TRANSACTIONS

OF THE

TEXAS ACADEMY OF SCIENCE.

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TRANSACTIONS OF THE TEXAS ACADEMY OF SCIENCE.

Vol. I.

INTRODUCTORY ADDRESS.

By Dr. Everhart, President of the Academy.

February 6th, 1892.

For some time past there has been a feeling on the part of some of those here present that the time was ripe for the formation of a Scientific Association in this State. This feeling needed but a word to find expression of approval and to inaugurate the movement. This word was spoken a little over a month ago, and immediate steps were taken to bring about the present result. The professors of science, natural and exact, in this University, held an informal meeting in the early part of January and decided to send to various men engaged or interested in scientific work in Texas invitations to meet here on the ninth of January for the purpose of organizing a Scientific Society. These invitations met with a most cordial response from everyone. The meeting was held at the time named and organization perfected.

The plan and scope of the Texas Academy of Science are intended to be somewhat similar to those of the National Academy of Sciences at Washington.

As will be seen in the constitution already adopted, the object of the Academy is threefold. In the first place it is intended that an opportunity should be given to the scientists of the State to have personal intercourse with each other, to exchange ideas, and to discuss scientific questions of the day. Were this the only object of the Academy, still its organization would be well worth the effort, for by this personal intercourse between men of different or kindred pursuits, and by this interchange of thought, and by the consequent regarding various questions from many different standpoints, men become less rusty in those branches of science other than their own, they become more tolerant of the opinions of others, and are compelled to leave those ruts fostered by isolation and freedom from contradiction. To the teacher especially is this feature of the Academy valuable. He, necessarily, has always to speak ex cathedra. In presenting subjects to his classes he is lawyer, judge and jury. To such a man discussions with his equals are a necessity. It is urged upon the members of this Academy, therefore, that they not only contribute to its success by scientific papers, but

There is, perhaps, a popular prejudice against the scientific man. This prejudice was formerly directed against mathematicians only, but is now being extended to other scientists. There is no outcry against them, but their advice and conclusions are often thought inferior to those of the so-called practical man. Unfortunately for the pockets of these people confiding in the judgment of the practical or rule of thumb man, their ventures nearly always come to grief. I believe that the amount of money lost in this way, even during the last twenty years, amounts to more than the national debt. This popular idea is due entirely to ignorance and to unfamiliarity with science and scientific men and methods. It is hoped that this Academy of Science will be able, both directly and indirectly, to help educate the people to put their confidence in those that are worthy of it. When this is brought about we will no longer have companies organized to make a Keely motor, nor to refine sugar by electricity, nor will we have men digging for gold in every rock, or looking for bituminous coal in alluvial formations.

I believe that with these aims before us we can make the Academy a success and a benefit to science. Texas has ample and first-class material in her young men for the making of future scientists, both pure and practical. We should encourage by every means in our power the study and prosecution of the exact and natural sciences, because, no matter what may be said to the contrary, on them rest our comfort, our welfare, our progress, physically, mentally, morally.

ON EXACT ANALYSIS AS THE BASIS OF LANGUAGE.

By A. Macfarlane, D. Sc., LL. D., Austin, Texas.

Read February 6th, 1892.

In recent years the invention of Volapuk has drawn the attention of thinkers to the problem of constructing an artificial language, and to the various solutions which have been attempted. In 1668 Bishop Wilkins published in the *Philosophical Transactions* of the Royal Society of London a scheme founded on a philosophical basis. He first of all attempts to make a complete enumeration and description of all that is or can be known, and then makes this dictionary of notions the basis of a corresponding dictionary of signs, both written and spoken. Such basis is necessarily a foundation of sand, for it supposes our knowledge to be perfect, and scientific investigation to be finished. Every considerable advance in knowledge would overturn the entire structure.

The great mathematician and philosopher, Leibnitz, devoted much thought to what he called a *Specieuse generale*—an artificial language which would serve not merely for communication, but also as an aid in reasoning and invention. He died without publishing even the outlines of his scheme; but from the success of the notation in which he clothed the ideas of the differential calculus we may infer that the non-development of his scheme has been a loss to exact science.

The inventor of Volapuk, J. M. Schleyer, of Constance, does not build on a philosophical classification; he is pre-eminently a linguist, and builds his artificial language on a comparative study of the important natural languages of the globe. The scheme comprises a dictionary of stems, taken mostly from the English language, and a grammar containing universally applicable rules for forming compound words, the cases of the noun, and a multitude of forms of the verb. He builds on a linguistic basis, and takes as his models the old synthetic languages.

In this paper I propose to show that the proper basis for an artificial language is scientific analysis and classification; and the two specimens of language so constructed will exhibit the enormous complexity of the problem.

