocholites canadensis*, or that heredity influenced the appearance of both, it would be necessary to find more forms of the same genetic series and study their history.

In some species of the genus Schroederoceras, the dorsal furrow appears as in Trocholites. The umbilical perforation is larger but still small in all of these, so that it can hardly be assumed that the bend is too gradual to have caused the dorsal furrow to arise in the paranepionic.

The gerontic stage of the species of this family, in fossils well enough preserved to be observed, has an impressed zone which is very short-lived in some species when the last whorl is free. The entire obliteration of this zone takes place in *Schroederoceras Eatoni* in one specimen, Pl. vi, Figs. 28–35, and in another it is present for a longer time after the volution becomes free, although evidently much reduced, Figs. 7 and 8, Pl. vii. In *Schroederoceras casinense*, Pls. vi and vii, similar obliteration can be observed.

The zone, however, persists long enough in these forms and others to demonstrate the important fact that it has a deep hold upon the organism. If this were not the case it could not exist in substages of senile degeneration. Its persistency is somewhat less in the species cited than many others, ex. *Eurystomites Kelloggi*, Pl. v, but it is sufficient to show that its continued existence in the ontogeny is not wholly limited by the continuance of close coiling and contact. That it is more or less dependent upon coiling with involution is obvious because it entirely disappears in some species in the older substages of the gerontic stage when these are free.

The Tarphyceratidæ and Trocholitidæ having so closely involute shells in the young are confined, with the exception of Trocholites, to the earliest or Calciferous faunas.

The next forms that one meets, having the impressed zone, occur in the Devonian. There are so far as known no shells having an impressed zone in the form of a dorsal furrow between the Hudson River group and the Devonian group, although there are many having the contact furrow.

The Devonian genus Cranoceras, referred to several times above, consists of two species with very large shells, and, so far as can be seen, purely arcuate forms, is the only case of a cyrtoceran form with a dorsal furrow that I have been able to find. The zone in this shape appears on the free inner or dorsal side and is obviously a dorsal furrow similar to that which appears on the dorsum of the nepionic stage. The section of this whorl is nephritic. The appearance of the dorsal furrow is very often in the young and in later stages of growth correlated with the appearance of a nephritic outline in the whorl. This happens so often that I at first supposed it was a general law of association the two appearing together. It is true, that in a number of forms, the nephritic form appears in association with the dorsal furrow, but in quite a number of others the outline is not nephritic, and yet a dorsal furrow arises as will be noted farther on.

The large size and gradual curvature of the cone in this genus makes it unlikely that the existence of the dorsal furrow is due to contact or to any mechanical effect of coiling. The dorsal furrow in these is either due to inheritance from other species, or is acquired in their later or ephebic stage.

The genus may be degenerate and may have arisen from coiled forms and the dorsal furrow and nephritic outline may have been derived from this source. Against this is the fact that the shells are of large size and the septa are closely approximate. Both of these characters are common in primitive Paleozoic shells and uncommon in degenerate phylogerontic series. The study of the fossils themselves does not seem to support this view of their affinities since it is difficult to point to any preëxisting coiled form from which they could have been derived. If it is assumed that they are primitive arcuate forms descended from other arcuate forms or straighter cones, it is easy to trace them back into the Silurian and point out their probable ancestors, in closely allied species which do not have a dorsal furrow.

The problem here assumes a very interesting character due to the fact that the Silurian forms of Cranoceras, *C. turnus*, and others have trigonal whorls and sutures which are in every way identical with the young of several nautilian shells of the same period and are evidently their ancestral radicals. These arcuate species, however, do not have dorsal furrows, and it seems, therefore, highly probable that here is a case of acquired characteristic coming in very late in the ontogeny of the ephebic stage, accompanied by a nephritic outline.

Contact furrows arise from close coiling in fossils like *Nedyceras vetustum* having similar subtrigonal whorls, but no examples are known in these groups of the appearance of a dorsal furrow in the young.

Anomaloceras anomalum is a remarkable Silurian fossil, on account of the habitual excentric position of the siphuncle, but this is always near the venter and in this species the form of the shell and character of the sutures show that the genus belongs in the same genetic group with Hercoceras.

In Hercoceras the evidence is very complete that the impressed zone originated as a contact furrow. In all the gyroceran forms of the allied genus, Ptenoceras, there is nothing of the sort. In the loosely coiled forms like *Hercoceras irregularis*, Pl. viii, Figs. 14 and 15, there is no dorsal furrow in the nepionic stage. Even in the closely allied *Hercoceras mirum*, although the last has a small umbilical perforation, there was no dorsal furrow in the single specimen examined and figured (Pl. viii, Figs. 11 and 12). So far it is obvious that close coiling does not of itself even with a favorable form of whorl necessarily bring about the genesis of a dorsal furrow.

If the sudden bending of a broad whorl was necessarily followed by the formation of a dorsal furrow it would certainly have been produced in *Hercoceras mirum*. A single exception in such cases becomes a very significant positive fact against this assumption, and that exception appears to occur in this species. The terminal member morphically of this series is Anomaloceras, and in the single species of this genus known, there is a dorsal furrow as shown in Figs. 16–20, Pl. viii. The umbilical perforation was small in this shell, and of course it can be claimed that the furrow in the paranepionic was produced by mechanical pressure, and not inherited from forms like Hercoceras, in which it first arose as a contact furrow.

Potoceras dubium, which has been figured on Pl. x, Figs. 15–22, has unfortunately no recorded locality, but as noted in the description there were indications that it was a Devonian fossil. At any rate, whatever its age, the characteristics were plain and the presence of a dorsal furrow in the paranepionic easily established.

The length of the ana- and metanepionic substages were decidedly Paleozoic, and so also was the large umbilical perforation. It is more difficult here to account for the genesis of the dorsal furrow upon the mechanical hypothesis than in Anomaloceras on account of the large umbilical perforation and the slow growth of the apex. Nevertheless it can be reasonably claimed that the abruptness of the gyroceran bend in this shell is sufficient to account for the dorsal furrow in the nephritic outline of the paranepionic substage.

In the preceding remarks I have dealt solely with those genetic series and forms in which the dorsal furrow appears, but there are many in which there is no sign of any furrow.

As has been said above, all of the straight and arcuate forms and the gyroceran shells, in none of which has either a dorsal or a contact furrow been found, except in Cranoceras. Passing these by, one comes to the nautilian shells which are transitional between the gyroceran and nautilian having the whorls in closer connection than in the gyroceran and a slight contact furrow. These, so far as known, have other correlative characters. The umbilical perforations are large and open, the apex of the conch is often free, the contact taking place on the venter of the ana- or metanepionic substage or later, and the whorls are subsequently never involute, or in other words, they are discoidal shells.

In these shells I have in Paleozoic time found no exception to the rule, that the dorsum of the nepionic stage is convex, and there is no dorsal furrow, a furrow being formed only after contact, and in later stages of development. One of the best examples of these series is that of Barrandeoceras. *Barrandeoceras Sternbergi* contains, as has been stated in the descriptions, two distinct forms, one *Barrandeoceras Sternbergi*, Pl. xiv, Fig. 3, has the whorls approximate, and in the other they are not in contact. The purely gyroceran character of these shells is apparent in the loosely uncoiled young as well as in the later stages. They are also valuable in showing that the flattening of the dorsum and a dorsal lobe may arise as in Pl. xiv, Fig. 5, independently of contact, and this and the form of the ephebic stage is precisely similar to that of the paranepionic volution of *Barrandeoceras tyrannum*. In this last and in *Barrandeoceras Sacheri* and *Bohemicum*, there is no dorsal furrow, but these ephebic characters of *Sternbergi* are repeated and a contact furrow is produced after the whorls touch.

Estonioceras is another series in which nearly all degrees of coiling can be studied, and here also the absence of a dorsal furrow in the nepionic stage is a marked characteristic. The contact furrow is maintained as long as the whorls are held together, showing progressive growth, but this rapidly disappears in the gerontic stage, as shown by the figures given on Pl. v and vii.

Remeléceras impressum is also a good example of the generation of a contact zone in the later stages of development given on Pl. viii, Figs. 1–8.

Another belonging to the same category is Eurystomites, of which the species are described and figured on Pl. v. This genus has also its corresponding gyroceran forms in *Barrandeoceras convolvans* described in the text and the resemblance of these to the young of true species of Eurystomites is very close.

The series of the Tainoceratidæ are interesting in this connection, because in the earliest species of Temnocheilus itself, which occur in the Devonian, there is no dorsal furrow, and only a contact furrow as is shown in Figs. 27 and 28, Pl. x. The umbilical perforation is not large, and in succeeding species in the Carboniferous, although there are several genera, there are none having the dorsal furrow.

Metacoceras cavatiformis, Fig. 16–19, p. 496, and Pl. x, Fig. 32, are good examples of this group.

Among the most remarkable of the Silurian series in which no dorsal furrow was present is that of the highly ornamented and modified genus Ophidioceras. The elaborate ornamentation of the shell and the costæ, combined with a peculiar hollow ventral zone bordered by ridges, the free living chamber and aperture with lateral and dorsal crests show this type to be very peculiar and highly specialized. The small size and shape of the umbilical perforation shows also very close coiling. One would suppose this amply sufficient in a quick-growing whorl like that of Ophidioceras to force the premature development of a dorsal furrow, but there is not the least sign of one in either of the three species examined and figured on Pl. viii. In this group a very interesting fact is noticeable in the gerontic stage. The impressed zone is persistent on the free dorsum until it meets a projecting spur which coincides with the more or less abrupt lituitean bend on the venter. On the other side of this spur, it has, however, such a hold upon the organization that it is not obliterated by the building of the spur, but is resumed again on the oral side, and continues to the edge of the aperture. In this last stage, however, the impressions made by the sharp ridges on the borders of the median ventral zone are obliterated, and when near the aperture the zone becomes narrower and shallower and finally disappears.

Endolobus (Pl. viii, Figs. 36–39) is another example of the absence of a dorsal furrow in a good-sized umbilical perforation and the presence of a contact furrow in the older stages.

The mechanical moulding of the dorsum upon the venter of the next inner whorl is shown of course in all of these examples, but it can be still better illustrated by such forms as Ophidioceras, just described, and *Apheleceras mutabile* (Pl. x, Figs. 29–31) and *Diorugoceras planidorsatum* (Pl. xii, Figs. 1, 2). These and many other examples besides those figured serve to demonstrate that in every shell, so far as known, the configuration of the dorsum is absolutely dependent upon the shape of the venter, the former being invariably a reverse or mould of the latter. The same is also true in the earlier stages of the contact furrow in those species that strike and envelop the apex of the conch.

The number of series which have close-coiled shells, but in which the impressed zone is purely a contact furrow, is in the Carboniferous even larger than in the Devonian, but it will suffice to refer to two extreme examples. Ephippioceras, which is a highly specialized species with peculiar sutures and septa and very involute, appears to belong in this category, and also Phacoceras. These forms are in part figured on Pl. ix.

Similar transitional shells with good-sized or large umbilical perforations are also present in the Trias, and are illustrated in *Syringoceras granulosostriatum* and *linearis*, Pl. xi. There are several other species in the Trias that belong in the same category, but it is not always easy to get preparations that will establish the fact that the dorsal furrow is absent.

The disappearance of the straight and arcuate types in this period together with the transitional nautilian shells has been remarked above, and in the course of the following pages this fact will be noticeable. In dealing with those types in the Carboniferous that possess a dorsal furrow, one is struck by their small number and their decisive testimony in favor of the assumption that the dorsal furrow is inherited.

The phylogerontic character of *Coloceras globatum* is evident from the figure of the ananeanic stage on Pl. x, and the comparison that may be made with the senile whorls of *Vestinautilus konincki*. It then becomes obvious that Coloceras belongs to the same genetic series as Vestinautilus, but that it inherits degenerative characters at an early stage. It is in other words a degenerate form with a highly accelerated development of the gerontic or degenerate characters of other species of the same series. Of course this acceleration affects both the ornamentation or ridges as well as the form. It is to be anticipated of course in species of this kind that other characters will also show acceleration. Accordingly one finds as shown in several figures that in *Col. globatum* a dorsal furrow is to be found in the paranepionic substage.

The umbilical perforation is of good size in this species, the curvature is often gradual and uniform, the ana- and metanepionic volution increases slowly in size, and there is apparently no mechanical agency in any of these characteristics that would have caused or led up to the appearance of the dorsal furrow in the paranepionic substage. Another point is obvious in this species. It is a descendant of a special series which probably arose from *Thoraceras Puzonianum* and *canaliculatum*, or some species of more ancient origin combining the characters of these two. This series then obviously passed through the distinct phases of gyroceran and nautilian evolution and acquired a contact zone, which in the highly specialized phylogerontic Coloceras became by the law of tachygenesis a dorsal furrow inherited in the paranepionic.

The facts in my opinion cannot be accounted for on any other hypothesis.

It is hardly doubtful when other involute and highly specialized shells have been fully investigated that many more examples of the accelerated inheritance of the impressed zone will be found.

Nannoceras Frieslebeni (Pl. xi) is the only species in the Dyas that I have been able to investigate, and this has a dorsal furrow and a small umbilical perforation. Its congeneric forms are also unknown, and its evidence is consequently not of much value, except in so far as it shows the occurrence of this class of forms in this period.

I was not able to obtain shells having small umbilical perforations and suitable for examination in the Trias, and have to leave that period a blank record except in so far as noted above.

The close-coiled shells of the Jura are, however, sufficiently abundant and the evidence very interesting.

In the first place, as noticed elsewhere, there are no arcuate radicals in existence. They have all disappeared in the Trias, and with them went also the transitional forms of all kinds, the gyroceran and even the primitive nautilian with very large umbilical perforations. Under these circumstances one should expect to find a decided change in the behavior of characteristics.

If the impressed zone was maintained and perpetuated by mechanical means, by the abrupt curvature of the whorl at the gyroceran bend, and had not through time or constant repetition become fixed in the organism and genetic, one ought to find in some species of the Jura having larger umbilical perforations than others, that a dorsal furrow was absent, or else variable and often very slightly developed.

Suppose, on the other hand, without paying any attention to the manner of the origin of the impressed zone, except in so far as the facts show that it appeared late in the life of primitive species and is an acquired character, one asserts that time and fixation in nautilian shells has made it hereditary.

It is then of no consequence whether a given shell of the Jura has a large or small umbilical perforation. Being a highly specialized nautilian shell and apparently without other than strictly nautilian progenitors, it follows from the law of tachygenesis, that the impressed zone ought to be represented by a dorsal furrow in the paranepionic substage, or earlier in every species. The mechanically generated contact furrow of transitional nautilian shells occurs in the ana- and metaneanic substages, rarely later, consequently if the dorsal furrow arose out of this through the law of tachygenesis it should appear in the preceding stages of the ontogeny before the whorls touch in every shell of the Jura.

It is of course possible that exceptions to this rigorous logical deduction might have occurred in diseased young individuals, or in species directly traceable to arcuate forms in the Trias, but so far no such shells have been found.

In looking at the apices of the species of Digonioceras and of Cenoceras, considerable difference is noticeable in the sizes of the umbilical perforation. For example those of *Digonioceras excavatum*, Pl. xi, and *Digonioceras*, sp. (?), Pl. xii, Figs. 6–11, are comparatively quite large. But in these the dorsal furrow appears at the same age as in *Cenoceras intermedium* and others having very much smaller perforations and more rapid increase of the metanepionic substage. In other words, the rapid increase of the ventro-dorsal diameters and other diameters and the sudden bending of the shell and the abrupt gyroceran curve of *Cenoceras intermedium* and *lineatum* and *clausum* have no effect whatever upon the genesis of the dorsal furrow. As if to make this conclusion still more secure, *Cenoceras aratus*, the single species in the Jura, which does present a slight acceleration in the development of the dorsal furrow, has an umbilical perforation which is of medium size and has also slower growth of the metanepionic and paranepionic substage than most of the shells of this period. This species, figured on Pl. xi, Figs. 32 and 33, has so large a perforation and so gradual an increase in bulk of the nepionic, that it affords no basis for a belief in mechanical causes. If it had been found that the dorsal furrow occurred a little later or not at all in this specimen then there might have been some grounds for the supposition that genism had had no influence upon the perpetuation of the impressed zone. But when one finds in place of retardation a slight acceleration in the development of the dorsal furrow the facts certainly appear to be very strong in favor of the ordinary theory of diplogenesis and tachygenesis.

The same argument applies with greater force to the Nautiloidea found in the Cretacic. These being more remote than Jurassic species from any primitive nautilian forms, they ought to exhibit the action of tachygenesis in the earlier appearance of the dorsal furrow at least in a considerable number of the species.

From the remarks already made above and from the figures given, especially on Pls. xii and xiii of this work, it may be seen that so far no specimen has been found in this period which did not show the presence of a dorsal furrow on the metanepionic volution, a substage earlier than most of the species of the Jura. This fact has already been used in other connections, especially in the discussion upon the relations of the dorsum to the venter in nautilian shells. It is very positive evidence against the supposition, that the configuration of the dorsum of the metanepionic substage has any effect upon the outline of the dorsum of the paranepionic even in cases where they are brought close together on the opposite sides of even the narrowest of umbilical perforations. Provided it did not touch it is obvious that the dorsal side of the paranepionic substage in Cretacic shells was free to assume any shape.*

In following the same theoretical line into the Tertiaries, the evidence is less satisfactory; only one species was found, *Eutrephoceras imperialis*, which gave any evidence. This had the dorsal furrow in the metanepionic substage. The Aturidæ, however,

*It will be easily seen that this argument could also be applied to the case of *Trocholites canadensis*, but in the absence of positive evidence in the genetic series of the Tarphyceratidæ I have thought it best not to assume that such use could be made of the parallel facts observed in Mesozoic shells.

showed the highest degree of tachygenetic development in all the structural characters of progressive evolution among Nautiloids. That is to say, the size of the apical chamber, the immediate assumption of a highly matured outline in the first suture which has the aturian generic lobes and ventral saddles, the subdorsan siphuncle, the minute umbilical perforation and the rapid increase of all the diameters of the apex in the nepionic stage and the almost complete involution of the apex and first whorl in neanic stage, all indicated a high degree of acceleration. It is therefore probable that in this family a correspondingly early inheritance of the dorsal furrow will also occur, unless there is some interference arising from the highly tachygenic development of the characteristics cited above in the metanepionic substage that may have replaced it or rendered it very obscure. Sections ought to have been made to establish this fact, but I could not obtain materials for this purpose in the limited time at my disposal.

The existence of the dorsal furrow has been observed in the metanepionic substages of the three existing species of Nautilus that are the most important, viz.: the least involute *Nautilus umbilicatus*, the most involute *Nautilus pompilius* and the degenerate shell of *Nautilus macromphalus*. It might of course be expected that some of the less involute shells of the Cretaceous, Tertiary or Present, if any such be found, would resemble the Jurassic shells in having a dorsal furrow in the paranepionic. I expected this might occur in *Nautilus umbilicatus*, but so far as I could see the dorsal furrow appeared in this shell quite as early as in *Nautilus pompilius* or *macromphalus*.

I here take the opportunity to refer to the structure of the shell of the dorsal side among Nautiloidea.

The shell of course in all forms with free whorls is as complete on the dorsal as it is on the ventral side. It is also complete on the dorsum in the nepionic stage of all nautilian species. An additional layer called by various names, but known in the modern Nautilus as the black or dark-colored layer, makes its appearance after contact and lies between the exteriors of the shells of the venter and dorsum in each whorl.

I have never been able to detect the homologue of this layer among fossils probably because it is necessary to look for it in sections under the microscope.

As regards the behavior of the shell in the impressed zone after contact it is obvious in all fossils, as it is in the Nautilus, that the outer porcellanous layer is apt to disappear in the contact furrow and that this disappearance is due to contact seems almost beyond question, especially in Schroederoceras and other shells that have free whrorls in the gerontic stages.

In Paleozoic shells, like *Eurystomites Kelloggi*, Schroederoceras, Estonioceras and many others the loss of the excretory function is only temporary, since the free volution is protected on the dorsum by a thick shell as soon as it begins to depart from the spiral. In all of these that I have observed, the contact area has not been large, but in *Anomaloceras anomalum*, *Trocholitoceras Walcotti*, *Endolobus avonensis*, Tarphyceras and others in which the contact is closer and the furrow broader, the outer porcellanous layer does not pass on to the dorsum.

Pompeckj* states that the mantle border of *Nautilus pompilius* on the venter and sides has triple folds and two furrows, which indicate that these parts of the rim of the border secreted the outer porcellanous layer which protects the body of the animal on the outer exposed sides. On the dorsum the continuation of this border is entire and not furnished with folds or furrows for secretion of the porcellanous layer which is also absent on that side.

The aperture is not built out on the dorsal side in any involute Nautiloid that I have been able to examine.

I have not yet been able to find in any of the involute shells observed to have this peculiarity and in which the suppression of the dorsal layer was more complete, that the last volution became free and that the deposition of dorsal shell layers was resumed in the gerontic stage. The evidence at present from this accords with that to be obtained from coiling, namely, that shells having a certain degree of closeness of contact or involution do not as a rule have a free volution in the gerontic stage. That the aperture might have become free and still be protected by adequate shell layers on the dorsum in the gerontic stage remains to be determined. That this must have been very rare, if it ever occurred, is shown by the fact that no shell has been observed in the Paleozoic and none have been seen in the Mesozoic, Tertiaries or recent Nautiloids, having such a gerontic stage at the apertural end of an involute whorl.

In recent Nautilus it is especially noticeable, as stated above,

* *Amm. mit "Anormal. Wohnkammer,"* p. 259.

that gerontic degeneration is slight and does not affect the amount of involution nor the size of the whorl. This may be due to the rarity of shells that have reached an advanced age or to the brittleness of the senile volution, but against this there is sufficient evidence.

Thus, in many Mesozoic fossils and in recent Nautili, shells are often found with the last two or three septa approximating and this is plainly a mark of the failure of the powers of growth and shows in most examples of large size that the animal has probably reached the extreme limits of its existence.

One fact is of great interest in this connection. Extreme cases of degenerative series are rare among Nautiloidea. The Lituitidæ stand alone as the only complete series that can be compared with several that are found among Ammonoidea. The Discoceratidæ have also some turbinate genera that can be closely compared with the helicoidal spirals of a number of Ammonitinæ. All such forms and others that may be supposed from their characteristics to exhibit similar characteristics, disappear with the Paleozoic and all, so far as I know, before the Carboniferous period. There are phylogerontic species like *Coloceras globatum* in the Carboniferous, but no uncoiled phylogerontic forms.

In Mesozoic, Tertiary and Cenozoic times, the uniformity of the type is conspicuous, and while it is plainly degenerating from the Carboniferous to the present, this process is not accompanied by the evolution of uncoiled series. The degeneration takes place as stated above in ornamentation of the shell and in the number and variety of the series and forms evolved, but not in the coiling, which is really progressive, nor yet in the sutures, since Aturia is certainly one of the most if not the most highly accelerated and specialized of the whole order.

These facts all bear directly upon the history of the impressed zone, since in all uncoiled whorls the primitive contact furrow tends to disappear and the outer dorsal porcellanous layer is restored to its full development on that side.