The inventor of Volapuk had before him the universally accepted notation for numbers, and in a language intended to be universal we naturally expect to find the nomenclature for numbers based on that notation. But in Volapuk this expectation is not realized. The words for the digits are;

1	2	3	4	5	6	7	8	9
bal	*tel*	*kil*	*fol*	*lul*	*mal*	*vel*	*jol*	*zul*

and for the tens

10	20	30	40	50	60	70	80	90
bals	*tels*	*kils*	*fols*	*luls*	*mals*	*vels*	*jols*	*zuls*

and we have in addition:

hundred	thousand	million	billion	trillion	quadrillion
tum	*mil*	*balion*	*telion*	*kilion*	*folion.*

In this scheme we observe the following defects: As regards the digits there is no word to express 0. As regards the expressions for the denominations, why should the denomination ten be denoted by the affix for the plural? It is an arbitrary use of the affix. The other names for the denominations are not more systematic than the English words; there is the usual jump from thousand to million; we are not told whether *telion* means thousand million or million million, and no words are provided to express fractional denominations. One writer even gives *telion* as meaning two millions, *kilion* as meaning three millions; and he evidently does this from the analogy *tels* 20 and *kils* 30. If *tel* expresses a multiple of *s*, it also expresses a multiple of *ion*.

According to English usage, billion means $1000{,}000^2$, trillion $1000{,}000^3$, and quadrillion $1000{,}000^4$, and so on; 1000,000 being the base and bi, tri, quadri, expressing the index of the power. According to the usage of this country and of France billion means $1000 \times 1000{,}000$, that is 1000^3, trillion 1000^4, quadrillion 1000^5, while 1000^2 is expressed by million; in this system 1000 is the base, but the prefixes of the words no longer express accurately the index of the power.

In physical works we meet with the highest development of the notation for number; it consists of a series of significant figures, and of a positive or negative power of ten. To vocalize this notation we require an elementary word for each of the elementary numbers 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, and a series of words for the integer powers of ten, and for the fractional powers of ten. As there are five elementary vowels, ten words for the digits may be obtained by prefixing the consonants b and l. Thus:

0	1	2	3	4	5	6	7	8	9
ba	*be*	*bi*	*bo*	*bu*	*la*	*le*	*li*	*lo*	*lu*

The word for a higher number is formed by taking the appropriate monosyllables in succession; for example:

11	12	23	123	105
bebe	*bebi*	*bibo*	*bebibo*	*bebala*

The integer denominations may be expressed by affixing *p* to the number for the place or power of ten, while the fractional denominations may be expressed by adding *n* instead of *p*, thus:

	10	10^2	10^3	10^4	10^5	10^6	10^7	etc.,
	bep	*bip*	*bop*	*bup*	*lap*	*lep*	*lip*	etc.,
and	$\frac{1}{10}$	$\frac{1}{10^2}$	$\frac{1}{10^3}$	$\frac{1}{10^4}$	$\frac{1}{10^5}$	$\frac{1}{10^6}$	$\frac{1}{10^7}$	etc.
	ben	*bin*	*bon*	*bun*	*lan*	*len*	*lin*	etc.

For example, 123 thousand would be vocalized by *bebibo bop*, and 45 hundredths by *buta bin.* In this system it is not 1,000,000 nor 1000 but 10, which is made the basis of the denominations.

Some years ago, in a series of papers on An Analysis of the Relationships of Consanguinity and Affinity,* I devised a working notation, both literal and graphic, and indicated a corresponding nomenclature. I propose to take this analysis and construct upon it another specimen of a scientific language, and test the efficiency of Volapuk by the system of words it provides for such relationships. A study of this problem shows clearly that a scientific language cannot spring suddenly into perfect form like Minerva from the head of Jupiter, but must be a thing of gradual growth; hence a natural language which adapts itself freely to scientific development is more likely to become universal than an entirely artificial language.

Let *a* denote the relationship of parent and *e* the reciprocal relationship of child, by forming the different permutations of those letters we get expressions for the several compound relationships. Those of the second order are:

Notation.	General Meaning.	Irreducible Meaning.
aa.	Parent of parent.	Grandparent.
ae.	Parent of child.	Consort.
ea.	Child of parent.	Brother or sister.
ee.	Child of child.	Grandchild.

The meaning given in the third column may not coincide exactly with that given in the second; where a reduction of the expression is possible—that is, where *a* is followed by *e* or *e* by *a*—the special or reduced meaning is excluded; thus, *ae* and *ea*, each in its most general meaning includes *self;* when the special meaning of *self* is excluded, *parent of child* becomes *consort*, and *child of parent* becomes *brother or sister.*

Similarly the relationships of the third order are:

*Proc. Roy. Soc. Edinb., Vol. X, p. 224; Vol. XI, pp. 5 and 162. Phil. Mag., June 1881, and Journal of the Anthrop. Inst. of London, for 1882.

Notation.	General Meaning.	Irreducible Meaning.
aaa.	Great grandparent.	Great grandparent.
aae.	Grandparent of child.	Parent-in-law.
aea.	Parent of child of parent.	Step-parent.
aee.	Parent of grandchild.	Child-in-law.
eaa.	Child of grandparent.	Uncle or aunt.
eae.	Child of parent of child.	Step-child.
eea.	Grandchild of parent.	Nephew or niece.
eee.	Great grandchild.	Great grandchild.

In the case of all these relationships, excepting the first and the last, the general meaning includes a simpler relationship to which it may reduce; for example, *grandparent of child* includes the simpler relaship of *parent*. In the same manner the relationships expressed by four, five, or any number of elements may be exhibited.

To change this notation into a nomenclature, all that is necessary is to insert some consonant, as *d*, between the vowels; for then each combination can be easily pronounced. In the systematic language so derived *ada* means grandparent, *ade* consort, *eda* brother or sister, *ede* grandchild, *adada* great grandparent, *adade* parent-in-law, *adeda* step-parent, and so on.

Each genus of relationship is divided into species by introducing the distinction of sex. Let the consonants *m* and *f* denote male and female respectively, then the species of the first order are *ma* father, *fa* mother, *me* son, *fe* daughter. If we introduce the distinction of sex after the vowel, we obtain the relationships

mam, father of man.
maf, father of woman.
fam, mother of man.
faf, mother of woman.
mem, son of man.
mef, son of woman.
fem, daughter of man.
fef, daughter of woman.

The species of the second order, obtained by introducing the distinction of sex before the first vowel only, are, *e. g.*:

mada, grandfather.
fada, grandmother.
made, husband.
fade, wife.
meda, brother.
feda, sister.
mede, grandson.
fede, granddaughter.

If the distinction of sex is introduced before the second vowel also, we obtain:

mama, paternal grandfather.
mafa, maternal grandfather.
fama, paternal grandmother.
fafa, maternal grandmother.
mema, brother-german.
mefa, brother-uterine.
fema, sister-german.
fefa, sister-uterine.

mame, father of son.	*meme*, son of son.
mafe, father of daughter.	*mefe*, son of daughter.
fame, mother of son.	*feme*, daughter of son.
fafe, mother of daughter.	*fefe*, daughter of daughter.

Thirty-two species may be formed by introducing the distinction of sex after the last vowel, but four of these species reduce necessarily to the relationships of self; for example, *mamem*.

The double relationship involved in *full brother* may be denoted by *memfa*, that of *full sister* by *femfa*, and that of *full brother or sister* by *emfa*. If, on the other hand, we wish to express that the brothership is only half, we may replace *d* by *t;* thus *meta*, half brother, *feta*, half sister, and *eta*, half brother or sister.

These principles suffice to supply a word for every possible relationship of consanguinity or affinity. The nomenclature is based on a notation which serves as the basis for a calculus,* and it seems to me that this is a developed specimen of the kind of language which Leibnitz had in his thoughts.

If we test Volapuk by the vocabulary which it provides for these relationships, we find that the words supplied are not founded on a scientific analysis, and, indeed, are far inferior to the terms supplied by the English language. The stem words are *cil* child, *son* son, *fat* father, *mot* mother, *man* husband, *blod* brother, *nok* uncle, *nef* nephew, *kosel* male cousin. All these stems, excepting the first, involve the masculine gender, and the corresponding feminines are formed by prefixing *ji*. Thus daughter is expressed by *ji-son*, wife by *ji-man*, sister by *ji-blod*, aunt by *ji-nok*, while the systematic word for mother is *ji-fat*. Thus there are no words to express the general relationships which are independent of sex. There is no stem to express the elementary relationship of parent. The principle which expresses a daughter as a she-son, and a sister as a she-brother appears to contain all the features of a bull. The English language in providing *bear*, *he-bear*, and *she-bear* is more logical.

In Volapuk *blod* means full brother; half brother is expressed by *lafa-blod*. The confusion of the inventor on the subject of relationships is so great that he sees no difference between step-brother and half-brother, for he expresses either by *lafa-blod*. Accordingly we have such absurdities as *lafa-fat* and *lafa-mot* (that is, half-father and half-mother) to express stepfather and stepmother. The prefix *lu* means *false*; *lu* and *lafa* are both given as the equivalent of the English step.

There is no general term for grandparent, or even grandfather. A word for paternal grandfather is obtained by adding the affix *el* (which

*Problem in Relationship, Proc. Roy. Soc. Edinb., 1888, and Reprint of Educ. Times, Vol. 49, p. 114.

denotes in general a masculine agent) to *fat*, producing *fatel*. Maternal grandfather is expressed by *motel*, the two grandmothers being expressed by *ji-fatel* and *ji-motel*. Grandson is denoted by *soulil*, granddaughter by *ji-soulil*, the affix *lil* having generally the force of a diminutive. Thus the derived relationships are not expressed by general rules for combining the elementary relationships, but instead, a few words are obtained in an arbitrary manner by attaching to the stems comparatively meaningless prefixes and affixes. It has been pointed out by several scholars* that the inventor of Volapuk makes a fundamental error in proceeding synthetically instead of analytically, and in this matter of terms for relationship we have an example of that fundamental mistake.

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* Dr. D. G. Brinton—"Aims and Traits of a World Language."
Dr. Horatio Hale—"An International Language."—Proc. A. A. A. S., Vol. XXXVII.

SOURCES OF THE TEXAS DRIFT.

By E. T. Dumble, State Geologist.

Read March 5th, 1892.

This paper is designed to indicate, only in the most general way, the sources from which some of the drift materials have been derived, which are found so widely scattered over Texas.

For this purpose, the area may be divided into four districts: First, Trans-Pecos Texas, the valley of the Rio Grande, and the country west of the Nueces—Rio Grande divide; second, the country between the Nueces and the Brazos; third, that between the Brazos and the Sabine; and fourth, the area west and north of the Cretaceous and Carboniferous contact, or Northwest Texas according to the Survey division. These are not intended to be understood as exact lines of division, because no exact delineation can be made, as the materials of the several districts overlap and are intermingled in many places and in many ways.