In Paleozoic time as well as in later times no involute shell has yet been observed with a free gerontic volution, that is to say, when the area of involution reached beyond the limits of the venter and the area covered extended inwardly on to the sides of the next inner whorls, the gerontic stage also remained involute, or, if decreasing in its ventro-dorsal diameters, this decrease never seemed to reach the extreme point of degeneracy, so as to allow the aperture to become again free and complete on all sides.

This is, of course, negative evidence and it may be, as in Ammonoids, that the dorsal edge of the mantle never loses in any series when restored to freedom the power to resume the shell-secreting structures and function on the dorsal side. It can be readily seen that as the whorl became gradually loosened from the inner whorl the mantle border would extend the secreting furrows inwards from both sides, or, more correctly speaking, perhaps, the non-secreting edge of the dorsal border would be contracted and finally disappear. There is no antecedent improbability that this might not take place in any involute nautilian shell at a sufficiently degenerative substage of its ontogeny. The remarkable fact, however, remains that it does not take place so far as I know, although I have constantly been on the watch for some such examples.

Ammonoidea.

It is not necessary to give any extended notices of observations on special groups in this order. I have already described the absence of the impressed zone in the ordinal radicals Bactrites and in most of the Nautilinidæ on pp. 361, 362, 411, 413 and the figures and explanations of Pl. ii, and Figs. 40–42, Pl. viii, of *Mimoceras lituum.* The more specialized genera of the Goniatitinæ have the impressed zone, but it is strictly a contact furrow and appears as shown in figures of *Agoniatites fecundus*, one of the Nautilinidæ, sometimes very late in the ontogeny. In other still more highly specialized species the loose coiling of the young, figured by Sandberger in several species of Gephuroceras, *Manticoceras latidorsale* of the Devonian and by the author in *Glyphioceras crenistria* and *atratus* of the Carboniferous* indicates, that this zone is either absent on the ananepionic dorsum, or, if present, must occur as a slight dorsal furrow due to tachygenesis. The larger number of the Goniatitinæ, as shown by Branco and the author, have, however, such closely coiled nepionic stages that, as in all Ceratitinæ, Lytoceratinæ and Ammonitinæ, so far as known, the umbilical perforation is closed along the mesal line as shown in Fig. 3, Pl. iii, and is represented only by funnel-like lateral prolongations, which do not appear to have an open connection with each other.

* *Embryology of Fossil Cephalopods*, Pl. iii.

The impressed zone is among most of the Ammonoidea therefore essentially a contact furrow, and the tendency to close coiling has been accelerated to so great an extent that contact takes place between the permanent protoconch and the ananepionic substage and a contact furrow is thus produced earlier than in any known Nautiloid. The position of the first septum in the aperture of the protoconch shows that contact must have taken place before it was deposited as the floor of the ananepionic living chamber, *i. e.*, at the very beginning of the building of the apex of the conch.

It is also obvious that this high degree of acceleration in development was attained in the Devonian, as a permanent hereditary character of the whole order since the Nautilinidæ are the only representatives of the Goniatitinæ in the Silurian and disappear in the Devonian. There are also but very few species with open umbilical perforations in the Devonian, outside of the Nautilinidæ, and so few in the Carboniferous, that Branco denies the correctness of my figures of the two species above mentioned. That open umbilical perforations should occur sporadically in the young of some Carboniferous species of Goniatitinæ is of course to be expected, and that Branco should not have found any simply demonstrates the rarity of their occurrence.

The history of the impressed zone among Ammonoidea is parallel with that of the Nautiloidea in regard to the shell layers on the dorsum. These are complete in Bactrites and all of the Nautilinidæ which do not have a contact furrow and incomplete in all Ammonoids that do have this furrow, the outer layer reaching only to the lines of involution. This is shown in Fig. 3, Pl. iii, and it is observable in this that the shell of the apex of the conch appears to end at the outer edges of the umbilical perforations, but this observation needs revision or confirmation. There is a third layer between the dorsal and ventral walls of the shell corresponding to the organic black layer of Nautilus and it is often calcareous and well preserved in some fossils.*

The extraordinary variety of degenerative series among Ammonoidea and their connection with the history of the impressed zone is of great importance in this paper.

The duration of the habit of close coiling and involution in the majority of shells from the Devonian to the Cretaceous is the most

*There is the same tendency to calcification here as in the case of the protoconch as compared with the membranous protoconch of Nautiloids.

noticeable and one of the most persistent characteristics of the general morphology of the order.

Nevertheless, in every example of uncoiled phylogerontic shells the impressed zone tends to become less and to disappear, obeying the same law as among the Nautiloids. There is, however, a difference in its behavior, which is at first rather confusing. Involute shells may have free gerontic volutions and in these the zone does not appear to have, as a rule, so deep a hold upon the organization of the Ammonoids that it does upon many of the Nautiloids. For example, in deeply involute Scaphitoid shells there may be free living chambers in the gerontic stage and the zone diminishes greatly, almost disappearing on the edge of the aperture. In crioceran and baculites-like forms, however, it does not appear to persist to any marked extent upon the dorsum beyond the cessation of contact in the young whorl.

There are no examples in the history of its retrogression which can be compared with the persistency exhibited in a number of Nautiloids. For example, in *Eurystomites Kelloggi*, Ophidioceras and others the impressed zone, although it may not be present in the nepionic stage before contact, and very shallow after contact, nevertheless persists in the gerontic stage. Although showing a tendency to disappear and finally vanishing at the aperture, the process is slow, and it has obviously made a strong impression upon the organism.

What has previously been said of the degenerative characteristics and degenerative series of the Nautiloidea may be of some assistance in clearing up this apparent anomaly. The phylogerontic transformations of the Lituitidæ, as stated above, are the only ones among Nautiloids that can be compared with any of the completely uncoiled retrogressive series of Ammonoids. Although in the Lituitidæ the impressed zone is a mere contact furrow of slight extent and obviously transient development, nevertheless they serve as a comparative standard to show how much more complete the degenerative changes are among the Ammonoids than among Nautiloids. If the observer studies any species of Ammonoid in the gerontic stage the same morphic law becomes apparent. As I have tried to show in *Genesis of the Arietidæ*,* the greater specialization and more complex ephebic development of the ontogeny in Am-

* Pp. 28–37.

monitinæ is attended by a correspondingly intensified series of degenerative changes in the gerontic stage.

Considering the nature and extent of these retrogressive changes in both ontogeny and phylogeny, one ceases to be astonished that the impressed zone disappears quickly in any individual and begins to wonder at the conservative power of genism which preserves the close coil of the nepionic stage as a definite record of the derivation of such straightened out shells as Baculites. I have tried to account for this by supposing that the young of even these degenerate forms had similar habits as those of their ancestors, or were specially protected. The former supposition may be the true one, since it is entirely in accord with the facts that the tendency to degeneration should not necessarily take effect upon the development of the earlier stages, but the latter can hardly be true.

The retrogressive forms have usually slenderer shells than the normal forms, and there is no evidence that they possessed any special pouches or contrivances for the protection of the young.

It is interesting in this connection to notice the results of an extended research made by Dr. F. J. Pompeckj upon these extraordinary Ammonitinæ. His observations include about all of the more remarkable distorted fossils of this kind from the Carboniferous to the Cretaceous, especially those which have contracted apertures and exhibit connections with normal forms. Dr. Pompeckj arrives at the conclusion that the living chambers having such peculiarities are one and all to be classed as senile characteristics.

His conclusions are as follows:

"1. Die Bildung 'anormaler' Wohnkammern ist nicht mit Resorptionserscheinungen verbunden; Resorptionserscheinungen sind an den Ammonitenschalen überhaupt nicht nachzuweisen.

"2. Ein Ammonit mit 'anormaler" Wohnkammer ist fast ausnahmlos als vollkommen ausgewachsen zu betrachten.

"3. Der 'anormalen' Wohnkammer gehen weniger veränderte Wohnkammern voraus und schliesslich in den Jugendstadien solche, die in vollkommen regelmässiger Spirale gewachsen sind; man darf daher bei der Beschreibung von Ammoniten nicht eigentlich von einer anormalen Wohnkammer sprechen, sondern von einer anormalen letzen Wohnkammer des ausgewachsenen Individuums.

"4. Die 'anormalen' Wohnkammern der Ammoniten sind nicht auf sexuelle Unterschiede zurückzuführen.

"5. Die 'anormalen' Wohnkammern und die mit denselben zusammenhängenden Formveränderungen des Ammonitentieres sind als senile Charaktere aufzufassen."

I am not prepared to adopt without more extended study the first of Dr. Pompeckj's results. Although he has presented very strong evidence, it is difficult to believe that in all cases when the aperture is contracted and the whorl or living chamber is excentric that this is never resorbed, because these so often occur in very small shells. These small shells are apparently of the same species with larger ones having similar chambers, and I have certainly considered them as individuals which had inherited the degenerative tendency to excentricity in their early stages. Dwarfs certainly occur having prematurely degenerative characters of this kind, and it may be that Dr. Pompeckj is right in his generalization, and that all such occurrences can be regarded in the same way.

Dr. Pompeckj does not deny that, when change of habit might be such as to favor the inheritance of gerontic characters, that they become genetic and that degenerative series might have been thus built up. If this occur at all the appearance of gerontic characters must take place according to the law of tachygenesis and in consequence of this appear earlier in the ontogeny of descendants of the same series. The shells in every degenerate series, therefore, ought to show this earlier inheritance in proportion to their degeneracy and to their place in the evolution of the series. In other words some at least of the more degenerate species would necessarily exhibit phylogerontic characters in their neanic stage and should be classified not as dwarfs but as young shells.

Through the kindness of Dr. C. E. Beecher my attention has been drawn to a species which is of importance in this connection and this has been loaned me by Prof. O. C. Marsh, Director of Yale University Museum. This extraordinary helicoidal shell, *Emperoceras Beecheri*, is exceptional in so far as it exhibits, in a magnified and unmistakable way, the action of tachygenesis upon gerontic characteristics.

The neanic stage has a single, straight, baculites-like cone which turns in the same plane, building out the peculiar form known as Hamites. This, after making the hamitean bend, deviates from the plane of growth of the neanic stage and becomes a loose but regular spiral which has generally heretofore been described as Helicoceras.

In Nostoceras similar phenomena are observable but, in this turrilites-like, closer coiled spiral, the young shells are quite different and it is not certain that they are irregular and similar to Hamites. The species of this genus and of Emperoceras and Didymoceras show that the spiral coiled stage is an ephebic stage, not a true gerontic stage of the ontogeny, because passing beyond this the gerontic stage appears taking on the usual retroversal form. The ephebic whorl departs from the spiral in this stage, again becoming excentric, and then builds back towards itself and towards the spiral, forming the peculiar crook found more or less in the paragerontic substage of the so-called Hamites, Ancyloceras, Scaphites.

Thus one gets in these two genera a demonstration that the turrilites and helicoceran modes of building the shell are acquired characteristics of the ephebic stage of the ontogeny interpolated between gerontic and neanic stages which have the usual characters of these stages in the ontogeny of degenerate forms.

These forms are also interesting in connection with the history of the impressed zone, because if they have close-coiled young, like those of the crioceran and baculites-like shell already studied, which is highly probable, they must have had a contact furrow in the nepionic stage and then lost it in the neanic stage. The genesis of another contact furrow in the still later stages of Nostoceras and similar turrilites-like spirals, is therefore secondary and phylogerontic, and is not strictly speaking a progressive characteristic. This furrow is also situated on the lateral aspect and not on the dorsum as in symmetrical shells.

The phylogerontic renewal of the impressed zone is also in Ptychoceras, a generic character, as pointed out to me by Mr. T. W. Stanton, to whose courtesy and the kind permission of Mr. C. D. Walcott, Director of the Geological Survey, and Mr. Goode, Director of the National Museum, I owe the fine materials described above.

The return of close coiling in gerontic stages of this species is a remarkable phenomenon. There is a gerontic umbilical perforation formed by the sudden bending of the gerontic living chamber which is elongated and not usually very small, but the gerontic bend is often very abrupt. The inner side at the bend is occupied by a gerontic dorsal furrow which reminds the observer of the dorsal furrow in the paranepionic substage of the coiled young of Nautiloids. As in the young of Trocholites and Tarphyceras the

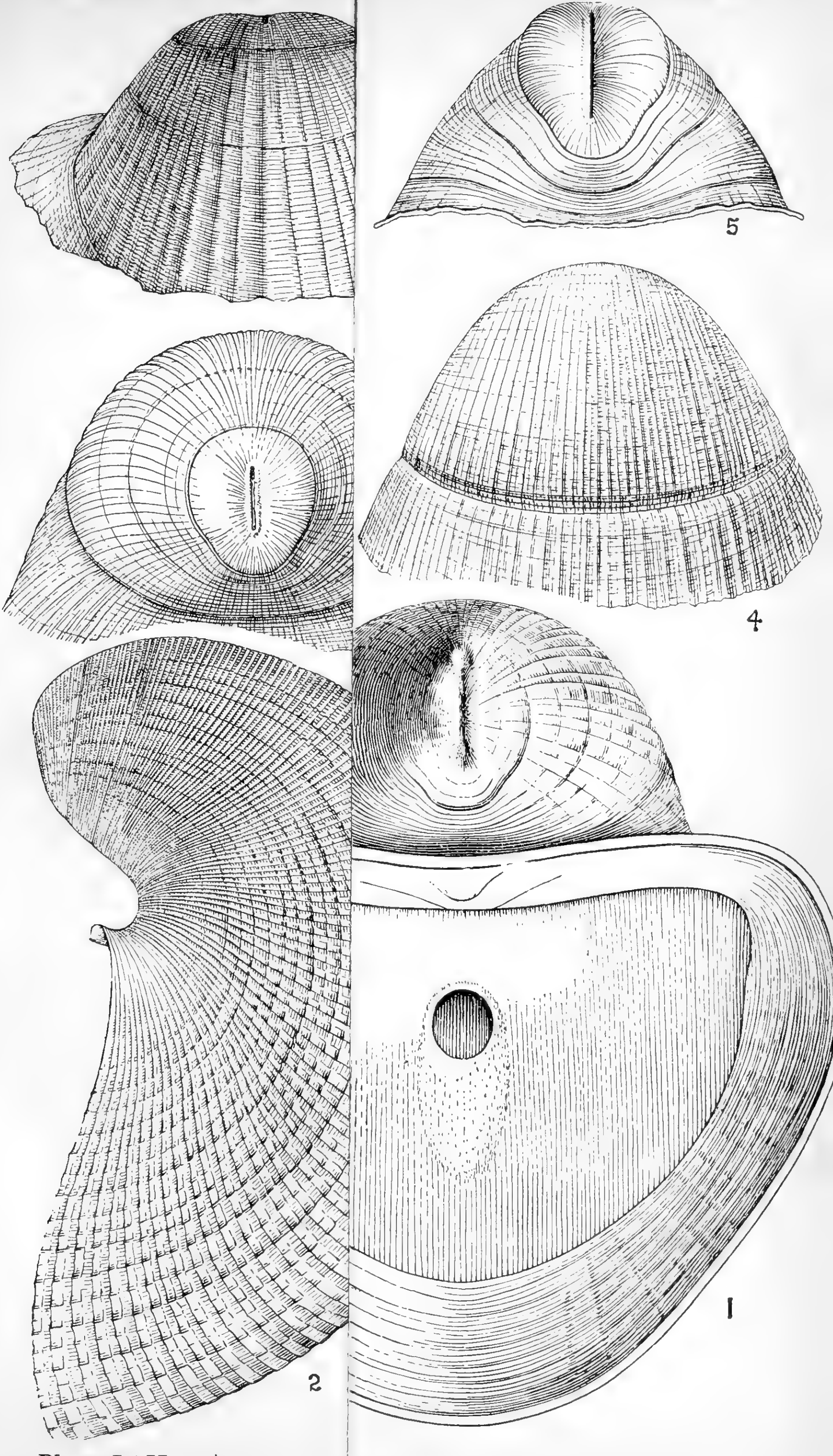

Plate I (Hyatt).

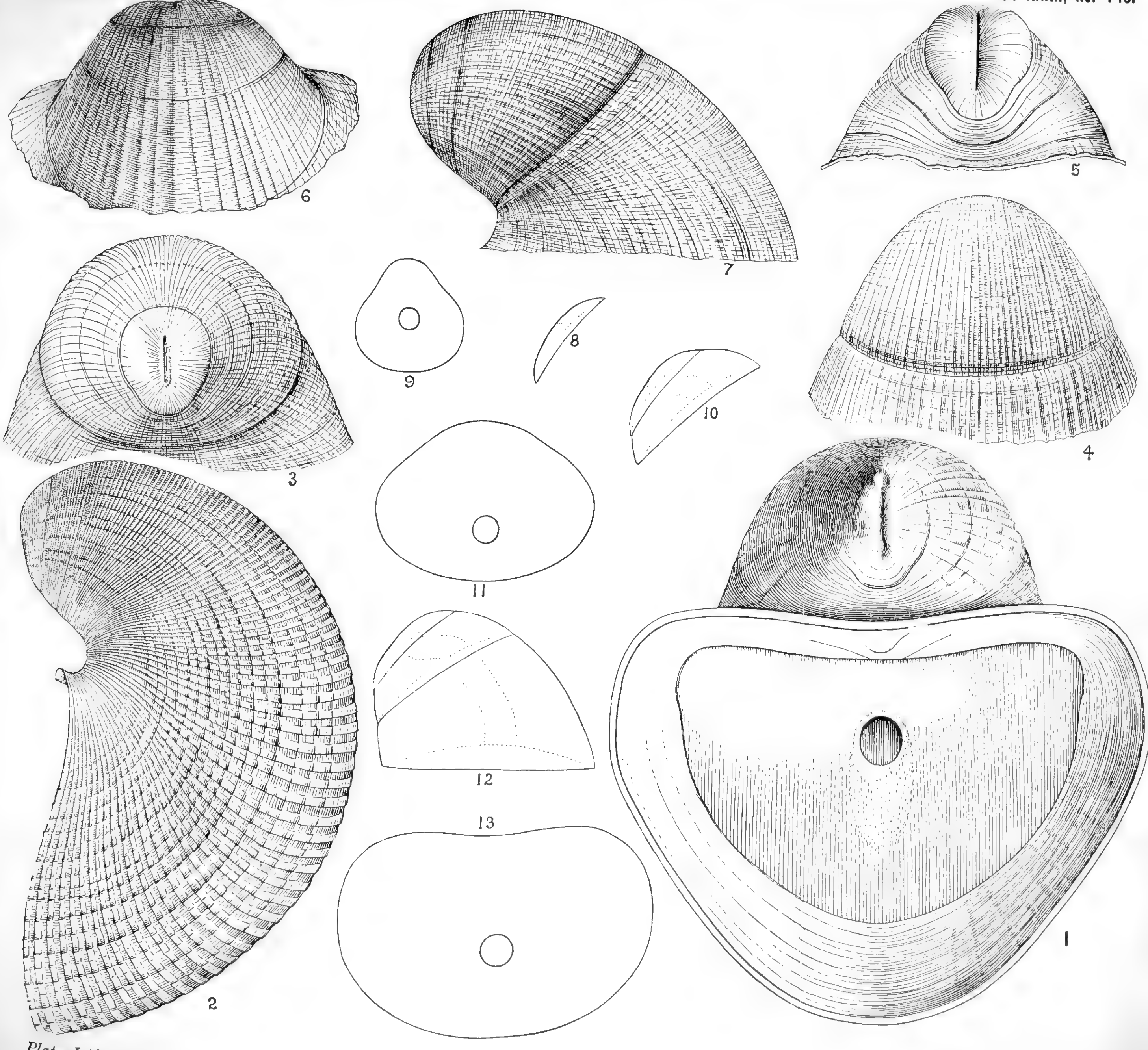

Plate I (Hyatt).

dorsum of the gerontic volution is brought into contact with the dorsum of the next younger volution and a contact furrow results, which so far as I know occurs in all the species properly referred to this genus, although very slight in some of them.

The significance of the facts brought out by the study of degenerative series has been fully discussed elsewhere, and need not be noticed again.

The facts and arguments brought forward seem to justify the following conclusions:

1. The impressed zone is primitively a contact furrow, an acquired characteristic of the dorsum of the whorls of nautilian shells having large umbilical perforations, which appeared either in the ananeanic or metaneanic substages, and rarely later in their ontogeny. There is abundant positive evidence that in these primitive forms this furrow is a purely mechanical result of the nautilian mode of growth, not appearing in the ontogeny before contact and either partially or entirely disappearing on the free gerontic volution.

2. The impressed zone does occur independently of contact on the free dorsum of the paranepionic substage as a dorsal furrow in some close-coiled, highly tachygenic, nautilian shells in the Quebec group and in the Devonian.

3. While there is no positive proof that the dorsal furrow originated through heredity in the paranepionic substages of these nautiloids of precarboniferous age, there is also no satisfactory evidence that it originated in the young of such species as have this character through purely mechanical agencies.

4. There is positive evidence that the similar dorsal furrow which also appears at the same age in the young shells of *Coloceras globatum* and perhaps *Coelogasteroceras canaliculatum* among Carboniferous nautiloids can be explained only when it is considered as a transmitted, tachygenetic characteristic.

5. This fourth conclusion is supported by the presence of a similar dorsal furrow in the paranepionic substage of the young shells of all of the nautiloids of the Jura, so far as observed.

6. The fourth and fifth conclusions are rendered still more probable by the presence of the dorsal furrow at an earlier age, the metanepionic substage, in all of the nautiloids so far as observed, from the beginning of the Cretaceous, through the Tertiaries to and including the living species of the genus Nautilus. Its presence on this cyrtoceran volution in Cretacic shells can be explained only

when it is considered as a transmitted, tachygenetic characteristic derived from ancestral, nautilian shells of the Jura, which have the same characteristic at a later age, *i. e.*, in the paranepionic substage.

7. The first conclusion is also sustained by the parallel phylogeny of the impressed zone in the ancestral forms of the Ammonoidea, the Nautilinidæ and especially in Mimoceras, the radical genus of this family.

8. The fourth, fifth and sixth conclusions are also supported by the presence of a contact furrow on the dorsum of the earliest age of the conch in the specialized and highly tachygenic forms of the Goniatitinæ of the Devonian and of all of the remaining Ammonoids to the end of the Cretaceous.

9. These cumulative results favor the theory of tachygenesis and diplogenesis, and are opposed to the Weissmannian hypothesis of the subdivision of the body into two essentially distinct kinds of plasm, the germplasm, which receives and transmits acquired characteristics, and the somataplasm, which, while it is capable of acquiring modifications, either does not or cannot transmit them to descendants.

Explanation of Plates.

Plate I.

Illustrations of nepionic stage and ananeanic substage in *Nautilus pompilius* from preparations made by Henry Brooks and drawn under his direction. They are all enlarged to show the details of the surface ornamentation and changes of form.

Fig. 1. The paranepionic aperture and earlier nepionic substages seen from the front, this preparation having been obtained by breaking down the full-grown shell. The septum which appears here necessarily belongs to a later time and shows the position of the siphuncle and its large size in the floor of a living chamber older than is represented in this figure, but in the same substage. The actual living chamber of this age was therefore deeper than is represented here at the beginning of the paranepionic substage. The subtriangular outline of the section of the shell is supposed to represent and probably does approximately represent the aperture. It is noticeable also that the dorsal furrow is well developed, although the shell has not yet completed the gyroceran curve.

Fig. 2. Side view of the same showing the apex. The ananepionic substage is not distinctly visible, but the constrictions showing apertures of the metanepionic substages are delineated.* This figure is especially intended to exhibit the changes that take place in the ornamentation of the shell.

Fig. 3. The ananepionic and metanepionic substages in another preparation seen from the front. The ananepionic is the elongated disk of the apex and scar in the centre of this. The metanepionic includes the shell outside of this to the outer constriction.

The details in this have not been completely drawn, but the transverse lines of growth are shown upon the shaded side of the drawing.

Fig. 4. Same from the ventral side, showing especially the latter part of the metanepionic substage and the deep constriction that in some specimens marks the termination of this substage. The lines of growth show no trace of a hyponomic sinus in this or any other preparation at this age.

Fig. 5. The same substages of the nepionic stage seen from the front in another preparation. The details of the transverse striation are not fully given in this drawing and this makes the ananepionic substage appear more gibbous than it really is. This impression is corrected by Fig. 6.

Fig. 6. View of the same from the venter, very carefully finished in all its details. The limits of the ananepionic substage and the aperture of the first part of the metanepionic substage are more plainly marked in this specimen than is usual.

* These drawings and others in this paper will appear to most observers to be upside down. They are really right side up and the conventional mode of representing these shells followed hitherto in all works is unnatural. It is full time that these forms should be pictured, as are all others in scientific and popular works, as they stand in nature. The greatest objection to this is the inconvenience of comparison with illustrations hitherto published, but this cannot be avoided, and must be endured for the sake of progress.

Fig. 7. Side view of the apex of the conch in another preparation showing the same substages and a part of the paranepionic substage.

Fig. 8. Diagram of the exterior of the ananepionic substage. This also shows the position of cæcum and septum of the first living chamber of the metanepionic in the interior, and supposed outlines of aperture of ananepionic substage. In the ananepionic substage the apex of the conch is empty and this diagram therefore gives the erroneous impression that the cæcum and first septum belongs to this substage, whereas it is obviously a part of the metanepionic substage.

Fig. 9. Front view of the same showing outline of aperture of ananepionic substage and also the position and size of the primitive siphuncle or cæcum first septum of the metanepionic substage.*

Fig. 10. Diagram of same and exterior of first living chamber of the metanepionic substage showing change of position towards the venter of the siphuncle in the septum of the second living chamber of same substage.

Fig. 11. Front view of the same with siphuncle of the same.

Fig. 12. Side view of the exterior of two first substages and supposed aperture, with the siphuncle and first septum of the paranepionic substage. The siphuncle, it will be observed, changes again towards the centre between these two septa.

Fig. 13. Front view of the same showing approximate outline of aperture taken from actual outline of shell in section at the constriction terminating the metanepionic substage. This shows the nephritic character in the volution and exhibits also the dorsal furrow beginning to form at this early age before the gyrceceran curve begins. This drawing is placed so that the observer can compare the outlines of the shell at this substage with that of the later age of the paranepionic substage in Fig. 1. In the latter the siphuncle has assumed the permanent position of the ephebic stage below the centre.

* Figs. 9–11 should have been reversed to accord with the side views and with the other figures.

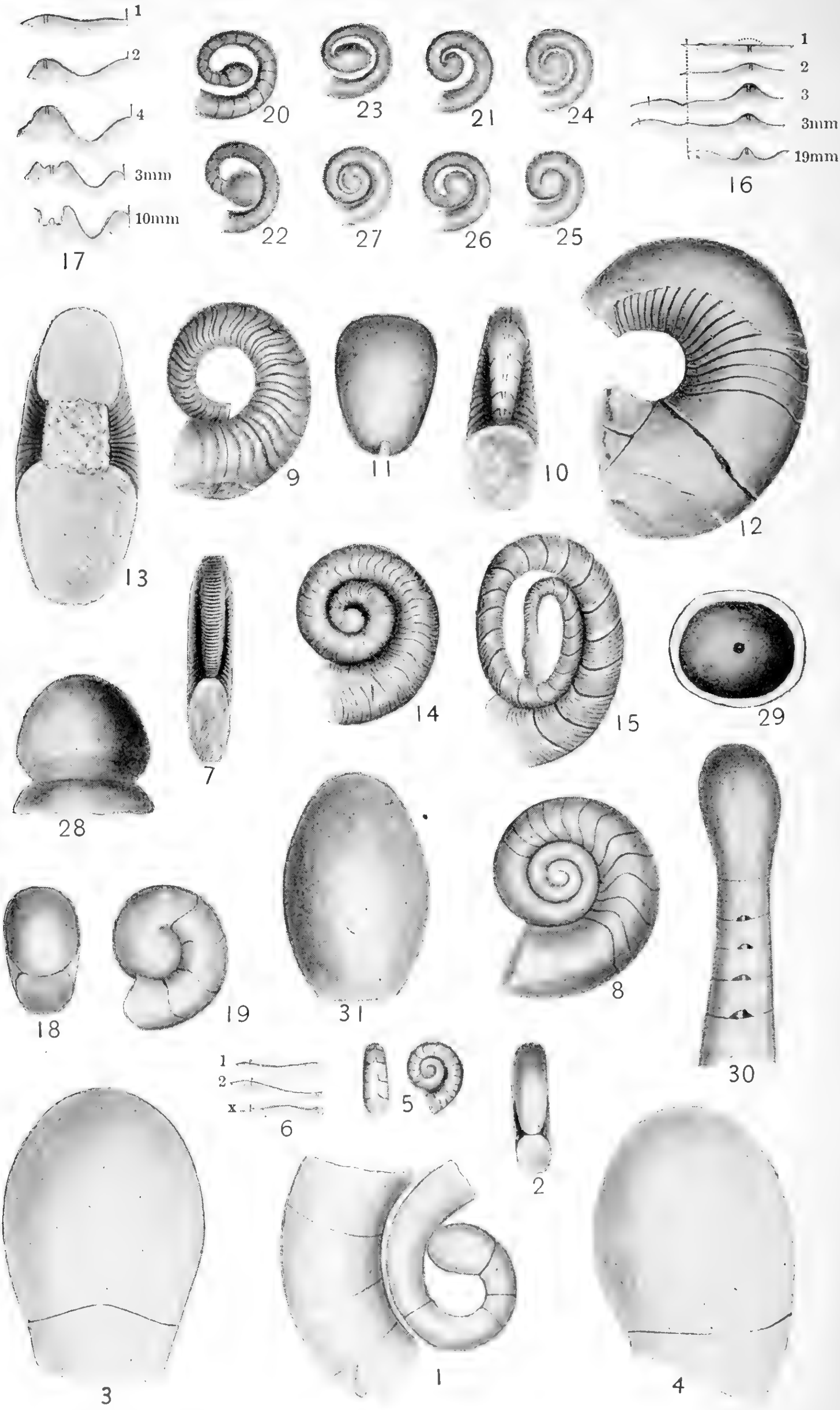

Plate II (Hyatt).

PLATE II.

Figs. 1–6. *Mimoceras* (*Goniatites*) *compressum*, after Branco, *Paleontographica*, xxvii, Pl. viii, much enlarged, to show the loose mode of coiling, absence of impressed zone, primitive nautiloid sutures of the young until a late stage, and protoconch joining the conch without any constriction on the sides or abdomen, but with a slight constriction on the dorsum, showing tendency to coil, these being typical ammonitoid characteristics. Fig. 6, 1 and 2 and x represent the first, second, and older septum, the septa of the later stages are shown with ventral siphonal lobe in Fig. 5. Fig. 20 is the same species after Sandberger.

Figs. 7 and 8. *Mimoceras* (*Goniatites*) *ambigena*, after Barrande, *Systeme Silurien*, Pl. iii, Fig. 22, and Pl. xii, Fig. 7, showing the absence of an impressed zone at a late stage, probably the ephebic stage of development.

Figs. 9–11. *Agoniatites* (*Goniatites*) *fecundus*, after Barrande (*ibid.*), Pl. x, Figs. 13–15, showing the absence of the impressed zone until a late stage; Fig. 11 is nearly natural size, and this shows, when compared with others of Barrande's figures of this species, which have the impressed zone in adults (Barrande, Pl. vii, Figs. 10 and 11), that this characteristic comes at a much earlier stage in some specimens, and is originated by close coiling, as it is in *Agoniatites Vanuxemi*, but at an earlier stage than in *A. fecundus*.

Figs. 12 and 13. *Agoniatites* (?) (*Goniatites*) *crebriseptus*, after Barrande (*ibid.*), Pl. vii, Figs. 1 and 2, reduced one-third, showing how similar to some nautiloids the adults of this genus may be, both in form and sutures,* with the exception of the ventral siphonal lobe, which alone enables one to place them among Ammonoids.

Figs. 14 and 15. *Agoniatites fecundus*, after Barrande (*ibid.*), Pl. xi, Figs. 2 and 4, enlarged to show the variation of the coiling of two varieties in the protoconchial and nepionic stages. These are both included under one name by Barrande.

Fig. 16. *Anarcestes* (*Goniatites*) *lateseptatus*, after Branco, *op. cit.*, xxvii, Pl. vi, enlarged, showing the immature ventral sutures of this with the primitive undivided siphonal lobe beginning in the second septum of the metanepionic substage. This continues substantially the same in aspect throughout life in the genera Mimoceras, Anarcestes, Agoniatites and Pinnacites, all Silurian forms of Goniatitinæ.

Figs. 17–19. *Gephuroceras* (*Goniatites*) *serratum*, after Branco, *op. cit.*, xxvii, Pl. vi, enlarged, showing sutures of Devonian Goniatitinæ with accelerated development. The mimoceran undivided siphonal lobe is here shown in the metanepionic substage, 2–4 septa, but in the paranepionic, where the coil is 3 mm. in diameter, the siphonal saddle arises in the centre of this lobe as a new character acquired in the later stages of growth.

Figs. 20–25. These give the protoconch and young of various species of Goniatitinæ of the Devonian after Sandberger, *Jahrbuch d. Nass. Verein*, 1851,

* *Mimoceras* (*Goniatites*) *lituus* is a still larger form, also figured by Barrande, which has no impressed zone and is very similar to many nautiloids which have similar compressed elliptical whorl and subventran siphuncles. His figure is reproduced here in reduced outline, Figs. 40, 41, Pl. viii.

Pl. iii. They are somewhat enlarged and show the loose coiling of several genera in the nepionic stages of development during this period of their evolution. Subsequently the coiling becomes closer, as has been demonstrated by Branco. Fig. 20, *Mimoceras compressum;* Fig. 21, *Anarcestes subnautilinus;* Fig. 22, *Agoniatites bicanaliculatus*, var. *gracilis;* Fig. 23, *Gephuroceras planorbe;* Fig. 24, *calculiforme*, and Fig. 25, *sublamellosum;* Fig. 26, *Manticoceras latidorsale*, and Fig. 27, *Glyphioceras diadema.*

Figs. 28 and 29. Protoconch of Orthoceras, after Clarke, *Am. Geol.*, xii, August, 1893.

Figs. 30 and 31. Protoconch of Bactrites, after Branco.

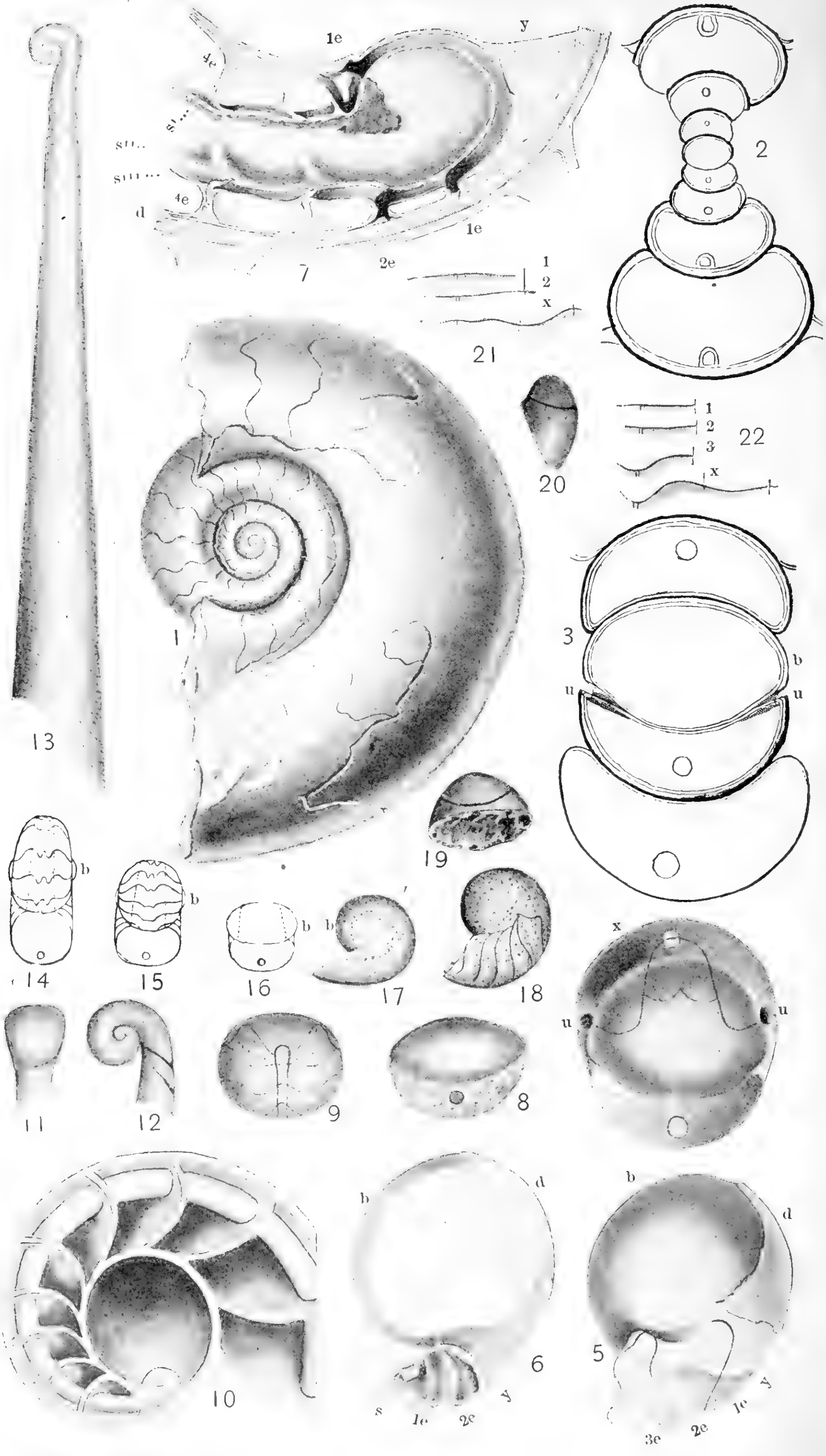

Plate III (Hyatt).

Plate III.

Figs. 1–7. *Deroceras (Amm.) planicosta*, Hyatt, *Embryology Ceph. Bull. Mus. Comp. Zoölogy*, iii, No. 5, Pls. i and ii.

Fig. 1, side view of nepionic and neanic stages, × 80 diameters. Fig. 2, section of another specimen, × 21.5 diameters; B, protoconch. Fig. 3, centre of same, enlarged to show the umbilical perforation (U) as it occurs in Ammonitinæ and most of the Goniatitinæ. Fig. 4, protoconch and first volution with ananepionic first septum; x, probably sutures of the first septum on the dorsum seen through the whorl; × 80.* Fig. 5, side view of protoconch, ananepionic first septum 1 e, and metanepionic septa, 2 e, 3 e; D, shell; B, naked cast of interior of protoconch; y, conical appendage of cæcum seen through the whorl. Fig. 6, section of same specimen exposing interior of the protoconch (y), the conical cæcal prolongation, and the fundus of the cæcum and the first two septa, S, being the neck of the small siphuncle at the third septum, which is broken off. Fig. 7, thin section of cæcum and part of conch with four septa, showing formation of cæcum by the first septum 1 e, the composition of the cæcal prolongation y, the neck of the cæcum formed by the second septum 2 e, the siphon begun by the third septum and continued by the fourth, both of which have funnels directed apically as in Nautiloids; S′, organic deposit in the interior; S″, inner layer; S‴, wall of siphuncle; × 317 diameters.

Fig. 8. *Deroceras (Ægoc.) planicosta*, Branco, *Paleontographica*, xxvii, Pl. x, showing protoconch from a different point of view and less magnified. Fig. 9, same, with first to fourth sutures showing.

Fig. 10. *Pleuroceras (Amaltheus) spinatum*, Branco (*ibid.*), Pl. xiii, enlarged, showing the interior of the protoconch; the septa of first whorl are cut exposing the cæcum. The septa are all convex and strictly ammonitoidal except the first, which is concave, as in Nautiloids and the adults of Mimoceras, Anarcestes and Agoniatites among Ammonoids of the Silurian period.

Figs. 11 and 12. *Crioceras Studeri*, Branco (*ibid.*), Pl. xiii, enlarged, showing the coiled young of this uncoiled degenerate form.†

Figs. 13–18. *Baculites compressus*, Brown, *Proc. Acad. Sci. Phila.*, 1891, p. 159; 1892, p. 136, Pl. ix. Fig. 13, enlarged young shell in the neanic stage, showing the lines of growth, aperture and rostrum on the ventral side. Fig. 14, front view of shell in the paranepionic substage; the siphuncle is not subventran. Fig. 15, front view with the two metanepionic and four paranepionic sutures, those with a siphonal lobe divided by a siphonal saddle being paranepionic in age. Figs. 16 and 17, front and side views, with restoration of the ananepionic substage. Fig. 18, side view of Fig. 15.

Figs. 19–21. Apex from the front and side and sutures of *Nautilus Clementinus*, after Branco, *op. cit.*, xxvii, Pl. ix.

Fig. 22. Sutures of *Nautilus deslongchampsianus*, after Branco, (*ibid.*), Pl. ix.

* This figure has no number.

† See also for similar forms Pl. xi, Figs. 40, 41.

Plate IV.

Fig. 1 *Baculites compressus*, enlarged sutures after Brown, see Pl. iii.*

Fig. 2. *Deroceras* (*Aegoceras*) *planicosta*, enlarged sutures after Branco, *Paleontographica*, xxvi, Pl. x. These show the ananepionic suture 1, the metanepionic or goniatitic sutures 2–4, and the paranepionic with divided siphonal lobe at the diameter of 1 mm. and 2 mm., and the next septum, the 7, here given, is transitional to the first neanic septum, the 8 of this series, which shows the beginning of ammonitic digitations in saddles and lobes and a divided dorsal lobe. By comparing this with the sutures of Pl. ii, Fig, 16, *Anarcestes lateseptatus*, and *Gephuroceras serratum*, Pl. ii, Fig. 17, it will be seen that the ephebic ventral lobes and smooth sutures of the Goniatitinæ, represented in Gephuroceras, are limited to the paranepionic in Deroceras. The goniatitic ventral lobe in other words is replaced in the ananeanic of Deroceras, representing the Ammonitinæ, by the digitate lobes and saddles of that suborder.

Fig. 3. *Vermiceras* (*Arietites*) *spiratissimum*, enlarged sutures, after Branco, (*ibid.*), Pl. ix, showing also acceleration of development through the replacement of the ephebic characters of the Goniatitinæ by those of the Ammonitinæ in the ananeanic substage.

Fig. 4–11. *Tarphyceras Champlainense*, (sp. Whitfield), Hyatt; Loc., Fort Cassin; U. S. N. Mus., Walcott Coll. Fig. 4, side view slightly enlarged, showing involution and small unbilical perforation; the crack indicates the direction of the section given in Fig. 5. Fig. 6 gives general section and the centre is of about the same age as Fig. 6. Fig. 7 is younger and shows beginning of the dorsal furrow narrower and deeper than in Fig. 6. Fig. 5 shows that it is probably due to the mechanical effects of the sudden bending shown in Fig. 7. Fig. 8, ideal section showing location of sections Figs. 6 and 7. Fig. 9, section of another specimen, natural size, showing a younger stage at the centre. Fig. 10, side view of same specimen. Fig. 11, enlarged section of metanepionic centre of Fig. 9, showing outline like that of *Nautilus pompilius* at the same age.

Fig. 12–16. *Tarphyceras prematurum*, Hyatt, Quebec Group; Loc., Port au Port, Newfoundland. Fig. 12, side view of fragmentary specimen, natural size, giving part of living chamber. Fig. 13, front view of same. Figs. 14 and 15, front and side view of nepionic and part of neanic stage slightly enlarged; Fig. 16, front view of nepionic whorl of same (× 2) showing a dorsal furrow and the abrupt bending of the whorl. The narrowness of the umbilical shoulders is not natural, being probably in part due to the obliquity of the septum and partly to erosion of the outline at this point.

Figs. 17–22. *Tarphyceras Aucoini*, Hyatt, Quebec Group; Loc., Port au Port, Newfoundland. Fig. 17, side view, natural size, of ephebic stage; Fig. 18, part of neanic whorl to show sutures. Fig. 19, section of ephebic whorls, natural size, of another specimen. Fig. 20, section, natural size, of another specimen, the upper whorls a little depressed by pressure; Fig. 21, the nepionic stage enlarged (four diameters) to show more accurate outline and the dorsal furrow and sudden bending of whorl and narrow umbilical perforation. Fig. 22, side view of same. The apex in all of these specimens was too much eroded to show the cicatrix.