The drift material of the Rio Grande, as observed in the bluffs and capping its banks, is composed of pebbles of flint, quartz, chalcedony, agate, obsidian, jasper, pitchstone, flints, and fragments of limestone. Agates, both the mossy variety and those of beautifully banded structure, are found abundantly; porphyry and quartz also occur and, after reaching the Tertiary, silicified wood makes its appearance in greater and greater proportion. Continuing down the river, the pebbles, although of similar character to those above, become gradually much smaller. Throughout the whole length of the river, these gravel deposits, which vary in depth from one or two feet up to twenty and thirty feet, are more or less indurated and mixed with sand, and more commonly with a tufaceous limestone, thus giving the true character of the Reynosa beds. The origin of this drift is readily traceable to the mountainous region of Trans-Pecos Texas, in which nearly every variety of pebble found here can be observed in its original location and forming the local drift as well. The flint and limestones are, of course, derived from the Cretaceous material bordering the river.

After crossing the divide between the Nueces and the Rio Grande, we come into a different character of drift. It is almost entirely made up of pebbles of flint and limestone, which are mixed with more or less sand, but frequently exhibiting the Reynosa phase. The quantity of pebbles of igneous and metamorphic materials, found along the Rio Grande, is almost entirely wanting in this region, and we have instead that which has been derived from the erosion of the Cretaceous rocks of the Balcones region. As we travel eastward, we begin to find mixed though this flint and limestone pebble, fragments of quartz, feldspar, granitic rocks, and often micaceous or gneissic pebbles, which increase rapidly in quantity and size toward the Colorado, and are found as far east as the Brazos, and even beyond it in places.

The drift of the Colorado is composed, for the most part, of pebbles of flints, chert, quartz, feldspar, agate, granite, metamorphic limestone, and jasper, from one sixteenth of an inch to six and more inches in diameter; while that of the Brazos consists of flints, quartz of various colors, agate, jasper, cretaceous fossils, and fragments of hard Cretaceous fossiliferous limestone, and Lydian stone. On both rivers the size of the pebbles grow gradually less towards the gulf. These pebbles, outside the flint and other material derived from the Cretaceous, correspond to a large extent with the rocks found in the Central Mineral Region, and are without doubt largely derived from that locality. Silicified wood is also abundant in the area covered by the Tertiary, and is derived from that formation.

In the third district, while such siliceous pebbles are not entirely absent, they are very much smaller and more infrequent, forming deposits of much less extent. The gravel is largely made up of ferruginous material, such as nodules of indurated sand, or carbonate of iron, and have their origin in the iron-capped hills which cover so large a portion of Eastern Texas. Silicified wood is abundant, derived from the adjacent Tertiary deposits. A certain quantity of the siliceous gravels also exist, which are doubtless derived from the old mountain range which crosses the Indian Territory into Arkansas, and it is possible that some of the drift of the Mississippi has also been diverted into this region.

North of the Central Mineral Region and west of the Cretaceous and Carboniferous contact, the drift is somewhat different, except on its southern border, where it is principally derived from the materials found in the Llano region. The gravel is largely composed of flints from the Cretaceous and fragments from the surrounding rocks of the Carboniferous, together with bright colored pebbles, often cemented together, which are undoubtedly derived from the Triassic of the Dockum beds. It origin will be found in the Wichita Mountains, the mountains of New Mexico, and possibly Trans-Pecos Texas, which were the enclosing hills of the waters under which they were deposited.

One character of pebble is very widely spread, and I have not yet found in situ the material from which it was derived. It is a quartzite of a brown color, frequently of a decidedly purplish cast, which I have observed almost everywhere west of the Brazos. I have not yet seen it east of that stream. I find it in the Colorado drift, in the Coal Measures and Permian area, on top of Double Mountains, in the basaltic hills of Fort Inge, in the Rio Grande basin, and in the mountains of Trans-Pecos Texas. Its origin will probable be found somewhere in the mountains of New Mexico.

It is as yet too early to speak decidedly of the period at which the drift was formed, or of the causes which took part in its formation and distribution. Of one thing we are sure: we have here no direct glacial action, though we may have an indirect result, caused by the melting of the waters of the glaciers, or snow fall accompanying them, or perhaps the overflowing of the Pliocene lakes; the rushing of waters to the lower ground occupied by the gulf, and the consequent distribution of the materials of the drift. The consideration of the subsequent rearrangement and modification of the materials by the waters of the gulf and fluviatile action must also be deferred until a closer study is made of them.

THE TEXAS METEORITES.

By W. F. Cummins.

Read April 2nd, 1892.

In various parts of the world fragments of stone and metal have been found which have been classed under the general term Aeriolite, from their supposed aerial origin. Where the composition is largely metallic they are known as Meteorites.

These substances have always been objects of interest, not only on account of their origin, but also on account of their composition and peculiar crystalization; and while there are almost as many theories in regard to the origin of the Meteorites as there are writers upon the subject, all agree that they come to the earth from some region outside of itself.

In the earlier part of this century several large fragments of metallic iron were discovered in the area now known as Texas, which have been given the collective name of The Texas Meteorites, and, both on account of their size and composition, are as interesting as any that have been found. As the history of the finding of these masses is not very well known, I propose to give a brief detail of it in this paper.