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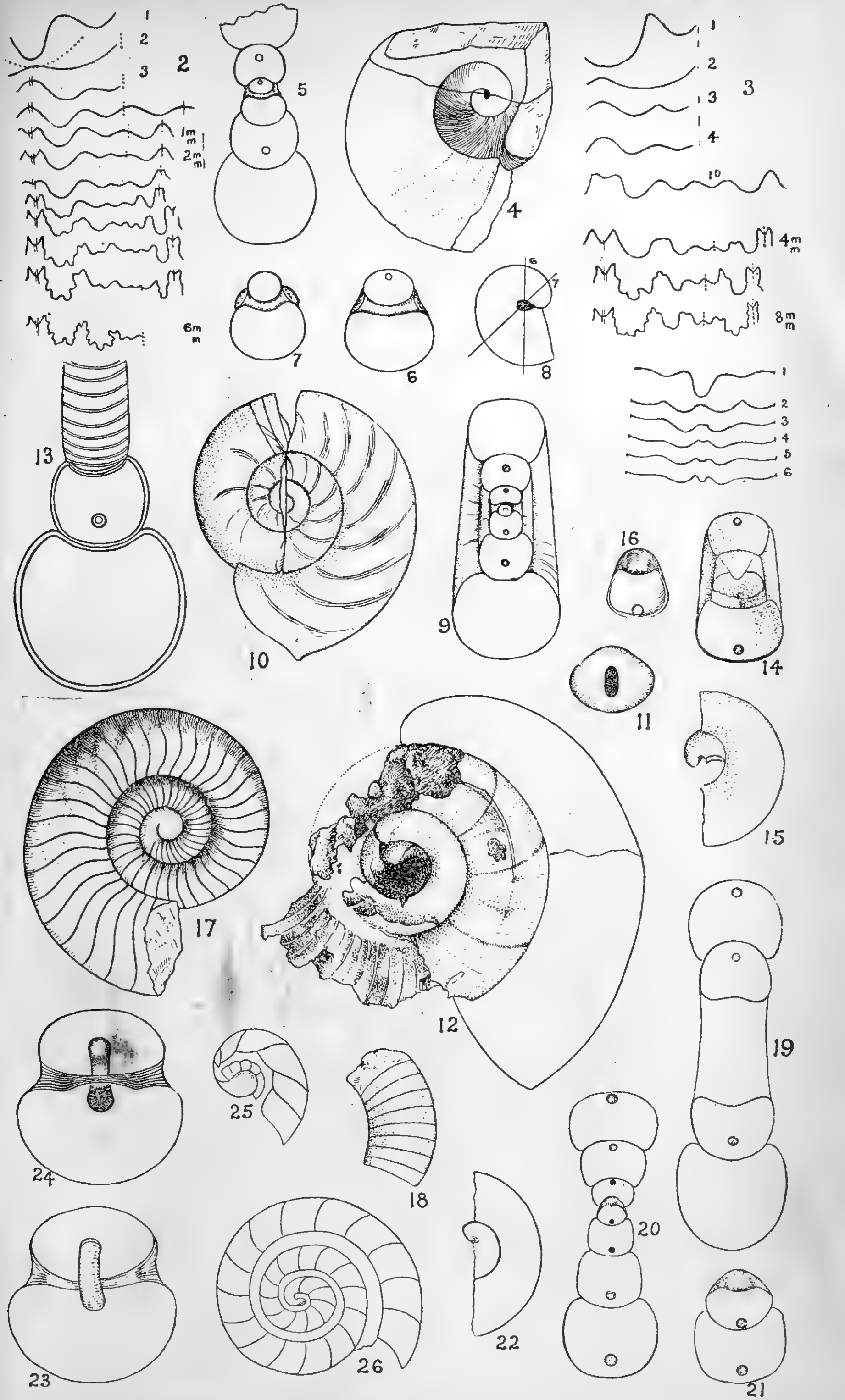

Plate IV (Hyatt).

Figs. 23 and 24. *Trocholites canadensis*, Hyatt; Loc., Falls of Montmorency (?); Coll. Mus. Comp. Zoölogy, Bronn Coll.

Fig. 23. Much enlarged. The siphuncle shows through the transparent venter of the nepionic volution and it passes from subdorsan in the paranepionic below to centren in the metanepionic above. The umbilical perforation appears beyond the siphuncle and has a well-developed dorsal furrow, can also be seen; Fig. 24 shows the gibbous outgrowth of the dorsum in the umbilical perforation at some distance from the gyroceran bend.

Fig. 25. *Trocholites* (*Lituites*) *internastriata* (sp. Whitfield), Hyatt. This was drawn from the centre of his original specimen, *Bull. Am. Mus. Nat. Hist. N. Y.*, Pl. xxix, Fig. 6, enlarged to show the centren position of the siphuncle in the first septum and its gradual approach to the dorsum in the paranepionic whorl as in *T. canadensis.* This also shows a much larger umbilical perforation than is found in *Canadensis* or *ammonius* or the species figured by Holm.

Fig. 26. *Trocholites* sp.? after Holm, *Pal. Abh. Dames et Kayser*, iii, Pl. v, Fig. 11, to show the probable beginning of the siphuncle to be nearer the centre than is described by him. His Fig. 9 of *Trocholites incongruus* shows also a small umbilical perforation and the siphuncle subdorsan, but its tip or cæcum is directed towards the centre of the apical chamber.

PLATE V.

Figs. 1 and 2. *Eurystomites undatus* (sp. Hall), Hyatt; Black River, Poland, Herkimer Co., N. Y.; Mus. Comp. Zoölogy, Walcott Coll. Natural size, showing large umbilical perforation and absence of dorsal furrow. A contact furrow is formed when the whorls come in contact in neanic stage. Siphuncle is too small and too near the venter in both inner whorls. (Fig. 3 is blank on this plate.)

Figs. 21–25. *Eurystomites rotundus*, Hyatt, Quebec Group; Fort Cassin, U. S. N. Mus., Walcott Coll. Enlarged slightly. Fig. 3, partly diagrammatic side view showing direction of section. Fig. 4, section. Fig. 5, section of nepionic somewhat nearer to that indicated in Fig. 3. Fig. 6 is about on that line and Fig. 7 is on the further side of it in the umbilical perforation. This series shows the large umbilical perforation and absence of impressed zone, until the whorls come into contact in the neanic stage.

Figs. 4 and 5. *Eurystomites* (*Naut.*) *Kelloggi* (sp. Whitfield), Schröder; Loc., Fort Cassin, Quebec Group; Walcott Coll. U. S. Nat. Mus. Fig. 4, reduced one-third, showing the cast with the partly exfoliated rough shell in the gerontic stage and the restored gerontic free whorl which is in outline. The matrix was preserved so as to give the dorsal outline of this restored volution but not the sides or the venter. Fig. 5, section of the termination of the gerontic whorl. This is ideal so far as the sides and venter are concerned and may be too long ventrodorsally, but the dorsum is correct and shows the much narrowed but still persistent impressed zone.

Fig. 6–10. *Barrandeoceras* (*Naut.*) *tyrannum* (sp. Barrande), Hyatt; Loc., Lochkov, Bohemia; Schary Coll. Mus. Comp. Zoölogy.

Fig. 6, front view of part of the nepionic volution showing the cicatrix ana-, meta- and part of paranepionic substages, the constriction next to the cicatrix and the one just beyond this belongs to the ananepionic substage; the second is also seen in Fig. 7 a, the next constrictions seen in both of these figures belong to the metanepionic substage. There is apparently no hyponomic sinus in these two substages and its absence indicates the limits of the metanepionic substage. It is not plainly visible on this specimen until near the cracked line, which is really the septum of the living chamber. Fig. 7, side view, shell was not on the living chamber, but has been restored from other specimens. Suture is about as indicated with ventral and dorsal saddles and broad shallow lateral lobes. Figs. 6 and 7 are $\times$ 4 diameters. Fig. 7 a, an enlarged side view of apex of Fig. 7 to show true aspect of this part. Figs. 8, 9 and 10, similar views of another specimen showing identity of cicatrix and youngest substages in both shells. The markings are so delicate that they are easily obliterated and are necessarily much coarser in these drawings than in nature. Fig 10 is enlarged about four diameters.

Figs. 11–14. *Barrandeoceras Sacheri* (sp. Barrande) Hyatt; Loc., V. ch. Prídoli, Bohemia; Schary Coll., Mus. Comp. Zoölogy. Fig. 11 shows the large umbilical perforation, the sudden bending of the whorl at the end of the metanepionic substage; this occurs also in Fig. 7 and Fig. 9. Fig. 12, front of same. Fig.

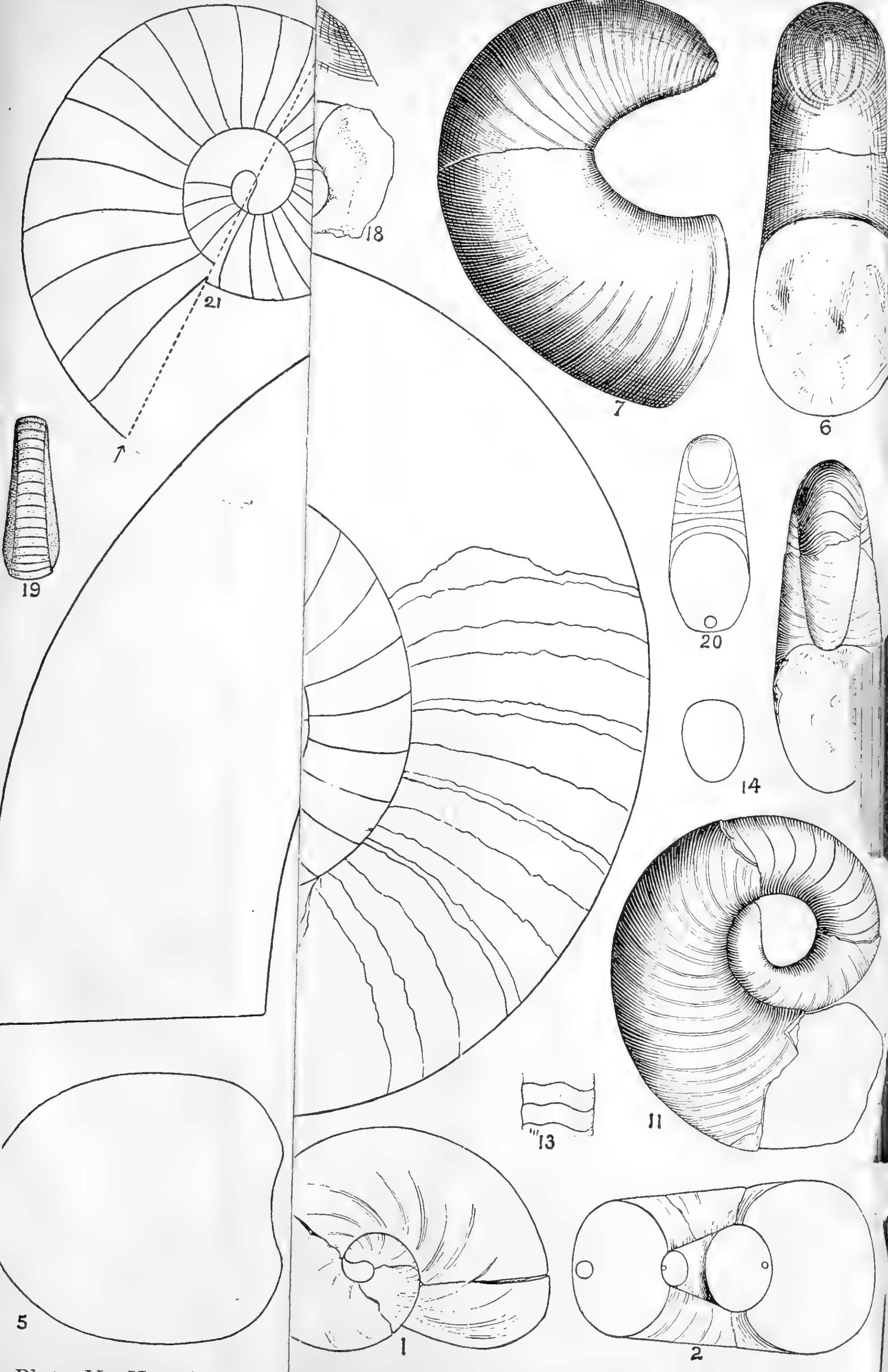

Plate V (Hyatt).

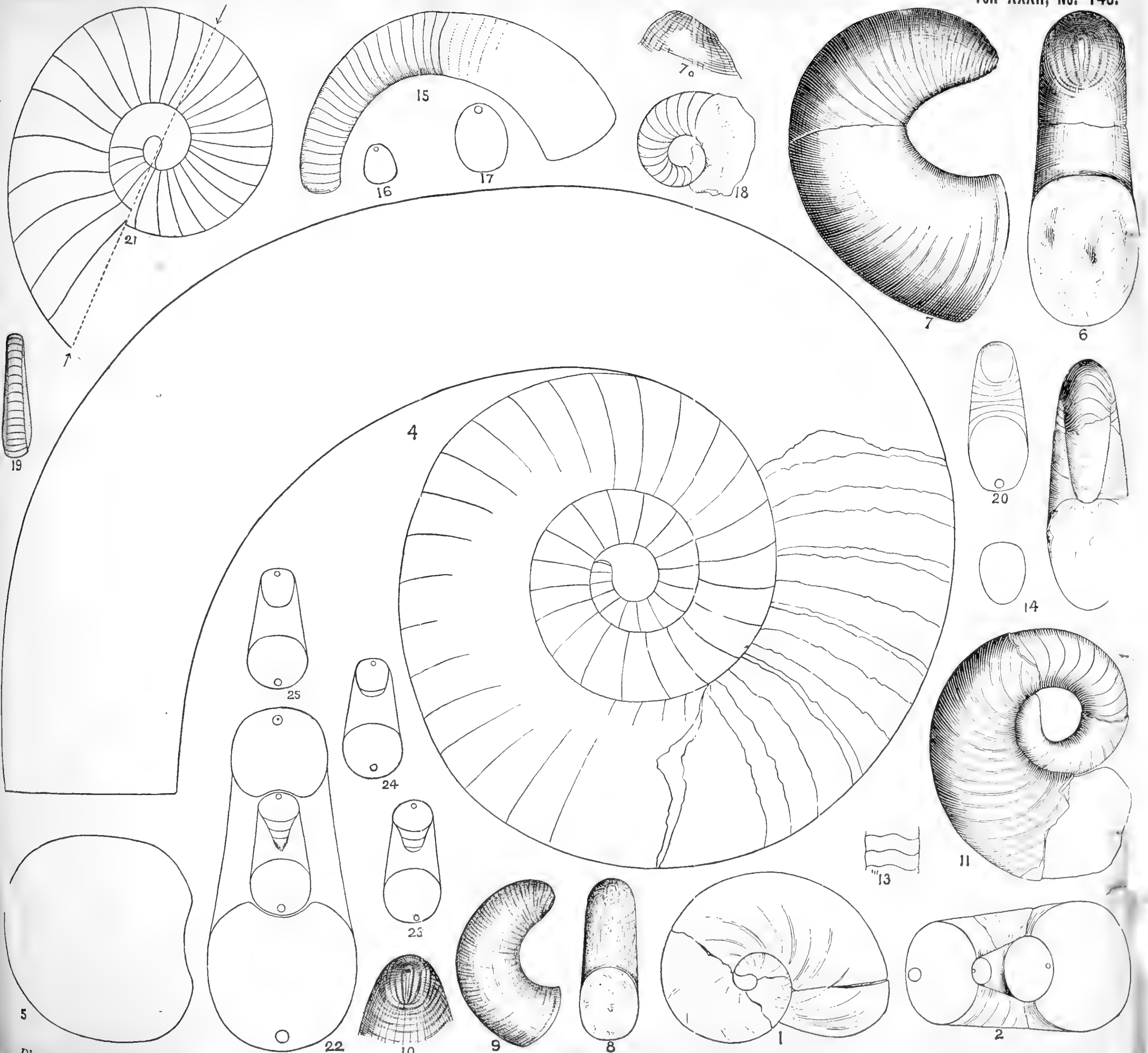

Plate V (Hyatt).

13 shows the dorsal side of Fig. 11 on the paranepionic whorl inside of umbilical perforation and just before the apex is reached. This has sutures with dorsal lobes and is flattened as is shown in section of the same, Fig. 14; this flattening also occurs in the paranepionic whorl of Fig 6.

Figs. 15–17. *Aphetoceras boreale*, Hyatt, Quebec Group; Loc., Schooner's Island, Newfoundland. Fig. 15, side view, and Figs. 16 and 17, sections all one-third reduced, showing form and absence of impressed zone. For other species of this genus see Pl. vi.

Figs. 18–20. *Pycnoceras apertum*, Hyatt, Quebec Group; Loc., Port au Port, Newfoundland. Fig. 18, side view, reduced one third, with apex restored. Fig. 19, view of venter of same encrusted with dorsal shell of older volution, the remainder of this volution having been destroyed by erosion. This shell shows the contact furrow and the dorsal lobes in the sutures of older stages. Fig. 20, view of the part of the nepionic whorl of Fig. 18, enlarged 2 diameters, showing the absence of dorsal furrow and the form of the metanepionic and paranepionic substages of this species. The remnants of the dorsal shell described above are omitted in this figure and in Fig. 18.

PLATE VI.

Figs. 1–4. *Tarphyceras extensum*, Quebec Group; Loc., Port au Choix, Newfoundland. Reduced one-third. Fig. 1, lateral view, showing position of siphuncle, septa in section and free volution. Fig. 2, section of living chamber at the termination restored by observation of the more perfect parts of the same volution. Dorsum appeared to have no impressed zone in this obviously the gerontic stage. Fig. 4, section of two ephebic whorls in part restored, showing impressed zone and general form. Fig. 3, section of younger whorl, restoration in part. Dimensions are incorrect in these sections, but the form is correct.

Figs. 5–8. *Aphetoceras Americanum*, Quebec Group; Loc., Port au Choix, Newfoundland. Reduced one-third. Fig. 5, side view showing gyroceran mode of growth, suture with ventral lobe and younger sutures with ventral and dorsal saddles. Fig. 7, section of the outer whorl. Figs. 7, 8, sections taken at the two contiguous breaks in the outer and next inner whorls. Dimensions of these sections are not correct, but form is properly represented.

Figs. 9–11. *Litoceras insolens* (?) (sp. Bill.), Hyatt, Quebec Group; Loc., Gargamelle Cove, Newfoundland. Fig. 9, side view of young specimens, very nearly natural size Fig. 10, interior whorls enlarged to show large umbilical perforation, costations of metanepionic, paranepionic and ananeanic substages, and the loose coiling of the ananeanic substage. Fig. 11, section of nepionic, ananeanic and anephebic volutions showing the absence of impressed zones in the nepionic and changes of form in older whorls. Compare this with the young of *Trocholitoceras Walcotti.*

Figs. 12–20. *Trocholitoceras Walcotti*, Quebec Group; Fort Cassin; U. S. Nat. Museum, Walcott Coll. Fig. 12, side view of type specimen natural size. Fig. 13, section of same. Fig. 14, section of centre of same enlarged to show the largest diameter of the umbilical perforation and the ananepionic substage and paranepionic with impressed zone. Fig. 20 gives location of this section and all the rest are taken between the two bisecting lines of this figure. Figs. 15–19, successive sections gradually passing out of the umbilical perforation and showing the position of the siphuncle and increasing depth of the impressed zone after contact These sections also show that the impressed zone occurs after the gyroceran bend in the beginning of the paranepionic substage, and is apparently a result of the great increase in transverse diameters, nephritic form of whorl and abrupt bending. Fig. 20, location of sections, ideal. The shape of the ananepionic volution in Fig. 13 is more accurate than in Fig. 14 or 15.

Figs. 21–27. *Schroederoceras teres* (sp. Eichw.), after Holm, *Pal. Abh. Dames et Kayser*, iii, Pl. v. Figs. 21 and 22 show the subventral cæcum in apical chamber and shifting of position to dorsad of centre in the ananeanic substage. Compare with *Schroederoceras Eatoni*, Fig. 35. Figs. 23–27, ananepionic, metanepionic substages, the septa belong wholly to the metanepionic. There is no dorsal furrow in this shell until the third septum is reached and by comparing this with sections, Figs. 21 and 22, it is seen that this indicates either the beginning, Fig. 21, or the completion of the gyroceran bend, Fig. 22, although Holm's Fig. 25 would lead to the supposition that the bending had not yet begun.

Figs. 28–35. *Schroederoceras Eatoni*, sp. Whitf., Hyatt, Quebec Group; Loc.,

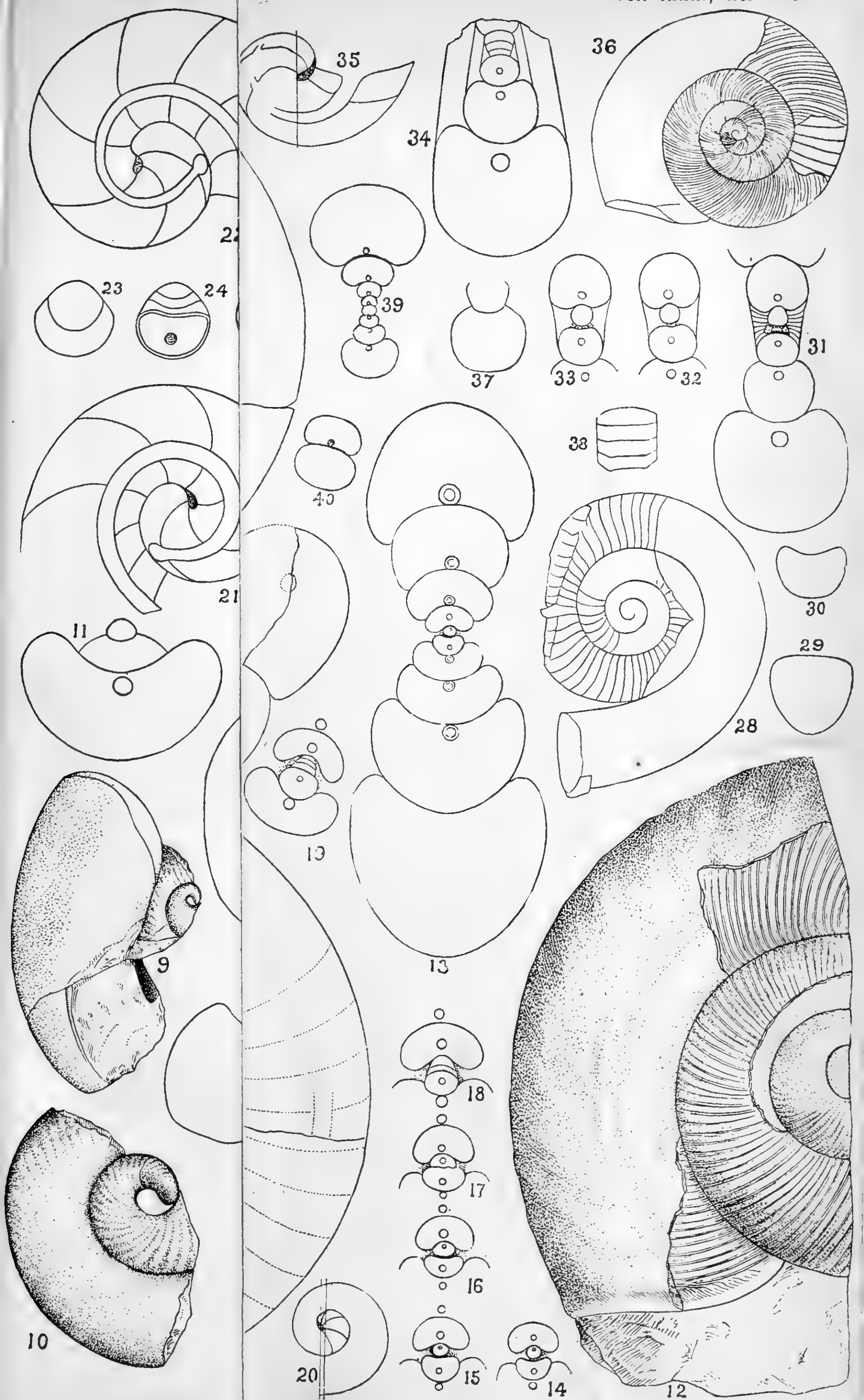

Plate VI (Hyatt)