In the year 1810, Dr. Bruce, of Philadelphia, Pa., published in Bruce's Journal a brief notice of a great mass of malleable iron from the Southwest. The following are the facts relating to the finding of it and its subsequent history:

"In the year 1808, while Capt. Anthony Glass was trading among the Pawnees and Hietan (Comanche) nations, he received information concerning a curious mineral which had been discovered in the territory of the Hietans by one of the Pawnees.

"Capt. Glass, with several of his party, went in company with some Hietans and Pawnees and saw the mass *in situ*. The Indians informed him that they knew of two smaller pieces, one about thirty and the other about fifty miles distant. On the return of Capt. Glass this intelligence excited no little curiosity.

"In 1810 two rival parties were made up for the purpose of obtaining this metal, one at Nachitoches, consisting of George Schamp, who had been with Capt. Glass, and nine associates. The other party at Nacogdoches, consisting of John Davis, who had also been with Capt. Glass, and eight or ten others."

The Nacogdoches party arrived first at their destination, but having, in their hurry to anticipate the rival party, made no preparation for carrying away the metal, they hid it under a flat stone and went away to procure wheels and draft horses.

The Nachitoches party arrived a few days later, and after searching several days succeeded in finding the object of the search. Being provided with tools, they made a truck wagon, to which they harnessed six horses, and set off with their prize toward the Red River. They crossed the Brazos River without much difficulty, but a straggling party of Indians having one night stolen all of their horses, they were detained until two of their party could go to Nachitoches for more horses. On arriving at the Red River some of their party went down in a boat with the iron, while others took the horses down by land. From Nachitoches the iron was taken down the Red River and Mississippi to New Orleans, whence it was shipped to New York, and was afterwards placed in the Yale Museum by the wife of Col. Gibbs. It is still there, and is known as the Texas Meteorite.

"In February, 1812, John Maley went with a few associates up the Red River, with a view of exploring the country and trading with Indians, and, if practicable, to bring away the two remaining masses of metal. He saw one or both of the masses, but being unable to make the remuneration for them demanded by the Indians, he continued his tour further west. Returning, he contracted to barter for the pieces of metal a certain quantity of merchandise, to procure which he returned to Nachitoches. On his second expedition up Red River, in 1813, he and his associates being robbed by a party of Osages of their merchandise and horses, were compelled to return on foot, relinquishing their object."

Nothing more seems to have been done at that time to obtain the other two pieces mentioned by Capt. Glass.

In 1829, Mr. Robert Cox, of Sparta, Tenn., wrote the editor of the American Journal of Science that a gentleman had returned from a five years absence in the province of Texas, during which time he had frequently been with the Comanche Indians, and a small party of them conducted him to a mass of metal lying on a creek, but he does not give the locality.

This is supposed to be one of the pieces mentioned.

In the month of May, 1856, Major R. S. Neighbors, who was United States Indian Agent at the reservation on the Brazos River, in Young County, Texas, a few miles south of where the town of Graham is now situated, obtained a piece of meteoric iron from the Comanche Indians. The meteorite was then on the eastern side of the Brazos River, about sixty miles from the reservation, in latitude 34 and longitude 100.

The history of this meteorite, as furnished by Major Neighbors, is as follows: For many years its existence was known to the Comanches, who regarded it with high veneration and believed it to be possessed of extraordinary curative virtues. They gave it the names Ta-pic-ta-carre (standing rock), Po-i-wisht-carre (standing metal), Po-a-cat-le-pi-le-carre (medicine rock), and it was the custom of all who passed by to deposit upon it beads, arrow-heads, tobacco and other articles, as offerings.

This is probably one of the three pieces mentioned by Capt. Glass, but it had evidently been moved from its former location, for, according to the Indians, the Mexicans had made several ineffectual attempts to remove it on pack mules, but had to abandon it on account of its weight.

In July, 1856, the meteorite was taken to San Antonio and remained in the possession of Major Neighbors until in the summer of 1859, when, at the earnest solicitation of Dr. Shumard, who was then State Geologist, he forwarded it to Austin and presented it to the cabinet of the State Geological Survey.

It remained in the collection of the State Geological Survey until the burning of the old Capitol. It was afterwards taken out of the rubbish of the old building by the Commissioner of Insurance, Statistics and History and by him placed in the collection of the State University, where it still remains. Since it was placed in the University collection it has been cut in two. The larger piece only remains in this collection. The smaller piece was given to some institution in the North, but by whom, or under what authority, I am not informed.

Before the burning of the old Capitol this specimen was said to be magnetic, but it is not so now.

It is probable that this is one of the three pieces mentioned by Capt. Glass, and the one mentioned by the traveler from Tennessee, before mentioned.

The original weight of this piece was three hundred and twenty (320) pounds.

Another piece of meteoric iron was presented to the State cabinet in 1859, said to have been picked up in Denton county, and first carried to McKinney, and in December, 1859, Mr. Higby, of McKinney, took a small piece of it to Austin, and in the winter of the same year Dr. Shumard procured a piece of it, weighing about twelve pounds, from a blacksmith in the town of McKinney. The original piece had weighed about forty pounds, the blacksmith having cut off pieces from the original mass and wrought them into cane heads and various other implements.