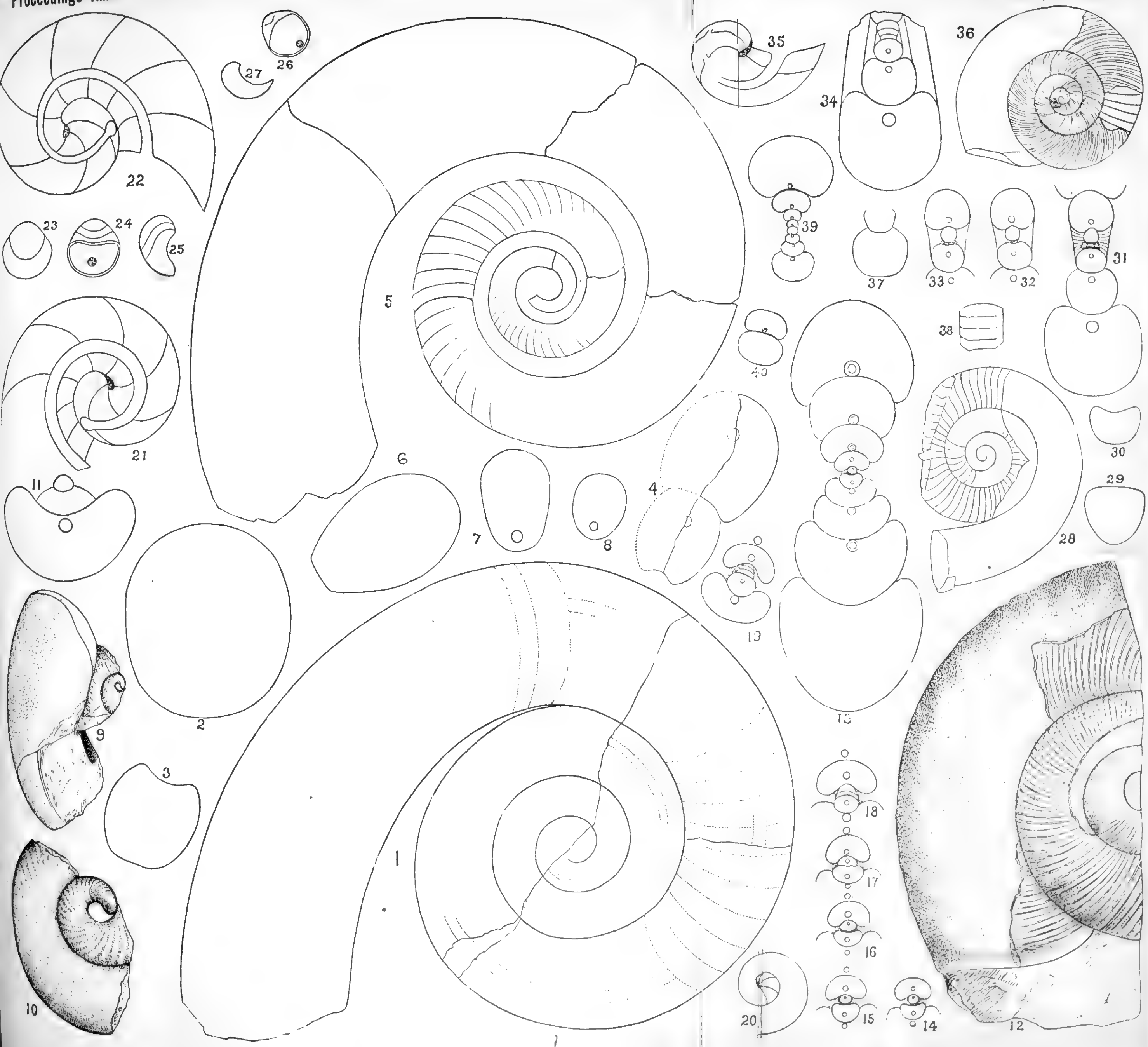

Plate VI (Hyatt).

Fort Cassin; Coll. U. S. N. Mus. and Am. Mus., N. Y. Fig. 28, side view of original (slightly changed), from Whitfield, *Bull. Am. Mus.*, Pl. xxxii, Fig. 1. Fig. 29, section of gerontic living chamber at the end. Fig. 30, section of ephebic whorl just above free end of living chamber. These two show the presence of a well-developed contact zone in the ephebic stage and its complete disappearance on the free gerontic volution. Fig. 31, shows a section of a specimen which exhibits the umbilical perforation with a core of the matrix; this cut passed inside of the line drawn through Fig. 35 and represents the metanepionic above the core and below it the paranepionic volution, the neanic being the next section of a volution above the metanepionic. Figs. 32 and 33, younger ages of the nepionic and older ages of the paranepionic volutions. Fig. 34, section along the line indicated in Fig. 35. Fig. 35, drawing enlarged from Whitfield's original Pl. xxxviii, Fig. 7. Umbilical perforation may be somewhat larger proportionally than in nature.

Figs. 36–38. *Schroederoceras casinense*, Quebec Group; Loc., Fort Cassin; Coll. Am. Mus. N. Y. Fig. 36, side view (somewhat changed), from Whitfield, *op. cit.*, Pl. xxxii, Fig. 2. Fig. 37, section of outer whorl of same near the line of broken shell on the living chamber of Fig. 36. Fig. 38, shows sutures on the venter of same specimen.

Figs. 39 and 40. *Trocholites canadense;* Loc., Falls of Montmorency, Bronn; Coll. Mus. Comp. Zoology. Fig. 39 gives section. Compare with that of *Trocholitoceras Walcotti.* Fig. 40 shows the centre of this; the lower volution is the nepionic and this shows how much wider this is than the older neanic volution above.

Plate VII.

Figs. 1–3. *Schroederoceras tubulatum*, Hyatt, pars *Lit. angulatus*, Saem.; Coll. Mus. Comp. Zoöl., Loc., Brevig, Norway. Reduced one-third. Fig. 1, side view of the fragment; the free whorl is restored as shown in this figure. The suture and form of the restoration was taken from the well-preserved dorsum and cast of the interior of the right side of the free whorl. The umbilical perforation is probably incorrect. The aperture follows the lines of growth, but is very likely incorrect and the ventro-dorsal diameter may be too long. Fig. 2, section, the outer volution being restored as regards the venter and right side; the dorsum and left side are accurate. Fig. 3, restored outline of living chamber at termination showing the obliteration of the impressed zone. See also Figs. 6–12, Pl. xiv.

Figs. 4–6. *Schroederoceras casinense*, Quebec Group; Loc., Fort Cassin; U. S. Nat. Museum, Coll. Walcott. Natural size. Fig. 4, side view showing living chamber aperture. Fig. 5, dorsum of living chamber with aperture and ephebic volution. This shows contact zone in the ephebic stage and its disappearance upon the free volution; the whorl was broken away and removed at xx. Fig. 6 showing dorsal crest of the aperture and replacement of impressed zone by a gibbous surface just beyond the shaded area in Fig. 5. See also Pl. vi.

Figs. 7 and 8. *Schroederoceras Eatoni* (sp. Whitf.), Hyatt, Quebec Group; Loc., Fort Cassin; U. S. N. Mus., Coll. Walcott. Natural size. Fig. 7, side view showing lines of growth, sutures, and aperture. Fig. 8, front of same with ventral sutures and rim of aperture removed showing the remnants of impressed zone. See also Pl. vi.

Figs. 9–12. *Estonioceras perforatum*, Schröder, Silurian. Fig. 9, side view after Schröder, *Pal. Abh. Dames et Kayser*, v, Pl. xxvi, Fig. 1 a, reduced one-third, showing free nepionic and free gerontic volutions with lines of growth. Figs. 10 and 11, Loc., Reval, Mus. Comp. Zoöl., Bronn Coll., showing paranepionic whorl with lines of growth on the dorsum and absence of dorsal furrow and lateral sutures, reduced one-third. Fig. 12, three sutures of upper part of dorsum of the paranepionic substage of Figs. 10 and 11, the shell removed and the whorl enlarged.

Figs. 13–19. *Estonioceras biangulatum*, Silurian; Loc., Breslau; Mus. Comp. Zool., Kranz Coll. Figs. 13 and 14, reduced one-third the abdomen of Fig. 13, is distorted by pressure.* Fig. 15, venter of paranepionic and section of neanic below with beginning of impressed zone (this is more accurately given in Fig. 15 a); above is ephebic whorl, but this and sutures are distorted by perspective. This view is taken from the interior of Fig. 13 with parts between fractures removed. Fig. 16, venter of ephebic stage, showing sutures with ventral lobes not saddles as on outer volution of Fig. 15. Fig. 17, dorsum of free gerontic volution showing lines of growth with dorsal crests, sutures with dorsal lobes; depression in cast perhaps annular muscle, which disappears on the sides; there are faint marks on the venter as if the upper edge of this may have risen into a saddle on that side as in Fig. 1, Pl. viii, of Remeléceras. The impressed zone disappears early on this volution. Fig. 18, venter of the same, showing change in sutures and return of

*The apex of this was not clearly seen and it may be free.

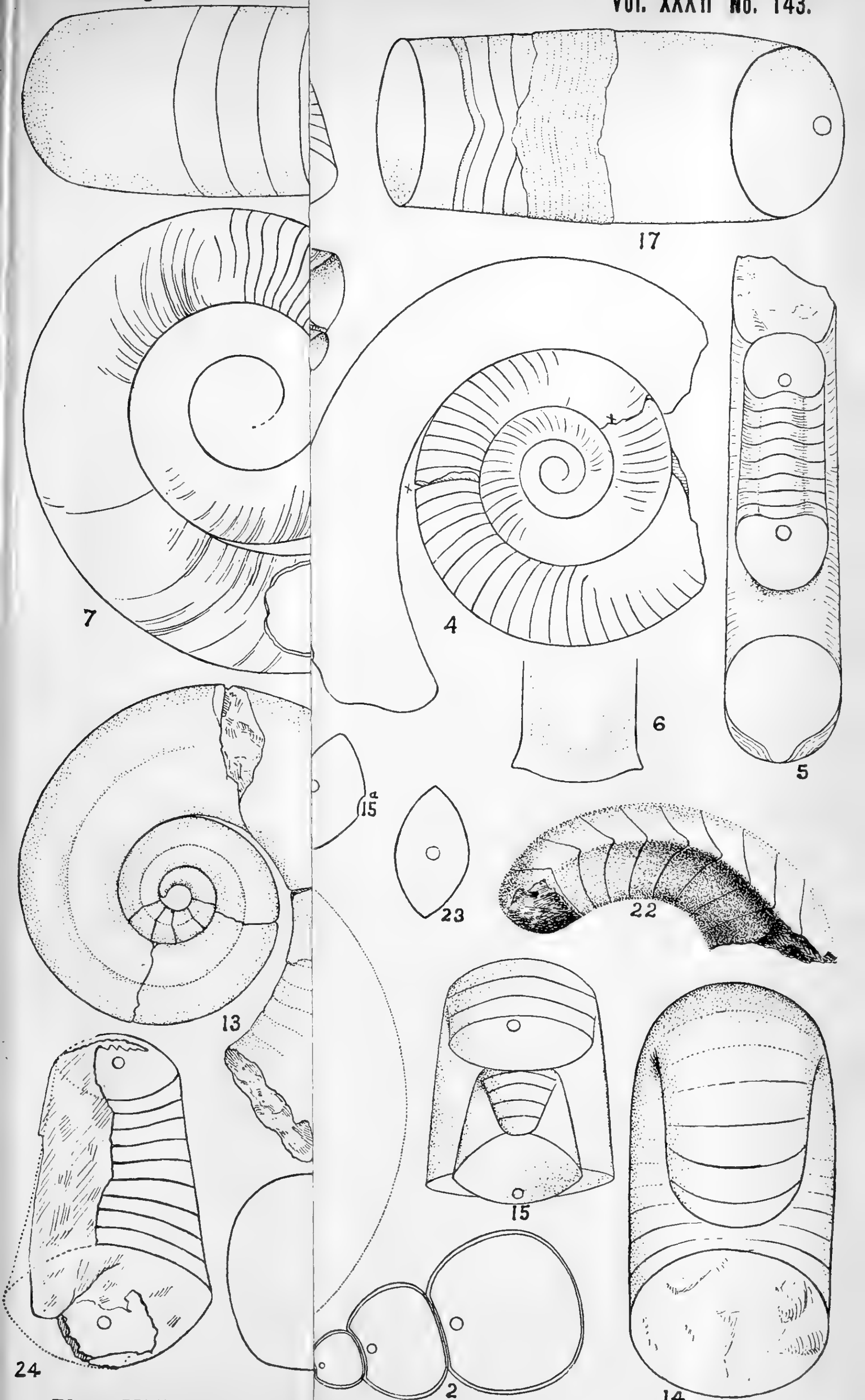

Plate VII (Hyatt).

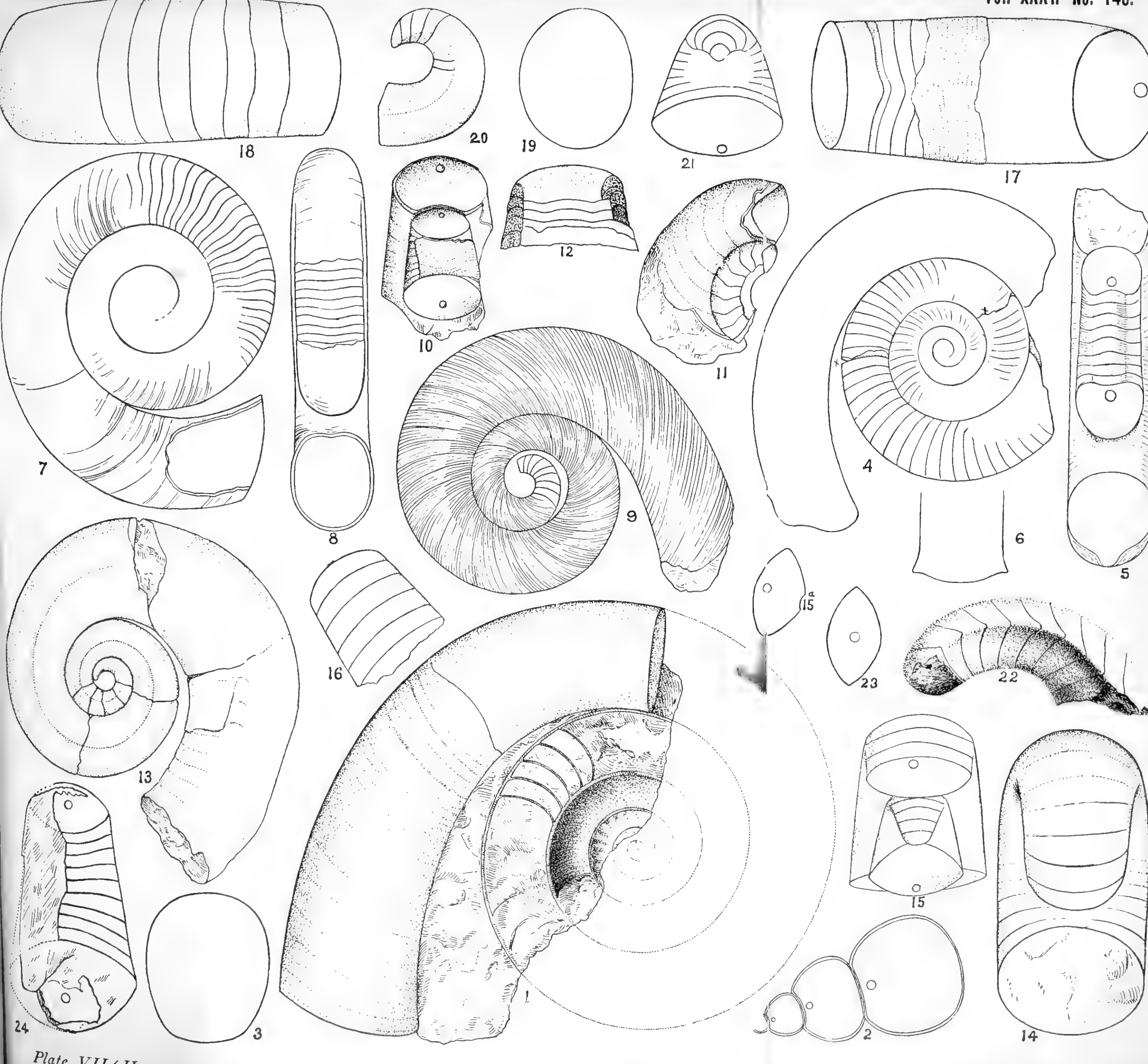

Plate VII (Hyatt).

saddles in the last three sutures of the paragerontic substage. Fig. 19, sectional view of terminal end of Figs. 17 and 18, showing dorsum slightly broader and flatter than venter.

Figs. 20 and 21. *Estonioceras imperfectum*, after Schröder, *op. cit.*, Pl. xxvii, Fig. 5 a, b, showing young enlarged with subventran siphuncle, etc., and no impressed zone.

Figs. 22–24. *Edaphoceras* (*Temnoch*) *niotense*, *Met. W. Geol. Ill.*, v, Pl. xix, Fig. 3, much reduced in size. Fig. 23, the dorsum is more convex than the venter.

Plate VIII.

Figs. 1–8.* *Remeleceras impressum*; no locality; Coll. Mus. Comp. Zoölogy. Natural size. Fig. 1, side view showing sutures and annular muscle in base of living chamber. Fig. 2, ventral side of fragment of same specimen. Fig. 3, dorsal side of same fragment with impressions of annular muscles on cast. Fig. 4, section of end of living chamber showing the decrease of the impressed zone in the anagerontic substage. Fig. 5, dorsal view of the second and younger fragment of same. Fig. 6, section of older end of same showing depth of impressed zone in the ephebic stage. Fig. 7, still younger fragment of same, showing the dorsal sutures of a late neanic or anephebic substage. Fig. 8, section.

Figs. 9–13. *Hercoceras mirum*, Barrande. Figs. 9–12, slightly enlarged, Koneprusy. Fig. 13, natural size, Hlubocerpy, Mus. of Comp. Zoölogy, Schary Coll. Figs. 9 and 10, side view and front of the ananeanic substage showing first beginning of contact furrow and the trochoceran form of the young which is more marked than in the adult. Figs. 11 and 12, side view and front of paranepionic substage of the same specimen showing the absence of the dorsal furrow just before the apex is reached.

Figs. 14 and 15. *Hercoceras irregularis* (sp. Barrande), Hyatt; Loc., Bohemia; Mus. Comp. Zoöl. Fig. 14, side view of meta- and paranepionic volution, showing the peculiar costæ without longitudinal ridges of this genus. Fig. 15 shows the form in section of the meta- and paranepionic whorl and the absence of the contact furrow in correlation with the rounded form of whorl. The cæcum is not correct; this organ is large and ventrocentran in this specimen.

Figs. 16–20. *Anomaloceras anomalum* (sp. Barrande), Hyatt; Mus. Comp. Zoölogy, Schary Coll. Slightly enlarged. Fig. 16, section passing through umbilical perforation which is filled with a peculiar dense shell-like deposit, not found so far in other forms, and also cutting the meta- and paranepionic substages. The neanic stage with a deep impressed zone and the two sections of the outer whorl which are in the ephebic stage. The siphuncle appears to be nearer the centre in the metanepionic substage in this and in Fig. 17 than in the later stages. There is a dorsal furrow at the usual place beginning beyond the gyroceran curve in the paranepionic substage in correlation with the nephritic outline of this substage. Fig. 17, view of a section of the metanepionic and paranepionic substages of same cutting deeper into the umbilical perforation which is becoming narrower. Fig. 18, a still deeper cut which has passed through the apex of the conch and shows the first contact of the whorls. Fig. 19 shows the beginning of the contact zone, the paranepionic section having passed into the ananeanic and below the rounded ananepionic has replaced the metanepionic volution. Fig. 20, a still deeper cut, showing the shell of the ananepionic substage becoming broader through the approach of the section to the exterior of the ananepionic apex. A shade farther and the ananeanic and metaneanic sections would blend into one long figure and the ananepionic would disappear.

Figs. 21–23. *Discoceras Graftonense* (sp. Meek and Worthen), Hyatt; Loc., Waukesha, Wis., Niagara Group; Mus. Comp. Zoölogy, Day Coll. Natural size.

* Fig. 1 has no number on the plate.