This piece remained in the State collection until after the close of the war, when it was removed from the collection by some unauthorized person, and its present whereabouts is not known. This may have been the third piece mentioned by Capt. Glass, but of this there is no certainty.

The exact locality where these meteorites were originally found, and where they were first seen by Capt. Glass, has never been accurately determined.

At the time Capt. Glass was trading with the Indians there was a

Pawnee village on Red River, a few miles below where Texarkana is now situated. In his notes written at that place he says: "We are informed by the Indians of a remarkable piece of metal some days' journey to the southward of the Pawnee village on the River Brazos," and he subsequently speaks of proceeding south and west in going to the locality.

Mr. L. Bringier, who had traveled in this country, and who saw the large mass of metal, says: "On the head of the Trinity River, longitude from London 95 degrees and 10 seconds, and latitude 32 degrees and 7 seconds, are or were several blocks of native iron, one of which was taken to New York. How did these masses come into the prairie (for they are in a prairie) is a question worth solving. A few miles to the west of these blocks of native iron a belt of trees is seen extending itself toward the south and southeast. The hunters know this by the name of Cross Timbers; they mean that it crosses the prairie, for there is no other wood in sight. This wood grows in a low ridge of limestone entending to the northwest shore of the Lake Sabine, bordering on the River Natchez; but whereas ten miles above the timber spreads from fifteen to twenty miles in breadth. It gives rise to the waters of the Trinity, whose west fork runs entirely through it. The country is silican, and a soil of gravel and loam produces a great variety of distinct qualities of grapes, etc. To the northeast are immense prairies which the eye cannot measure."

According to this description the locality would be west of either the Upper or Lower Cross Timbers, and in Denton, Cook or Montague county. The Elm Fork of the Trinity heads east of the Upper Cross Timbers, and the West Fork of Trinity runs through both the Upper and Lower Cross Timbers. I know of no place where either of these belts of timber is only a mile wide. So I can not locate the place by this description.

Mr. John Maley traveled in these regions subsequent to the removal of the large mass, but visited one or more of the smaller masses. He says: "Crossing the river at the Pawnee village we took a southwest course, over large ledges of limestone and extensive prairies. After a journey of three days we were conducted by the Indians to this metal. It lay a few miles from the mountain, which appeared to be the same that I have before described as running parallel to the river."

At another time he mentions the metal as being about two hundred miles a little north of west from Nachitoches, on the ridge between the waters of the Red River and the River Bravo. The following instructions for finding the locality of the iron were given by Mr. Wm. Barby, a geographer of that date. He says: "If with one of Mr. Melish's maps of the United States in your hand, you run your eye up Red River to the Pawnee village, you will perceive a small creek entering Red River a short distance below the village. This creek is called by the French hunters and traders Bayou Bois d'Arc. It was at its mout the transportation party reached Red River with their prize. Continue your glance upon the map a little south of west, to the headwaters of the river Brassos-a-Dios, and you will find the words 'Haywa Wandering.' Through the latter you will perceive a small creek represented flowing south into the Brassos. From comparing their account of their journey from Red River and of their return to that stream, I am induced to believe that the latter creek flows from or near where the mass of iron was found. The place is about north latitude 32 degrees 20 minutes, and longitude 20 from Washington City."

Even with this minute description it is impossible to locate the place with any degree of certainty, as the Melish map to which he refers is so very inaccurate in that part of it, that nothing can be determined by it.

There are several small pieces of meteoric iron in the State Geological collection, found in Wise and Montague counties. These pieces come from wells dug in the Trinity Sands at the base of the Cretaceous. With a magnet innumerable small pieces, not larger than grains of sand, can be taken from the sand of the wells at Decatur, Wise county, and at Sunset, in Montague county.

Whether these small pieces are a part of the same fall as that of the larger pieces described, from the same district, has not yet been determined.

ON THE PRECIOUS AND OTHER VALUABLE METALS OF TEXAS.

By W. H. v. Streeruwitz.

Read February 6th, 1892.

By the term precious metals we generally understand only gold, silver and platinum, although some of the rarer metals command a considerably higher price. More expressive is the German word *edelmetalle* (noble metals). This refers not only to the commercial value alone; it also indicates certain qualities, which, abstracting from their scarcity, commercial value or the amount of labor and skill required for their reduction, give to them a prominent position among the metallic elements. So, for instance, to qualify a metal to be an *edelmetall* it requires, before everything, a limited affinity for oxygen, the power to resist certain solvents, and perhaps the property to be reduced to the metallic state without reagent fluxes.

Gold, next to iron, has the widest distribution; it is found in Quaternary deposits and in Archæan schists. It may be found in plutonic and volcanic eruptive rocks; in sedimentary formations, as placer gold, in nuggets, grains, scales, flour gold, sometimes in crystals; in older not sedimentary rock, from which all placer gold derives its origin, in veins and veinlets, alone by itself in metallic state, or alloyed with other metals or in ores, particularly sulphides, and in this case probably dissolved rather than disseminated in the ores. The great affinity between sulphur and most of the other metals is wanting in gold, but it combines readily with tellurium, and the tellurides may be regarded, from a metallurgical standpoint, the equivalent to the sulphides of other metals.

Platinum, up to this time, was found under similar conditions as gold, only in the metallic state, alloyed with other metals or pure, together with the other metals of the platinum group in the placers or in older rocks.

Though the platinum is scarcer, less fusible, resists acids better than gold, and is therefore practically more useful, and though its price at present is higher than that of gold, it must be regarded less precious than gold. Its price fluctuates with the momentary demand, and any new "strike" may throw down the price to about half its present quotation, which never was and probably never will be the case with gold, the market value of which is only slightly altered by speculation.

Silver exists in nature in the metallic state pure or alloyed to gold or to some of the base metals, in ores as sulphide, chloride, chlorobromide, telluride, etc., sometimes pure, but mostly in combination with the ores of base metals, particularly with the ores of lead, copper, zinc, tin, antimony, with arsenides, etc. And though its distribution is not as general as that of gold, it is found in larger quantities in and with the ores of base metals.

Though all these may be well known facts, I had to mention them, because one or the other point might assist me to demonstrate theoretically the possibility and probability of the existence of precious metals in Texas. The same reason makes it advisable to mention some principles of mining geology, which principles are based on the experience of centuries.

Ore deposits in general are more frequently found in older than in newer rocks. They more frequently exist in mountainous regions than in level countries, oftener in close proximity to eruptive rocks than farther removed from them, more frequently with older than newer eruptive material, and more frequently with and in plutonic than in volcanic rock.

Ore deposits are indicated by direct outcrops of the ore, of quartz, carbon spars, barite, fluor spar, aragonite, mica, garnet and many other minerals, forming the gangue, among them particularly iron cappings, etc.; by peculiar discoloring and decomposition of the surface; by springs or moisture on the surface; by richer, poorer or peculiar vegetation; by float pieces, etc.

Now, Central Texas, and more so the region between the Rio Grande and Pecos river, are mountainous, many peaks reaching the height of 6000, 7000 and 8000 feet, "El Capitan," in the Guadaloupe range, about 10,000 feet.

The mountains of the Central district, as well as of Trans-Pecos Texas, belong to older and oldest geological formations.

Older and newer eruptive rock prevails in the mountains of West Texas and appears over several thousand square miles in the Central district; or in short, the conditions favorable to ore deposits exist in the Central district (the center of which is Llano county) as well as in Trans-Pecos Texas.

The mountain ranges in Colorado, Arizona, New and old Mexico are ore-bearing, as is proved by mines and prospects. They are built up of the same materials, and at least partly contemporaneous and under the same conditions as those of West Texas and the Central district, and the mountain ranges of West Texas at least are the continuations of the Mexican, New Mexican, Arizona and Colorado ranges through Texas. Gold is found *in situ* in older rocks—granites, gneissic rocks, schists and many others, and in their detritus. All these rocks occur frequently and very extensively in West Texas and the Central district, so their detritus.

The same rock species, in some places with serpentinous rocks, are the matrix in which platinum is found, and these rocks in themselves and in contact with each other, with limestone, etc., are regarded ore-bearing all over the globe where mining is carried on. Why should the mountains of Texas be an exception to the rule? This, I think, is sufficient to demonstrate the possibility and even the probability that precious and base metals can be found in Texas.

Besides, we find in the mountains of the Central district, as well as in the Trans-Pecos portion of the State, direct and distinct indications of ore deposits. The granites, porphyries and schists abound in quartz leads from a few inches to twenty and more feet in thickness. Carbon and other spars we meet surprisingly often in the eruptive and metamorphic rocks. Mica, garnets, aragonites, in short nearly every kind of promising gangue rocks, are found in both districts. They are mostly "mineralized" (colored by metallic combination) on the surface already, or are even ore-bearing there.

Iron outcrops and outblows, equivalent to the "eiseiner hut" (iron hat) of the German miner, the "gossan" of the Welsh, the "almagres" of the Mexican, the "pacos or colorados" of the South American, are of common occurrence; and many of these outcrops contain copperstain traces of lead, zinc, silver, gold, and so count among the best and most distinct indications.

Discoloring by metallic oxides and decomposed leads are frequently met with and promising prospect holes sunk on such places.

In the Central district many seep springs and wet streaks, indicating gangues and veins, exist. This form of indication is extremely scarce in West Texas, not because they do not exist there, but because the foot of the mountains, where we have to look for this phenomenon, is buried in most places under thick layers (frequently more than 1000 feet) of the detritus of the rocks. In the Central district peculiarities in the vegetation show plainly the strike of gangues and veins; as for instance streaks of live oak brush running for miles with gangue outcrops, or where post oak forests cover the ground, the leaves of the trees are fresher green and considerably larger along the gangues. Even in West Texas, where there is not much vegetation worth speaking of, on the mountain slopes streaks where the grass is better over the leads can be observed.

Finally float pieces of ore-bearing rock must attract the attention of the experienced observer. I am in possession of many good specimens of silver-bearing lead and copper from the Central district, and to mention only a few of the best float pieces which I picked up in Trans-Pecos Texas, I refer to three gold specimens of respectively 4, 11 and 17 1-2 ounces of gold to the ton; true, small pieces only, but proof enough that gold ore is in the mountains.