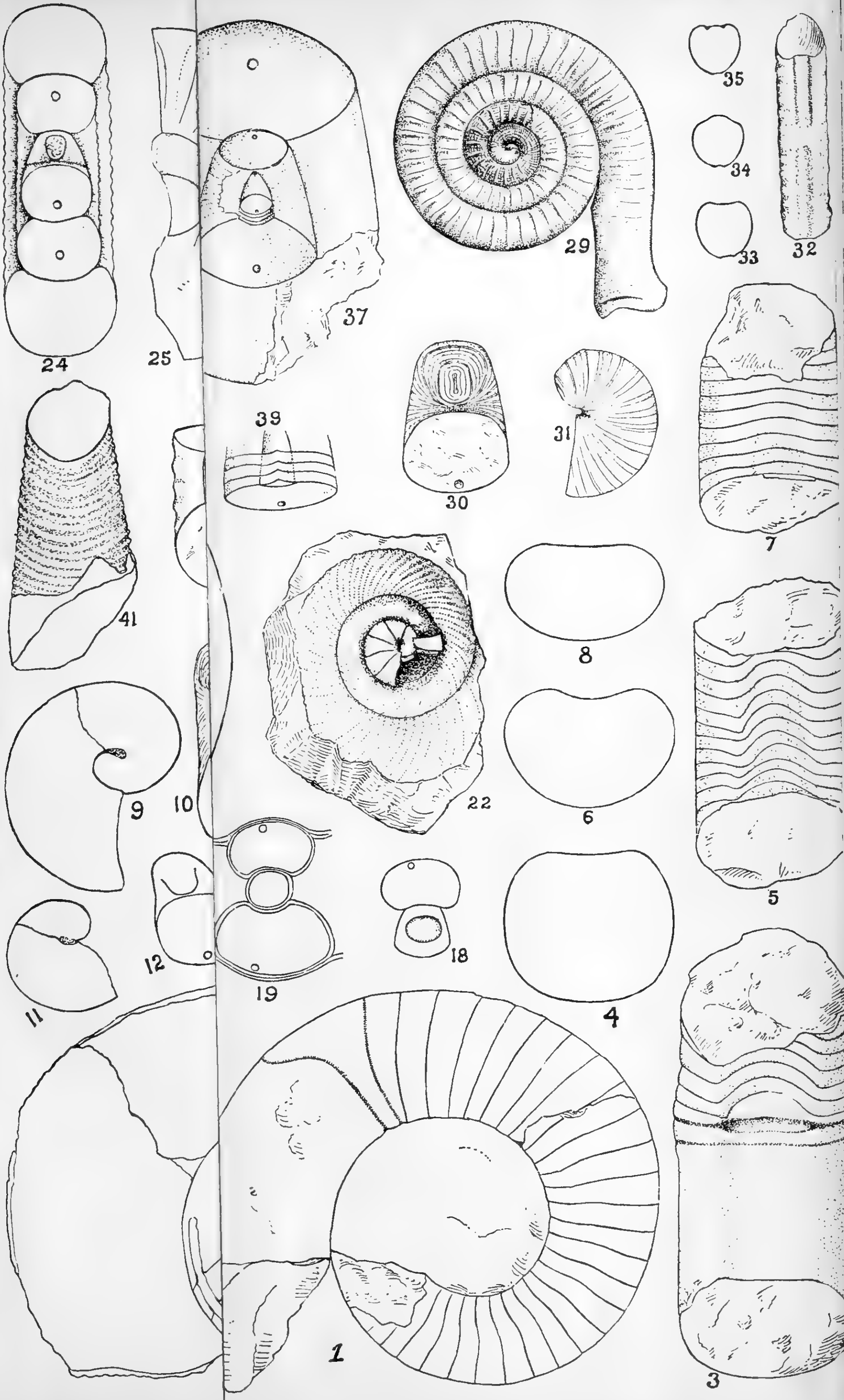

Plate VIII (Hy

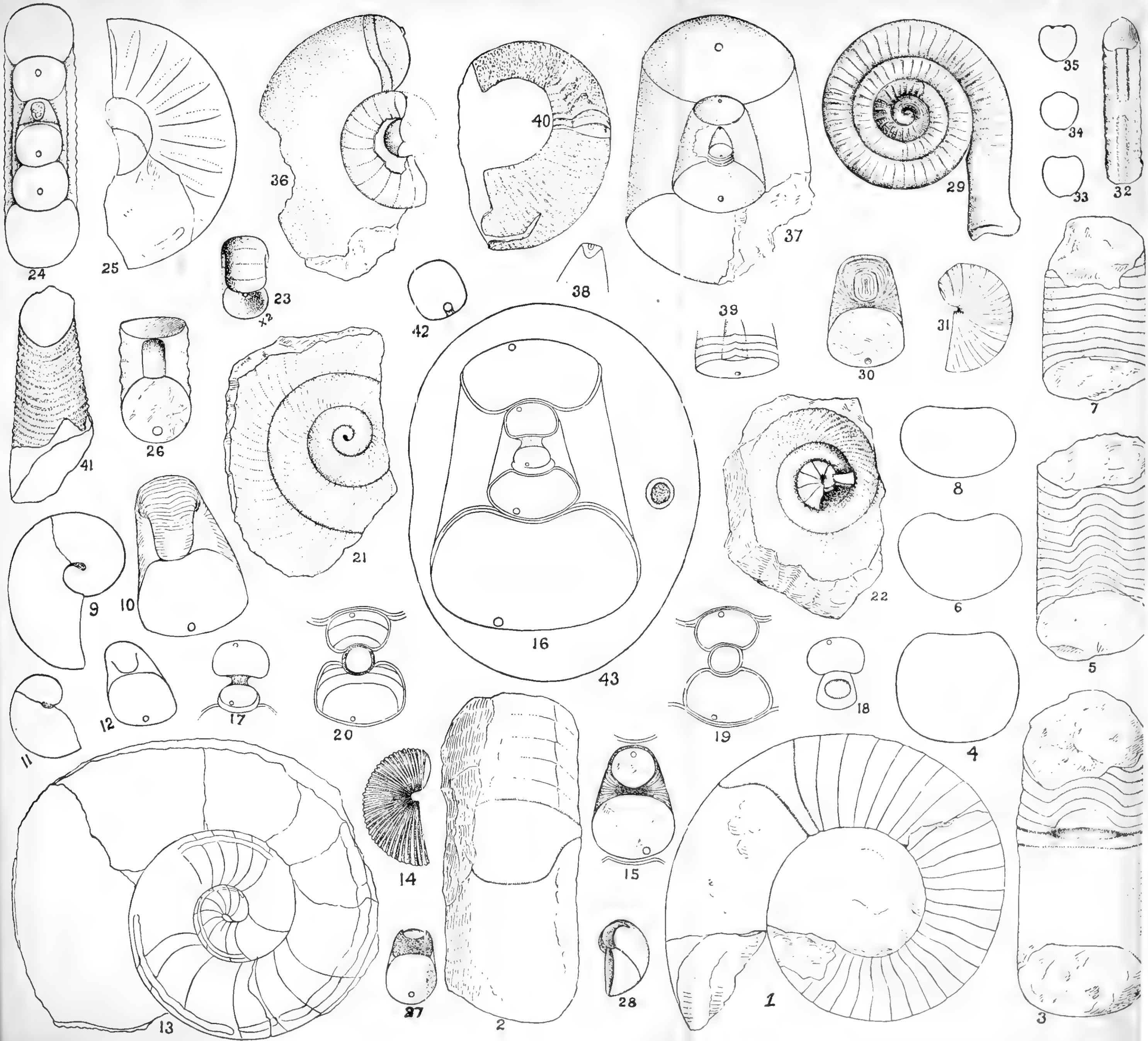

Plate VIII (Hyatt).

Fig. 21, side view of a cast of a mould of this species. Fig. 22, a similar specimen, but with nepionic stage and the beginning of the ananeanic substage in relief preserved in the centre, showing small umbilical perforation, subdorsan siphuncle (see also Fig. 23 for front view of same) and sutures. The sutures have slight ventral lobes in the ananeanic, but are almost if not quite straight on the venter of the paranepionic substage (shown in Fig. 23). The first suture was not visible in this specimen.

Fig. 24 and 25. *Ophidioceras tener*, Barrande; Mus. Comp. Zoölogy, Schary Coll.; Loc., Bohemia. × 3 diameters. Fig. 24, front view of section of neanic and ephebic volutions, the nepionic in relief in the centre. The outline of the ananepionic substage is given, but the cicatrix was unluckily destroyed by the incautious use of acid in cleaning it. The position of the siphuncle is nearer the venter than in older stages. Fig. 25, side view somewhat larger to show the constrictions on the nepionic whorl and the great comparative size of the apical chamber and the first suture and constriction.

Figs. 26–28. *Ophidioceras tessellatum*, Barrande; Mus. Comp. Zoölogy, Schary Coll. Fig. 26, × 3, to show dorsal outline of paranepionic volution without a dorsal furrow and ananeanic dorsum just below this with the beginning of contact furrow made by envelopment of the apex. Figs. 27 and 28, × 4 diameters, to show similar characters to those of *O. tener*, and, the matrix filling the umbilical perforation having been retained, this specimen shows also just how the paranepionic volution strikes the apex. The absence of an impressed zone is also noted in the paranepionic and position of siphuncle.

Figs. 29–35. *Ophidioceras rudens*, Barrande; Loc., Bohemia; Mus. Comp. Zoölogy, Schary Coll. Fig. 29, natural size; Figs. 30 and 31, × 4 diameters; Figs. 32–35, natural size; Fig. 29, side view showing general form of this species and of the genus; Figs. 32–35 show the history of the contact furrow on free whorl with gibbous median dorsal face and lateral dorsal furrows or faces as in section 35, and also as on all of the close-coiled whorls. In the centre is the area of the spur, shown in section Fig. 34, and in the lower part is the modified contact furrow growing slightly narrower and shallower towards the aperture. Section of this part is given in Fig. 33; Figs. 30 and 31, side and front views of nepionic stage of another specimen showing cicatrix, form of ananepionic substage, which is a compressed almost quadragonal ellipse, metanepionic with venter broader than dorsum and paranepionic with dorsum broadening out more but still narrower than venter.

Figs. 36–39. *Endolobus avonensis* (sp. Dawson), Hyatt; Carboniferous; Loc., Joggins, Nova Scotia; Coll. L. Agassiz. Natural size. Fig. 36, side and front views showing the ana- and metanepionic substages in the centre (see also Fig. 38, enlarged view, showing form more accurately and cicatrix). The ananeanic substage coming in when the apex is reached and the absence of the impressed zone until after this contact is shown above the apex in Fig. 37. Below this is seen the dorsal sutures and deep impressed zone produced by contact (shown also in Fig. 39, more enlarged).

Figs. 40–42. *Mimoceras* (*Goniatites*) *lituum*, after Barrande, *op. cit.*, Pl. x, showing the young and probably the adult of this form without any impressed zone and its similarity to some species of Nautiloidea, reduced one-third.

Fig. 43. *Cranoceras* (*Cyrt.*) *lineatum* (sp. De Verneuil), Hyatt; Devonian, Pelm near Gerolstein; Mus. Comp. Zoölogy, Schultze Coll. Fig. 43, outline to show the impressed zone which seems to appear in this cyrtoceran form in correlation with the nephritic outline independently of contact.

Plate IX.

Figs. 1 and 2. *Thoracoceras* (*Cyrt.*) *puzosianum* after De Koninck, *Calc. Carbon.* Pl. xxxiii, Figs. 10 and 11, to show in an adult of arcuate form the same ornamentation and form that are also present in the young of the more highly ornamented species like *Thoracoceras canaliculatum* and the young of many nautilian forms. See Figs. 11–13 of *Vestinautilus Konincki.*

Figs. 3 and 4. *Thoracoceras* (*Cyrt.*) *canaliculatum*, after De Koninck, *ibid.*, Pl. xxxiii, Fig. 9, to show the spinous character of the ornamentation produced by prominent lines of growth in crossing over the longitudinal ridges; also for comparison with the young of Triboloceras, Vestinautilus, Rineceras, etc.

Figs. 5–13. *Vestinautilus* (*Naut.*) *Konincki* (sp. De Koninck), Hyatt; Figs. 5–8, after De Koninck, *ibid.*, Pl. xxx, Fig. 1; Figs. 11–13, Hyatt, *Emb. Ceph.*, Pl. 4; Figs. 9 and 10 original. This series shows ontogeny of this species. Figs. 9 and 10, nepionic stage and ananeanic substage. Figs. 11–13, ana- and metanepionic with rounded whorl and cyrtoceran form and ornaments like *T. puzosianum;* the roughened spinous ornaments come in later in the paranepionic substage. The limit of the paranepionic is shown in Fig. 9, the ananeanic begins in last half of the first volution when the inner longitudinal ridges cease on the sides. Compare abdomen with ephebic stage of Triboloceras, Fig. 15. The ephebic stage begins near the end of the first half of the second volution when the gibbous face and the lateral dorsal flutes or faces begin to appear in the zone of involution as in Fig. 7. The anagerontic substage is shown in the loss of the ornaments in Figs. 5 and 6, and also in the diminution of the hollow central ventral zone and tendency of the abdomen to become rounded.

Figs. 14 and 15. *Triboloceras* (*Gyroc.*) *intermedium*, after De Koninck, *ibid.*, Pl. xxxiii, Fig. 4.

Figs. 16–19. *Vestinautilus* (*Naut.*) *pinguis*, after De Koninck, *ibid.*, Pl. xxx, Fig. 6 a–c, and Fig. 7 a, b. Figs. 18 and 19 show the anephebic substage with spinous ornaments, the loss of these in the succeeding part of the ephebic stage and the replacement of the ventral hollow zone, which is present in the nepionic stage of this species, by a gibbous face like that of the gerontic stage of Konincki. Figs. 16 and 17 show the parephebic substage and anagerontic substage, the latter occurring through loss of the lateral fluted faces as in Fig. 5, of Konincki. In the succeeding gerontic substages the whorl loses its angularity.

Figs. 20 and 21. *Rineceras* (*Gyroc*) *tessellatum*, after De Koninck, *ibid.*, Pl. xxxiii, Fig. 5, 5 a.

Figs. 24 and 25. *Lispoceras* (*Naut.*) *sulciferum*, after De Koninck, *ibid.*, Pl. xxxi, Fig. 7 a, b.

Figs. 26 and 27. *Phacoceras* (*Naut.*) *oxystomum*, after De Koninck, *ibid.*, Pl. xvii, Fig. 3.

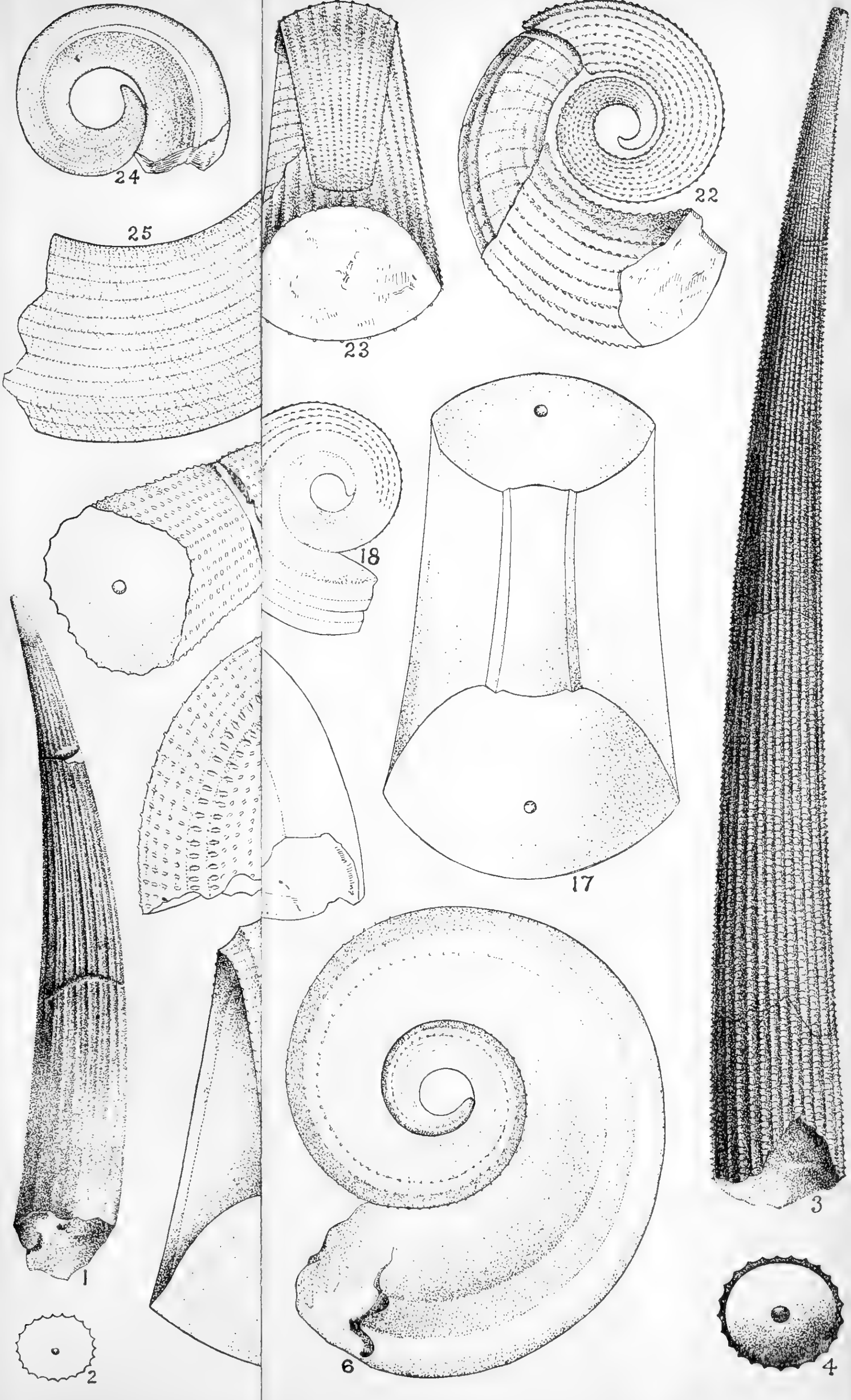

Plate IX (Hyatt).

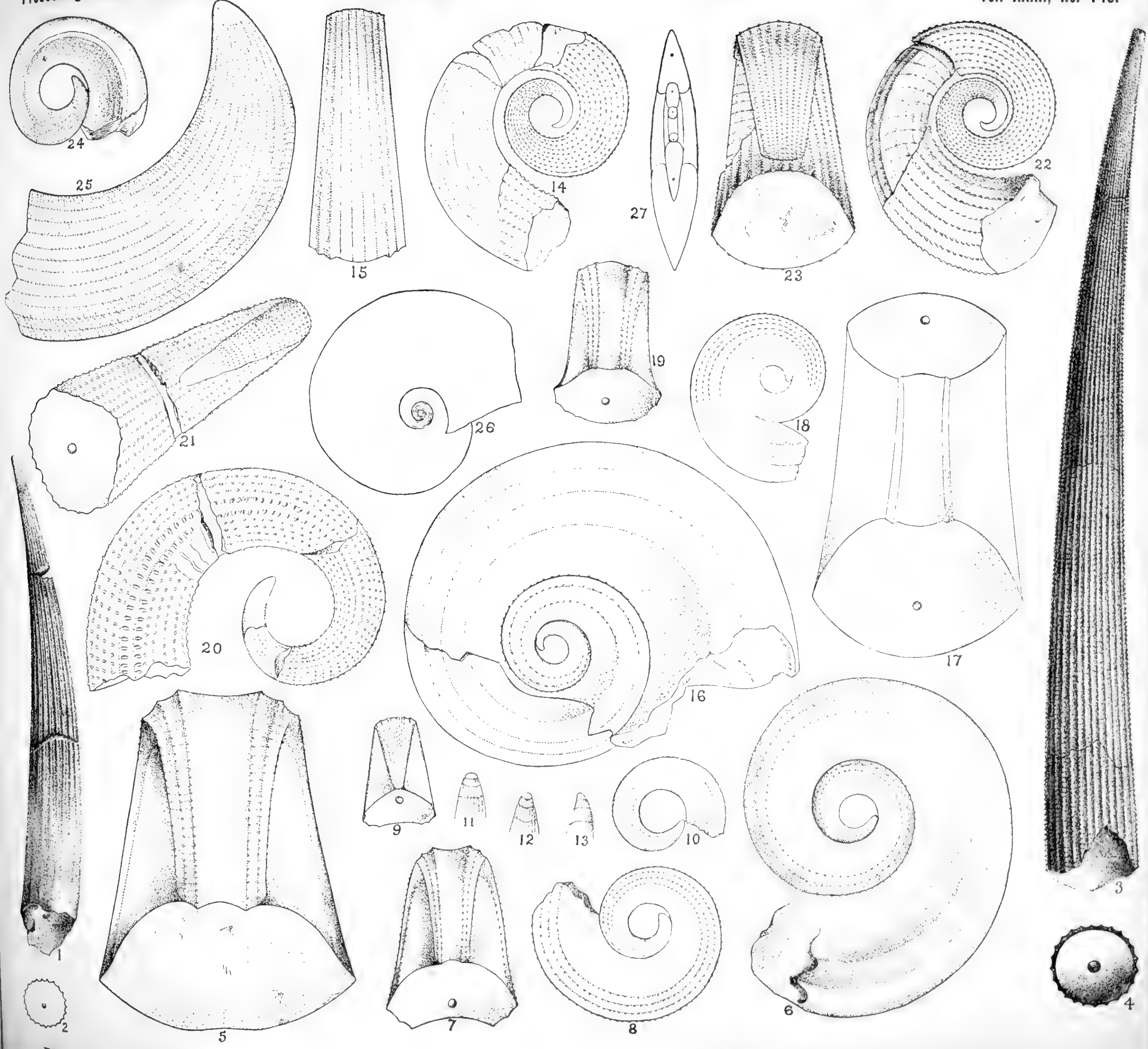

Plate IX (Hyatt).

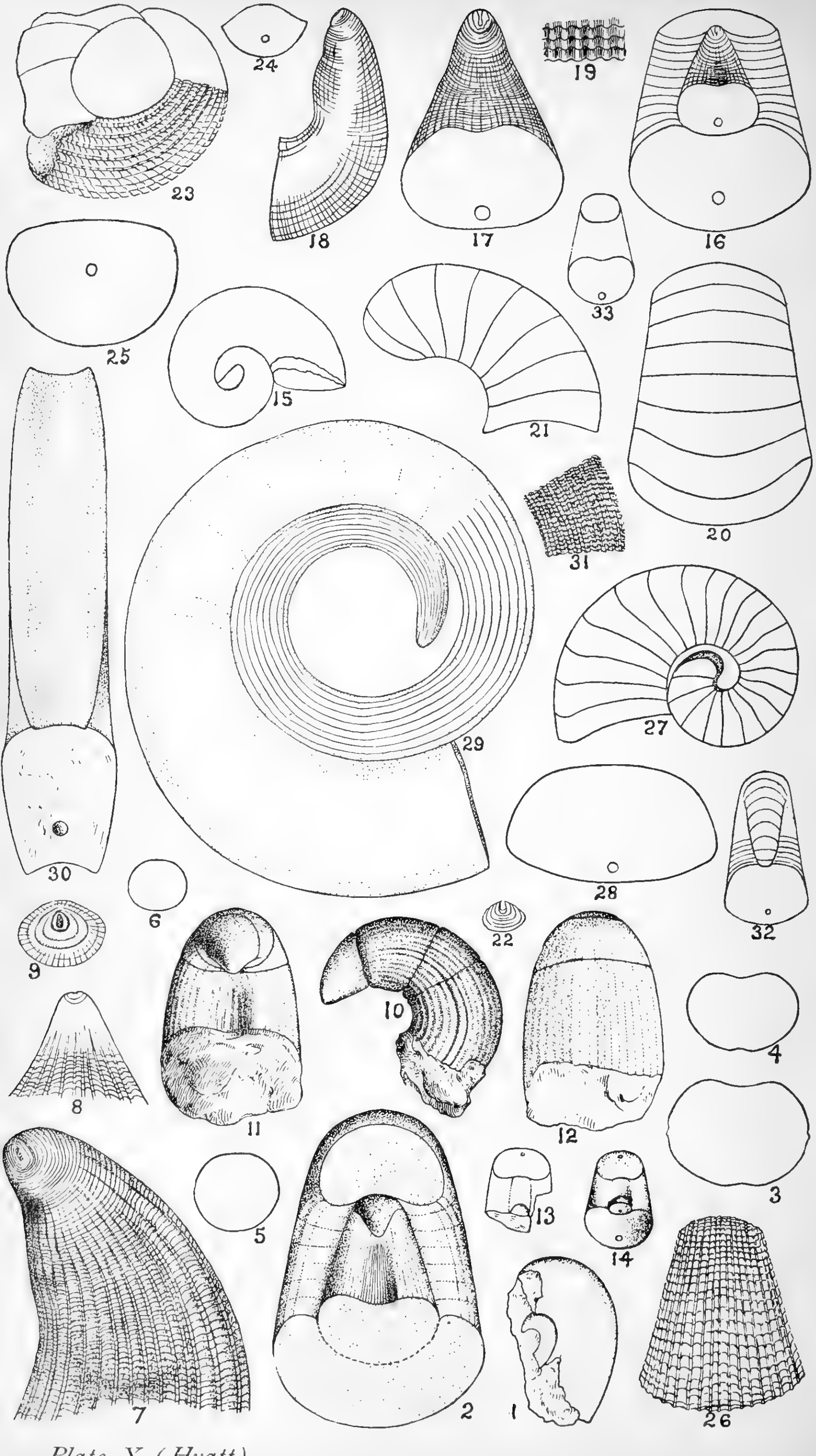

Plate X (Hyatt).

PLATE X.

Figs. 1–14. *Coloceras* (*Naut.*) *globatum* (sp. De Koninck), Hyatt; Loc., Visé, Belgium, Carboniferous; Coll. De Koninck, Mus. Comp. Zoölogy.

Fig. 1. Side view of nepionic and neanic volution, natural size. Fig. 2, same enlarged in front view and ends of volutions restored; compare neanic volution with the gerontic volution of *Vestinautilus pinguis*, Pl. ix, Fig. 17; it will be seen that this genus resembles the latter in the lateral fluted faces, but has rounded sides, such as have been described as appearing in the paragerontic substage of that species; Fig. 2 also shows the impressed zone well-developed in the paranepionic substage. Figs. 3–6, sections of meta- and paranepionic substage of Fig. 10, showing development of outline and correlation of impressed zone with nephritic form. The ananeanic substage begins immediately after this on the latter half of the still uncoiled first volution and then the longitudinal ridges disappear on the abdomen and also the crease or hollow central ventral zone, the section becomes in the metaneanic similar to that of the upper volution in Fig. 2. Fig. 7, enlarged oblique view of apex of same, showing the ana- and metanepionic substages and the beginning of the impressed zone in a shaded crescent near the base of the figure. Fig. 8, view of venter of another specimen ananepionic and a part of metanepionic showing the beginning of the hyponomic sinus in the bands of growth. Fig. 9, end view of same with cicatrix. Figs. 10–12, views of another specimen showing the first three sutures, impressed zone and ventral hollow zone of the paranepionic substage. Fig. 13, shows the impressed zone of the ananeanic substage and the beginning of the true impressed zone after contact in the shaded crescent-like depression from which the apex has been removed. Fig. 14, another specimen of same age with the pseudo-impressed zone and the apex (ananepionic substage) in place. In all sections the venter is the lower side.

Figs. 15–22. *Potoceras dubium.* Fig. 15, side view slightly enlarged showing shape of umbilical perforation and abrupt bending of the paranepionic substage when the zone begins. Fig. 16, front view of ana-, meta- and paranepionic substages and neanic volution in part. Figs. 17 and 18, enlarged views of same without the neanic volution. Fig. 19, enlarged view of details of bands of growth and longitudinal ridges taken from same. Figs. 20 and 21, views of ephebic volution, natural size. The history of the impressed zone is parallel with that of Coloceras except that it comes in only after the abrupt bending of the first whorl, and the form and character of the ana- and metanepionic substages differ. Fig. 22, view of the ananepionic substage showing the flattened aspect of apex. Figs. 22 and 9 (the latter described above) are, however, more distinct than the specimens.

Figs. 23–26. *Ephippioceras* (*Naut.*) *ferratum* (sp. Owen), Hyatt; Loc., Edmondson Co., Ky., Carboniferous; Mus. Comp Zoölogy. Enlarged four diameters. Fig. 23, side of fragment of paranepionic substage, showing also umbilical perforation, apex restored and fragment of cast of ananeanic substage with parts of two sutures. Fig. 26, venter of same. The longitudinal ridges are wider apart and broader at their crests on the sides than on the central parts of the venter as shown in Fig. 23. Figs. 24 and 25 show sections of both ends of the fragment covered by shell in Fig. 23.

Figs. 27 and 28. *Temnocheilus* (*Naut.*) *subtuberculatum* (sp. Sandberger), Hyatt; Loc , Wissenbach; Coll. Mus Comp. Zoölogy; Devonian.

Fig. 27, side view of ana-, meta- and paranepionic and perhaps beginning of ananeanic substages before the whorls touch. It will be observed that the apex is not enveloped even in this closely coiled form and that the dorsal furrow is not present at the end of the volution, Fig 27, which is given in the section Fig. 28.

Figs. 29–31. *Apheleceras* (*Naut.*) *mutabile* (sp. D'Orb.), Hyatt: Loc., Carboniferous; after D'Orbigny, *Pal. Universelle*, Pl. lxxxviii, Figs. 1, 2 and 4. Show the free apex and moulding of the dorsum to fit the hollow venter of this species. Fig. 31 shows the surface of the shell of earlier substages.

Fig. 32. *Metacoceras cavatiformis* (same specimen as Figs. 16–19, p. 496 of this paper) showing the beginning of the impressed zone at contact with the apex.

Fig. 33. *Cœlogasteroceras canaliculatum*, Hyatt; Loc., Edmondson Co., Ky.; Mus. Comp. Zoöl.; Carboniferous. A section across the meta- and paranepionic volution showing the large umbilical perforation, comparatively slow increase in size of the first whorl and presence of a dorsal furrow in the paranepionic substage.

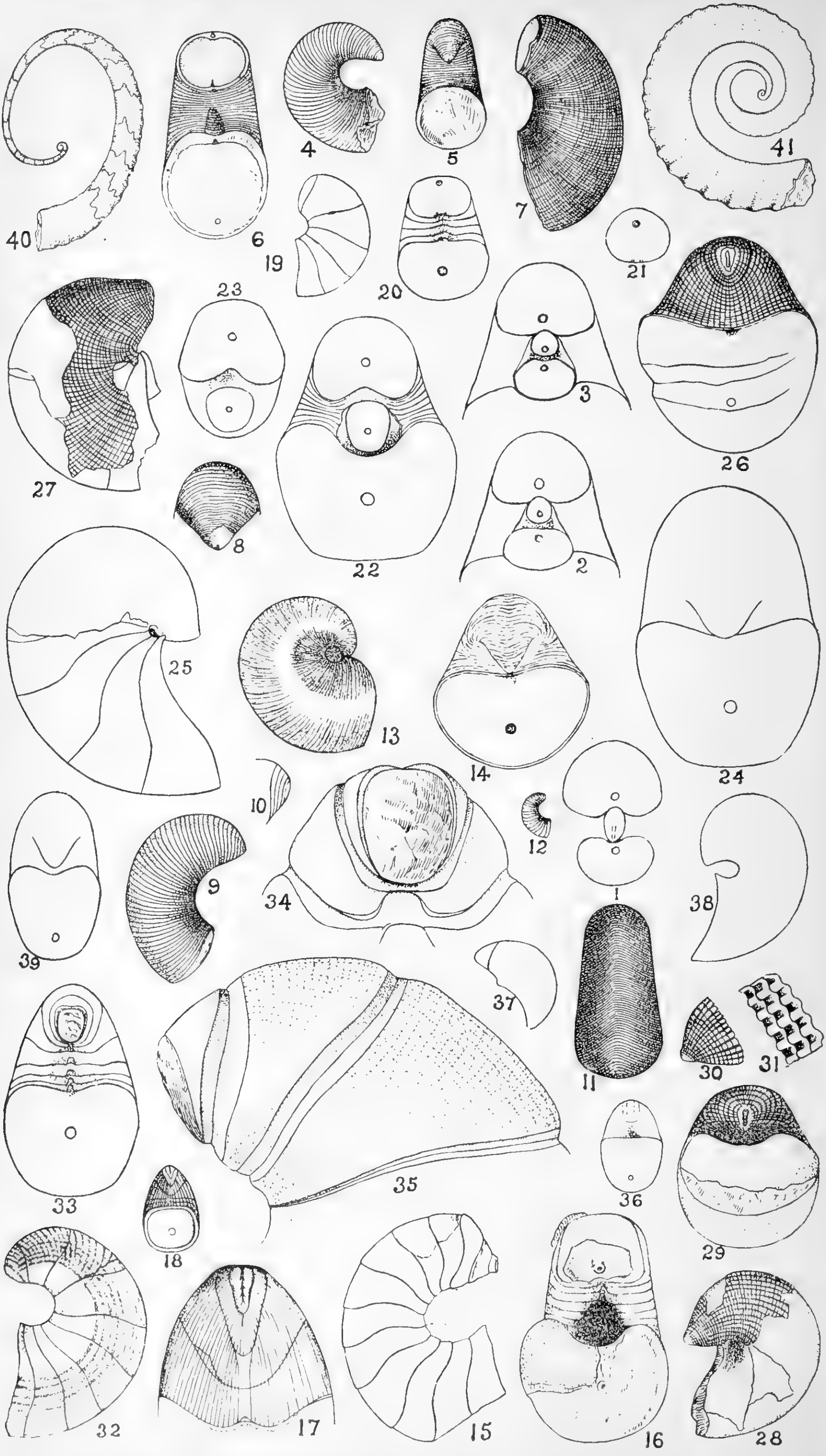

Plate XI (Hyatt).

Plate XI.

Figs. 1–3. *Peripetoceras* (*Naut.*) *Frieslebeni* (sp. Geinitz); Loc., Tunstall Hill, England; Mus. Comp. Zoöl.; Dyas. Natural size. Fig. 1 shows the section through the apex of the conch, the ananeanic volution below and a later age of the neanic stage above. Fig. 2, the cut has passed through the umbilical perforation, the metanepionic above this and the paranepionic below; above the metanepionic is the paraneanic or anephebic substage. Fig. 3, the cut has approached the farther side of the umbilical perforation and shows an older age of the metanepionic and a younger age of the paranepionic with a deeper and better defined dorsal furrow than in Fig. 2.

Figs. 4-8. *Syringoceras* (*Naut.*) *granulosostriatus*, after Mojsisovic's *Medit. Triaspr.*, Pl. lxxxii, Figs. 7 and 9, Trias. Figs. 4 and 5, nepionic stage enlarged. Fig. 8, more enlarged view of apex, with a cicatrix. Figs. 6 and 7, paranepionic and ananeanic substage with longitudinal striations and beginning of impressed zone after contact.

Figs. 9–12. *Syringoceras* (*Naut.*) *Linearis*, after Laube; *Fauna St. Cassian Denksch. Akad. Wien*, 1869, Pl. xxxvi, Trias. Fig. 12, natural size. Figs. 9–11, enlarged. Fig. 10, to show more accurately shape of apex. All show nepionic stage and development same as in *granulosostriatus*.

Figs. 13 and 14. *Digonioceras* (*Naut.*) *excavatum*, after D'Orbigny, *Terr. Jurass.*, Pl. xxx, Lias. These show the nepionic stage with an impressed zone existing before contact, also the annular lobe.

Figs. 15 and 16. *Cenoceras* (*Naut.*) *intermedium* (sp. Sow.), Balingen, De Koninck Coll. Mus. Comp. Zoöl.; Middle Lias. Slightly enlarged. These show the large umbilical perforation and sutures, the paranepionic and ananeanic substages. The dorsal furrow is present only in the paranepionic substage and the beginning of the contact furrow is shown also in the shaded area on the dorsum of Fig. 16.

Figs. 17 and 18. *Cenoceras* (*Naut.*) *intermedius* (?) (sp. Sow.), after Barrande and Hyatt, *Syst. Sil.*, Pl. cccclxxxix, Fig. 7; D'Orbigny Coll. Jarden des Plantes; Middle Lias. These show the ana- and metanepionic substages with cicatrix and sutures, but no impressed zone.

Figs. 19–21. *Digonioceras* sp. ? (similar to *excavatus*), Balingen; De Koninck Coll., Mus. Comp. Zoöl.; Middle Lias. Natural size. Fig. 19 shows sutures, etc., of paranepionic substage. Fig. 20 gives outline of same from dorsum with the dorsal furrow in the paranepionic, the upper outline of this figure is incorrect since the dorsal furrow begins immediately below this. Fig. 21 gives this outline correctly, it being the last of the ananepionic substage at the second suture; in Fig. 21, the venter is placed uppermost for comparison with Fig. 20.

Figs. 22–27. *Cenoceras lineatum* (sp. Sow.), Bayeux; Coll. Duval, Mus. Comp. Zoölogy; Inferior Ool. Fig. 22, natural size, showing umbilical perforation, metanepionic substage below perforation and paranepionic above this, the neanic stage being below the metanepionic volution. The dorsal furrow is well developed in the paranepionic substage. Fig. 23, the reverse of the two upper sections of Fig. 22.

Figs. 24 and 25, views of another specimen, showing the nepionic stage, enlarged 3 diameters, showing the position of the siphuncle ventrad of centre and dorsal furrow in paranepionic substage. The sutures, of course, belong to the neanic stage. Fig. 25 shows the minute umbilical perforation and the close coiling of the whorl. Figs. 26 and 27, apex of same, enlarged 3 diameters and giving ornamentation of shell and cicatrix. The dorsal furrow begins at the first or gyroceran bend in the paranepionic substage.

Figs. 28–31. *Cenoceras lineatum* (?), *Oolite* (*Naut.*) *aratus* of Quenstedt's Coll., Tübingen, from sketches in my notes, showing the nepionic stage with dorsal furrow as in *lineatus*.

Figs. 32–35. *Cenoceras* (*Naut.*) *aratus*, Saemann's original specimen; Mus. Comp. Zoölogy; Middle Lias; Suabia. Figs. 32 and 33, enlarged 2 diameters, showing markings on the cast, form of nepionic stage, large umbilical perforation and sutures. The shell probably had longitudinal ridges and bands of growth on the dorsum as well as on the venter. Figs. 34 and 35, copied from *Embryology Ceph.*, Hyatt, Pl. iv, much enlarged and corrected to show ana- and metanepionic substages and annular lobe, which begins in the third suture. The dorsal furrow begins between the third and fourth sutures, the last being the oldest in Fig. 35. The curvature is uniform, gradual, and there is apparently no mechanical cause for its early appearance in this shell.

Figs. 36–39. *Cenoceras* (*Naut.*) *granulosus* (sp. D'Orb.), Chatillon; Coll. Boucault, Oxfordian; Coll. Mus. Comp. Zoöl. Slightly enlarged. Figs. 36 and 37, showing extraordinary quick growth of the dorso-ventral diameters in ana- and metanepionic substages and beginning of paranepionic with dorsal furrow in what is probably the fourth septum. Figs. 38 and 39, similar views of another older specimen in paranepionic substage. See also Pl. xii, Fig. 31.

Fig. 40. *Crioceras* (?) *Studeri*, Ooster, after Barrande, Callovian, much enlarged, to show the close-coiled first volution.

Fig. 41. *Ancyloceras* (?) *calloviense*, after Barrande, Callovian, much enlarged, to show the close-coiled young.

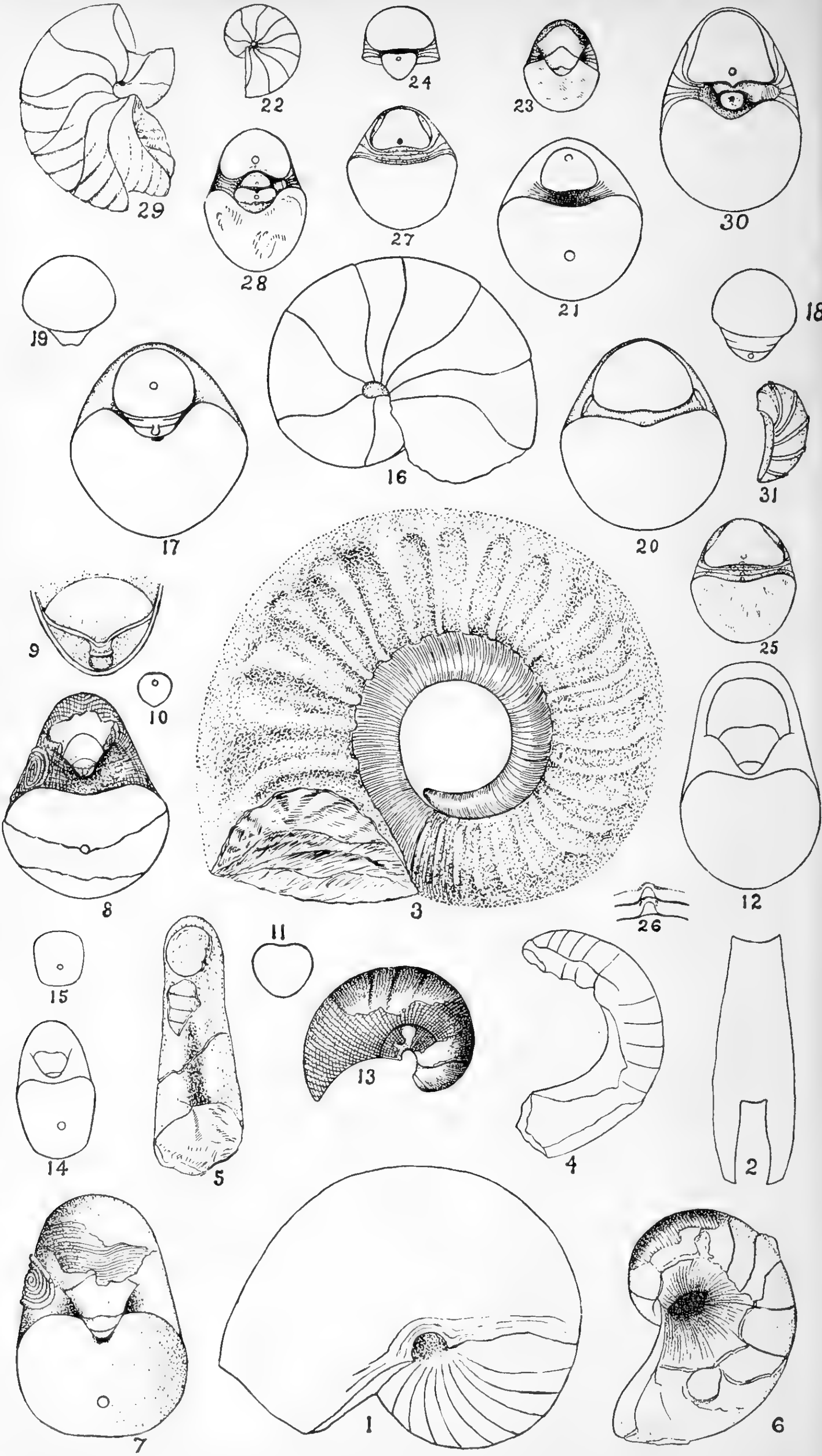

Plate XII (Hyatt).

Plate XII.

Figs. 1 and 2. *Diorugoceras* (*Naut.*) *planidorsatum*, after Portlock, *Geol. Rep. Londonderry*, etc., Pl. xxxv, Fig. 1; Carboniferous. Fig. 1, side view, reduced considerably. Fig. 2, section of outer whorl showing how completely the contact furrow is moulded to the form of the whorl.

Figs. 3–5. *Pleuronautilus superbus*, after Mojsisovics, *Das Gebirge um Hallstadt*, i, Pl. xviii, Trias. Fig. 3, reduced one-third, showing the striated nepionic stage, the very large umbilical perforation, free ananepionic substage, also the close-coiled stages. Figs. 4 and 5, lateral, dorsal views of the fragment of what is probably another species reduced one-third, showing an impressed zone as described and figured by Mojsisovics.*

Figs. 6–11. *Digonioceras rotundum*, Oolite; Coll. Mus. Comp. Zoölogy; no locality.

Figs. 6 and 7, side and front views of nepionic stage and ananeanic substage, natural size, showing especially the large, pear-shaped umbilical perforation and the amount of involution which covers only about one-half of the side. The outer part of Fig. 6 still has remnants of the dorsal shell of the enveloping neanic and ephebic whorl and parts of four septa clinging to it. Two older sutures in the paranepionic volution and two younger in the metanepionic volution are also shown and first to the third are seen in Fig. 7, which also shows the narrow ana- and metanepionic substages. Fig 8, the same broken down, showing the apical chamber and cæum enlarged in Fig. 9. Fig. 10, section of ananepionic substage at first septum. Fig. 11, section of metanepionic passing apicad of second septum and showing early beginning of impressed zone, both have the venter downwards.

Fig. 12. *Cenoceras* (*Naut.*) *clausum*, after Barrande and Hyatt, *Syst. Sil.*, Pl. cccclxxxix; D'Orb. Coll. Jardin des Plantes; Oolite; somewhat enlarged, shows the well-defined impressed zone in the paranepionic substage and the first three sutures.

Figs. 13–15. *Cenoceras* (*Naut.*) *clausum* (?), St. Vigor le Grand near Bayeux, Bronn Coll. Mus. Comp. Zoöl.; Lower Oolite. Fig. 13, somewhat enlarged, showing the shape of umbilical perforation and ana-, meta- and part of paranepionic substages. The amount of involution is shown by the dark line. Fig. 14, front view of same, natural size. Fig. 15, enlarged to show shape of ananepionic substage at first septum, the venter down.

Figs. 16–21. *Cymatoceras* (*Naut.*) (sp. ?), Texas. Fig. 16, side view of nepionic stage, and ananeanic substage with sutures enlarged two diameters. The approximation of the fourth and fifth sutures appeared in several specimens of the young of this species. The third and fourth sutures are too close together in this drawing and the spaces between the fifth, sixth, seventh and eighth, somewhat too wide. The spaces between these last are not so wide as that between the third and fourth in the original, this space being also slightly less than that between the second and third. Fig. 17, section of apex and ananeanic substage enlarged two diameters with the deep zone of contact. Figs. 18 and 19, the appearance of the

*See p. 547, above.

apex as the grinding plane passed inwards. Fig. 20, same showing the metanepionic and paranepionic, both with dorsal furrows opposed to each other. Fig. 21, section of ana- and paranepionic volutions. This cut passed in the plane of the first septum, truncating the fundus of this and then obliquely across the suture line of the fourth septum. The second suture has a well-defined annular lobe and cone.

Figs. 22–27. *Cymatoceras* (*Naut.*) *deslongchampsianum* (sp. D'Orb.); Rouen; Coll. Boucault and Bronn; Mus. Comp. Zoöl; Cretaceous. Figs. 22 and 23, side and front views, natural size, nepionic stage and ananeanic substage (this shell has faint longitudinal ridges and transverse bands on the casts not shown in any drawings) the sutures and small umbilical perforations are shown. Fig. 24 shows metanepionic outline at second septum and paranepionic between the fifth and sixth septum of the same specimen, both with dorsal furrows. Fig. 25, the reverse of the same specimen. Figs. 24 and 26, part of cast of chambers in the dorsal furrow of Fig. 24, showing the annular lobes. Fig. 27, another specimen showing ananepionic substage at the first septum with a dorsal furrow, and paranepionic also with dorsal furrow between fifth and sixth septa.

Fig. 28. *Cymatoceras* (*Naut.*) *simplex* (?); Yeoville, England; Coll. De Koninck, Mus. Comp. Zoöl.; Cretaceous; showing the nepionic volution and part of the neanic stage. The slight subangular, umbilical shoulders which begin to appear in the anephebic substage. The longitudinal ridges and transverse bands are absent on this cast, but this may be due to the state of preservation.

Figs. 29 and 30. *Cymatoceras* (*Naut.*) *radiatum* (sp. Sow.); Rouen; Boucault Coll., Mus. Comp. Zoöl.; Craie Chlorite. Natural size. Fig. 29, side view showing the fourth and subsequent sutures with the broad bands and constrictions beginning in the ananeanic substage. In this the eighth and ninth sutures show closer approximation than any of the preceding. Fig. 30 shows the same with the ananepionic substage at the first septum and the paranepionic at the fifth. The dorsal furrow begins immediately between the first and second septum in the metanepionic substage as is shown by the cast of umbilical perforation and by Fig. 1, Pl. xiii.

Fig. 31. *Cenoceras granulosus*, showing the ana- and metanepionic substages with fragment of the dorsal shell and septa of the ananeanic whorl clinging to the venter indicating the amount of involution and the depth of the contact zone.

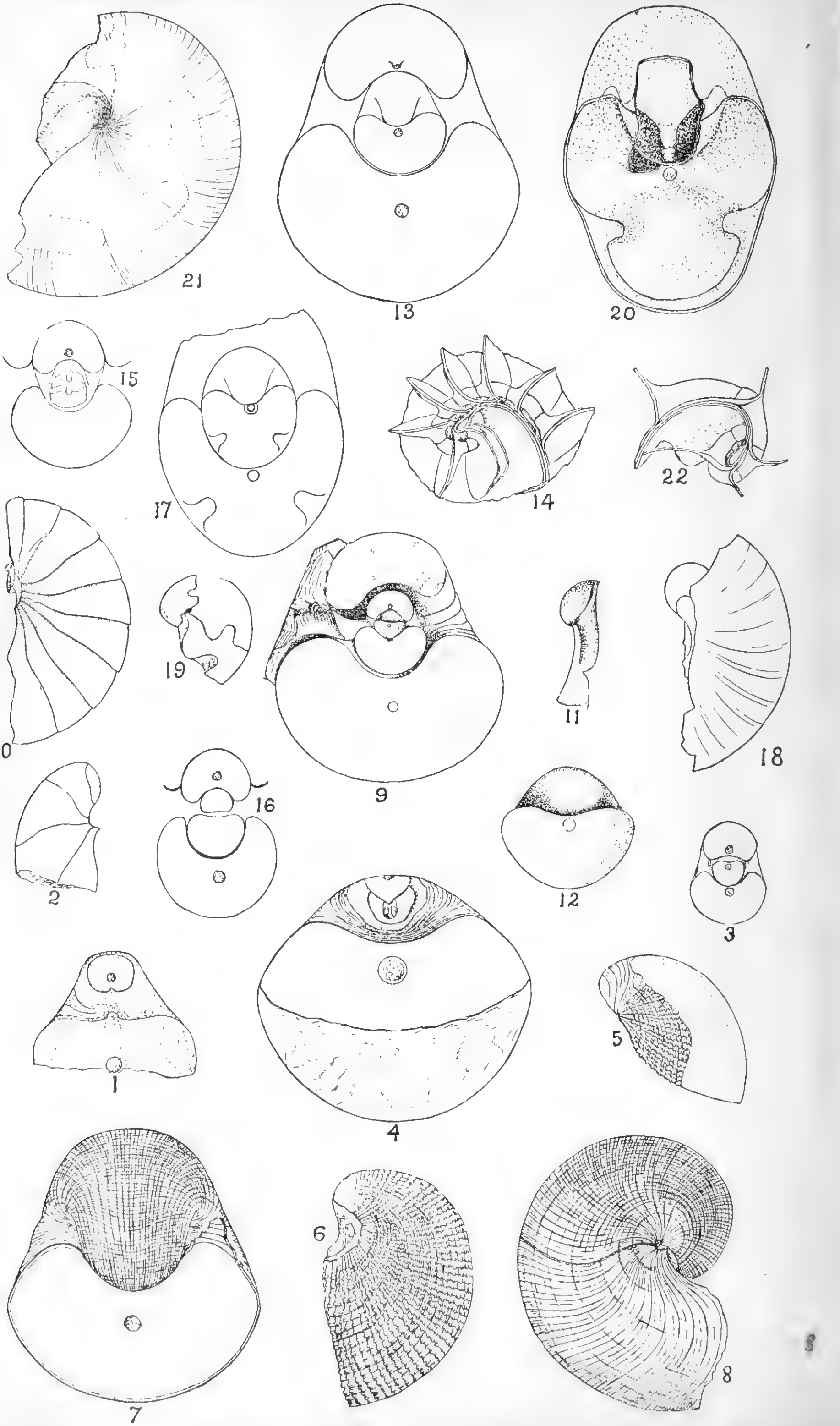

Plate XIII (Hyatt).

Plate XIII.

Figs. 1 and 2. *Cymatoceras* (*Naut.*) *radiatum*, showing the reverse of Fig. 30, Pl. 12, enlarged to 2 diameters. The beginning of the dorsal furrow is indicated by the shaded area reaching from near the first septum to the edge of the lower or fifth septum.

Fig. 2, side view of same, showing that the dorsal furrow began on the dorsum of the metanepionic substage between the first and second septa and in advance of the gyroceran bend.

Fig. 3. *Eutrephoceras* (sp. ?); Loc., France; Duval Coll., Mus. Comp. Zoöl.; Cretaceous; natural size; showing the dorsal furrow in the meta- and paranepionic substages and section of the ananeanic stage below.

Figs. 4–8. *Eutrephoceras De Kayi*, Dakotah, Cretaceous, preparations by Henry Brooks. Fig. 4, enlarged 6 diameters, and Fig. 5 same, enlarged 4 diameters, view of ana-, meta- and part of paranepionic substages. The citatrix is a double depression and the ananepionic outline is given just beyond this. There is a plate of the nacreous layer ventrad of this and partly covering it, with a shaded area. This spot is evidently the apex of the cæcum seen through the nacre. The two first substages are very short and smooth, but the dorsal furrow is present although exceedingly shallow before the bending begins in the later metanepionic. The umbilical perfoiation is present, as shown in Fig. 4, but is very small and elongated, comma-like in shape. Fig. 6, enlarged 4 diameters, shows the perforation in an older stage, but it is not correctly given. It is exposed by shaving off the angle of the last septum and the perforation is consequently actually the reverse of what it is in the centre of the umbilicus. This preparation, however, does show accurately the contact of the paranepionic dorsum with the dorsal side of the ananepionic substage and how close the coiling is. Figs. 7 and 8, side and front view enlarged 2 diameters of the meta- and paranepionic substages, the ornamentation becoming less in the latter which is terminated by a permanent constriction in this specimen, and also the anephebic substage in which the longitudinal ridges disappear and bands of growth assume the fine unbroken outlines of the adult. Fig. 7 is erroneous in making too great difference between the ventral lines of growth in the young parts of the whorl. The hyponomic sinus really appears about the middle of the paranepionic substage.

Figs. 9–12. *Eutrephoceras Faxoense*, Faxoe, Denmark; Krantz Coll., Mus. Comp. Zoölogy; Cretaceous. Fig. 9, front view, natural size, showing the cast of the umbilicus continuous with the very small umbilical perforation of the young. Fig. 10, side view of the same specimen. Fig. 11, young with first septum delineated. Fig. 12, front view of same, showing the aspect of the apex and the umbilical perforation, the dorsal furrow apparently beginning as in *Eutrephoceras De Kayi.* Both of these are enlarged 4 diameters.

Figs. 13–16. *Eutrephoceras* (*Naut.*) *imperialis* (sp. Sow.); Isle of Sheppy and Isle of Wight; Mus. Comp. Zoölogy; Tertiary. Fig. 13, front view of inner whorls enlarged 2 diameters. Fig. 14, fragment of nepionic or neanic stages, showing the minute umbilical perforation, the absolutely subdorsan position of siphuncle in these early substages. This specimen has a double first septum. Fig. 15, front of specimen from Isle of Sheppy, showing similar position of siphuncle at about the same age. Fig. 16, another specimen from same locality, showing the dorsal furrow in both metanepionic and paranepionic substages. Both the last are enlarged 2 diameters.

Figs. 17–19. *Aturia Morissi Michellotti;* Baldasseres, Mus. Comp. Zoölogy; Tertiary. Figs. 17 and 18, front and side views of the nepionic and neanic stages enlarged 6 diameters. Fig. 19, nepionic stage, showing the umbilical perforation, seen from the exterior as a small black spot.

Figs. 20–22. *Aturia zizac*, Sow.; Mus. Comp. Zoölogy; Tertiary. Figs. 20 and 21, side or front view of specimen from Dax, Bronn Coll., enlarged ten times, showing apical character, siphuncle, first septum with deep lobes and cæcum. Fig. 22, side view of fragment of another specimen with umbilical perforation, ananepionic substage in section and siphuncle.

Plate XIV.

Fig. 1. *Eutrephoceras De Kayi.* Reduced one-third. Two dorsal sutures, showing the linguæ form, minute, median saddles.

Figs. 2–5. *Barrandeoceras Sternbergi* (sp. Barrande); Schary Coll., Mus. Comp. Zoöl. Reduced one-third. Fig. 2, from Lochkov, variety in which whorls do not touch at all. Fig. 5, section of one, same locality, in which whorls barely touch, showing that it has no contact furrow. Figs. 3 and 4, specimen in which whorls touch in ephebic stage, but become free at the base of the living chamber. This has throughout a flattened dorsum, but no contact furrow. The appearance of a furrow in Fig. 4 is due to compression. These figures show also the narrow dorsal lobes of the sutures.

Figs. 6–12. *Schroederoceras tubulatum*, n. s. Reduced one-third. Coll. Mus. Comp. Zoöl.; Loc., Brevig, Norway; Silurian. Figs. 6 and 7, nepionic stage. Figs. 8–12, ana- and metaneanic substages.

Figs. 13 and 14. *Didymoceras nebrascense* (sp. Meek). Reduced one-third. Loc., near Buffalo Gap, So. Dakota; Coll., Yale University Museum; Cretaceous. Views of the parephebic substage and gerontic stage.

Figs. 15–17. *Emperoceras Beecheri.* Reduced one-third. Loc., near Buffalo Gap, So. Dakota; Yale University Museum; Cretaceous. Fig. 17 shows the earlier stages with Hamites-like whorls from above. Fig. 16 shows the similar apex of Fig. 15 corresponding in age to part of Fig. 17. Fig. 15, side view of Fig. 16, giving the ephebic stage with its tubercles and bifurcated costæ and the parephebic substage with single costæ and no tubercles.

Figs. 18–21. *Ptychoceras crassum;* Whitfield Coll., U. S. National Museum; Loc., Boulder, Col.; Cretaceous. Fig. 18, side view of ephebic and gerontic limbs, with gerontic umbilical perforation, reduced one-third. Fig. 19, section of same, natural size, showing the gerontic contact furrow. Fig. 20, view of dorsum of gerontic limb, in and just orad of gerontic umbilical perforation, natural size; shows the gerontic dorsal furrow, with dorsal crests in lines of growth and one costation and below the contact furrow. Fig. 21, section of the upper end of Fig. 20, showing the gerontic dorsal furrow.

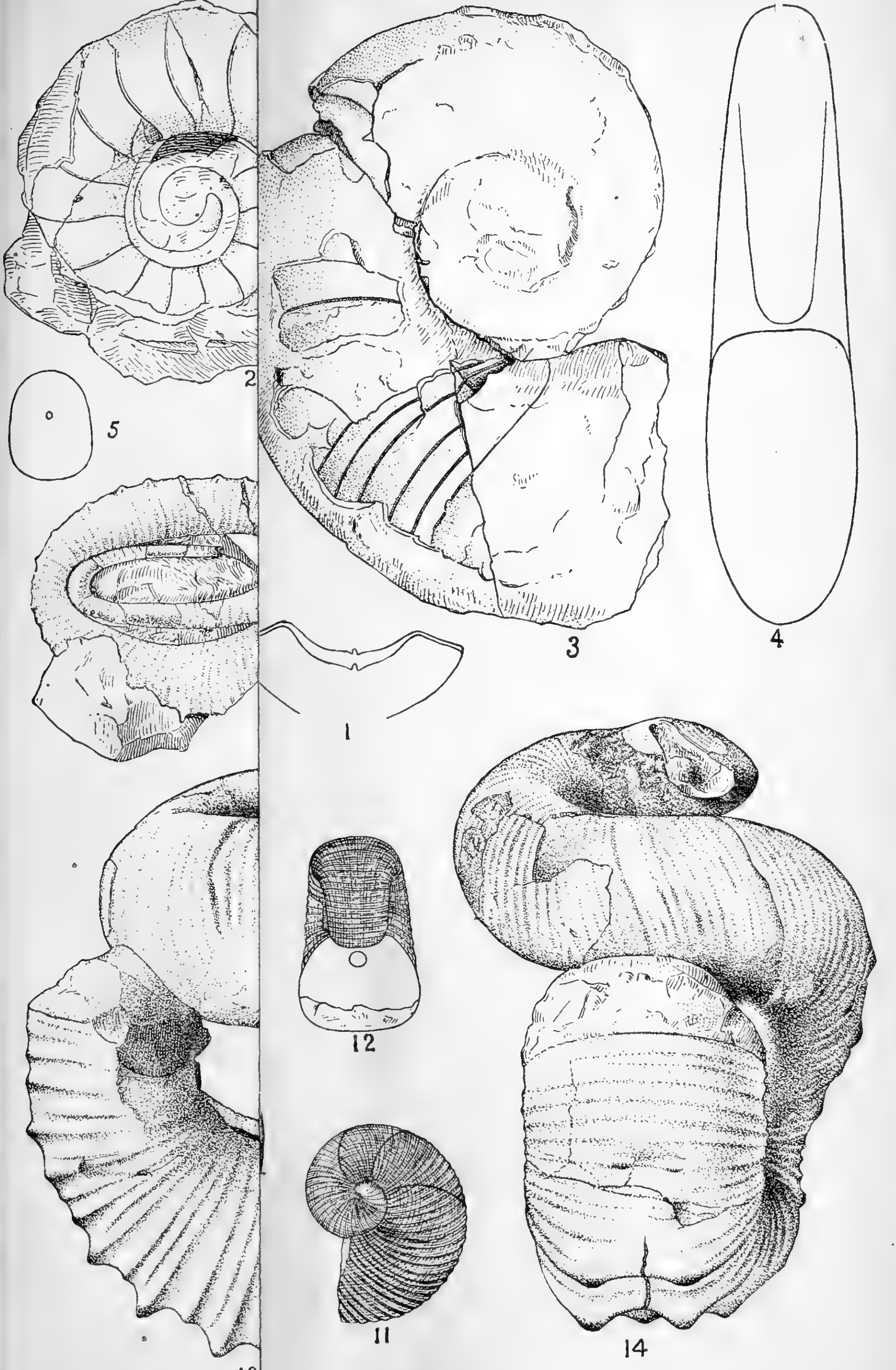

Plate XIV (Hy

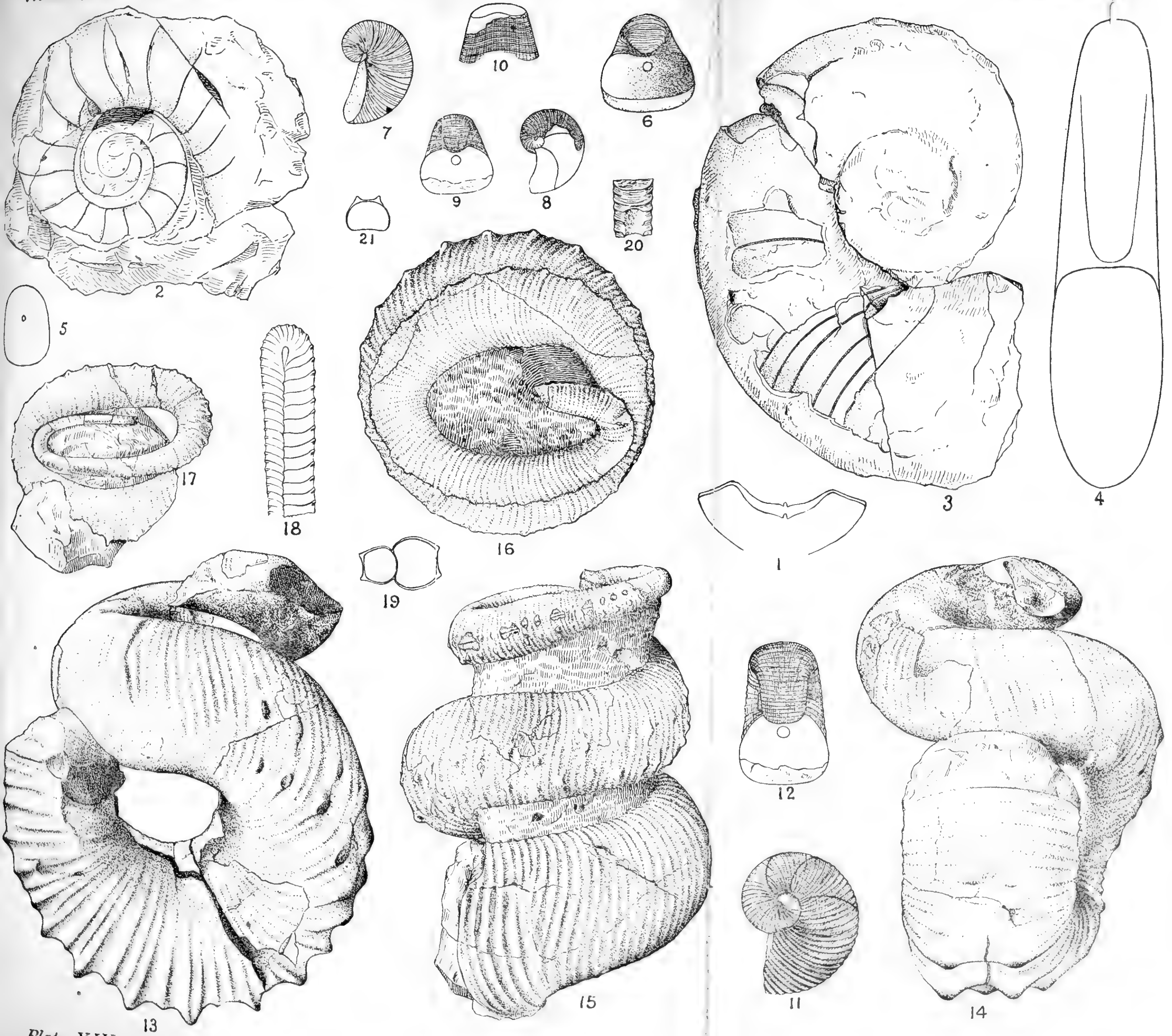

Plate XIV (Hyatt).

Index to Phylogeny of an Acquired Characteristic.

PROCEEDINGS

OF THE

AMERICAN PHILOSOPHICAL SOCIETY

HELD AT PHILADELPHIA FOR PROMOTING USEFUL KNOWLEDGE.

VOL. XXXII. MAY, 1893. No. 143.

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☞ It is requested that the receipt of this number be acknowledged.

☞ In order to secure prompt attention it is requested that all correspondence be addressed simply "To the Secretaries of the American Philosophical Society, 104 S. Fifth St., Philadelphia."

PUBLISHED FOR THE SOCIETY

BY

MACCALLA & COMPANY,

NOS. 237-9 DOCK STREET, PHILADELPHIA.

EXTRACT FROM THE LAWS.

THE HENRY M. PHILLIPS PRIZE ESSAY FUND.

Miss Emily Phillips, of Philadelphia, a sister of Hon. Henry M. Phillips, deceased, presented to the American Philosophical Society, held at Philadelphia for Promoting Useful Knowledge, the sum of five thousand dollars for the establishment and endowment of a Prize Fund, in memory of her deceased brother, who was an honored member of the Society. The Society accepted the gift and agreed to make suitable rules and regulations to carry out the wishes of the donor, and to discharge the duties confided to it. In furtherance whereof, the following rules and regulations were adopted by the Society:

First. The Prize Endowment Fund shall be called the "Henry M. Phillips Prize Essay Fund."

Second. The money constituting the Endowment Fund, *viz.*, five thousand dollars, shall be invested by the Society in such securities as may be recognized by the laws of Pennsylvania, as proper for the investment of trust funds, and the evidences of such investment shall be made in the name of the Society as Trustee of the Henry M. Phillips Prize Essay Fund.

Third. The income arising from such investment shall be appropriated as follows:

(*a*) To making public advertisement of the prize and the sum or amount in United States gold coin, and the terms on which it shall be awarded.

(*b*) To the payment of such prize or prizes as may from time to time be awarded by the Society for the best essay of real merit on nate the subjects for competing essays. It shall report annually to the Society, on the first Friday in December, all its transactions, with an account of the investment of the Prize Fund, and of the income and expenditures thereof.

An award of the Prize will be made during the year 1895; essays for the same to be in the possession of the Society before the first day of January, 1895. The subjects upon which essays are to be furnished by competitors are as follows:

1. The sources, formation and development of what is generally designated the Common Law of England.

2. The theory of the State, treated historically and upon principle, with a discussion of the various schools of classical, mediæval, and modern thought upon the subject.

3. The historical and doctrinal relations of the Roman Law and the English Law, illustrated by parallels and contrasts.

The Prize for the crowned essay on either of these subjects will consist of the sum of five hundred dollars lawful gold coin of the United States, to be paid upon the awarding of the Prize.

The essays must be sent addressed to Frederick Fraley, President of the American Philosophical Society, Hall of the Society, No. 104 South Fifth Street, Philadelphia, Pa.

☞ **Members who have not as yet sent their photographs to the Society will confer a favor by so doing; cabinet size preferred.**

☞ Members will please communicate any change of address or inaccuracy in name.

☞ A few sets of the Society's Transactions, New Series, 1818 to 1893, XVIII vols., 4to, can be obtained from the Librarian. Price $90.00.

the Science and Philosophy of Jurisprudence, and to the preparation of the certificate to be granted to the author of any successful essay.

Fourth. Competitors for the prize shall affix to their essays some motto or name (not the proper name of the author, however), and when the essay is forwarded to the Society, it shall be accompanied by a sealed envelope containing within the proper name of the author, and, on the outside thereof, the motto or name adopted for the essay.

Fifth. At a stated meeting of the Society, in pursuance of the advertisement, all essays received up to that time shall be referred to a Committee of Judges, to consist of five persons, who shall be selected by the Society from nomination of ten persons made by the Standing Committee on the Henry M. Phillips Prize Essay Fund.

Sixth. All essays may be written in English, French, German, Dutch, Italian Spanish or Latin; but, if any language except English, must be accompanied by an English translation of the same.

Seventh. No treatise or essay shall be entitled to compete for the prize that has been already published or printed, or for which the author has received already any prize, or profit, or honor, of any nature whatsoever.

Eighth. All essays must be *clearly* and *legibly* written and on one side of the paper only.

Ninth. The literary property of such essays shall be in their authors, subject to the right of the Society to publish the crowned essays in its Transactions or Proceedings.

Tenth. A Standing Committee, to consist of five members appointed by the President, and, *ex officio,* the President and the Treasurer of the Society, shall continue in office during the pleasure of the Society, and any vacancies that may occur in said Committee shall be filled by new appointment by the President.

Eleventh. The said Committee shall have charge of all matters connected with the management of this endowment and the investment of the same, and shall make such general rules for publishing the terms upon which said prize shall be competed for, and the amount of the said prize, and, if it shall deem it expedient, desig-