But we have to deal not only with conditions and circumstances justifying the conclusion that the presence of ores is possible and probable in Texas; we have also direct proof by the few mines worked in the State. The Shafter mine in the Chinatti mountains (the old Sierra Pilares) on Cibolo creek, shipped already three years ago every month between 30,000 and 40,000 ounces of silver, milling only with ten stamps. The same mine produces, besides the free milling ores, considerable quantities of silver-bearing galena, which is not free milling, but nevertheless valuable.

The Hazel mine, at the foot of the Sierra Diabolo, in El Paso county, also well developed at present, had shipped up to June, 1891, about \$78,000 worth of silver-bearing copper ore, and shows in sight about \$20,000,000 worth of ore.

The Bonanza and Alice Ray mines (hardly more than half-way developed prospects), both on the same lead, bring in sight a vein of silver-bearing lead and zinc sulphides for a distance of 300 feet in length, about 500 feet high (or deep), and from two inches to two feet wide.

Other small prospects brought excellent ores. Analyses made of specimens, which I had frequently picked up from the dumps, show from three upwards to three hundred ounces of silver to the ton, some of them with gold besides. Others show gold from traces up to three ounces, copper to fifty per cent, lead to sixty per cent, zinc to thirty and even fifty-four per cent, alone or with precious metals, not to mention the excellent iron ores (magnetic ore, hematite, goethite, etc.), the traces of tin, etc., and the ores containing uranium, molybdenum, etc., and specimens not yet examined sufficiently to give an opinion about them.

Most of the outcrops and prospects I mentioned are from a few hundred yards to ten or twelve miles distant from the railroad, and roads partly exist or could easily be built from the ore deposits to the railroad, which conditions compare very favorably with those in Arizona, Colorado and Mexico. Then why are the mineral resources of West Texas not better developed?

Before everything, they are not much better known than Texas is in general. In the opinion of Northern and Eastern capital, Texas is a waste prairie, full of the longhorned Texas steers and cowboys, both a holy terror. This prairie, or parts of it, so reason Northern and Eastern parties, may become one day valuable for agricultural purposes, and till then rented out to the cattle raisers at from two to five cents an acre, which, at the investment from 50 cents to say even \$2 per acre, pays a good interest on the money invested, and so they invested in prairie land and they did well. West Texas, however, was and is looked upon by its own Legislature and by the State administration as a valueless desert, an incumbrance rather than a benefit to the State. In politics its vote is not heavy enough to interest politicians in its existence, still less in its welfare, and so the drawbacks which kept back and keeps back to the present time the development of Trans-Pecos Texas, exist to-day. Among them incorrect surveys. Every expert and honest surveyor admits this. The survey of a mining claim requires great accuracy of its corners and lines. Every prospector understands this very well, and is not at all anxious to open a mine for the benefit of somebody else; and so the incorrect surveys keep off and drove off some expert prospectors from very promising indications. There are a number of Spanish or Mexican land grants clouding the titles of at least 2000 square miles of the best mining land. Of course no prospector who has only a trace of common sense will risk to throw his work into objects the ownership of which is not yet decided. Our mining law, though better than nothing, is very defective, and requires cumbersome descriptions and sending in of specimens, and what not. The price of the mining land is $25 per acre, the assessment work the same as in the mining districts in other States and Territories of the United States, and consequently expert prospectors (the only useful kind) prefer to prospect on United States land, in countries where they are not subject to so many formalities; where they find reliable assayers and surveyors, and are tolerably safe that their claim is located where it is intended and not half a mile on the land of other parties.

Besides, a number of so-called experts and prospectors from California and Colorado and other mineral districts brought distrust on Texas mining lands. They were neither mining experts nor prospectors, but common swindlers, who, with specimens stolen from mines or collections, but represented to be found in such and such a place in Texas, swindled parties out of hundreds, in some cases even of thousands, of dollars.

Our home prospectors, with very few exceptions, are anything but experts; most of them know so little of mining in general, and of ores in particular, that they frequently throw the best ore on dumps. They expect too much from little or no work at all—say about a bushel of coined twenty dollar gold pieces from every five feet of digging, or two tons of silver from every ton of ore. They are lacking in the principal qualifications of a prospector, to work hard, patiently and untiring, and to have at least a limited knowledge of mining and of the minerals for which they prospect. A prospector who works as an employe for others must also be a man of undisputed honesty.

There are other drawbacks, such as we meet frequently in other mining districts—for instance, scarcity of water, of fuel, difficulty to procure provisions; but they are not worse than in Arizona and many parts of New and old Mexico, and Trans-Pecos Texas has the advantage of not having any Indians, so that miners and prospectors can work and sleep in perfect safety.

And since the surveys can be corrected, the mining laws amended, the suits about land grants may finally be decided, the country better settled and gain political weight, I do not hesitate to predict the development of the mineral resources of Trans-Pecos Texas, and I sincerely hope and expect this my prediction will be verified, as my prediction that the mineral resources of Llano county would be acknowledged was verified already in 1887.

THE EDUCATIONAL NEED OF THE SOUTH.

By Edgar Everhart.

Read May 14th, 1892.

During the past fifty years two factors in our present civilization have been so developed that they have practically revolutionized the world. These two factors are steam and electricity.

They have enabled man to overcome space and time, and have almost brought the whole civilized world into the relationship of a single family. So potent has been the change effected by these agents that hardly a condition exists to-day that existed one hundred years ago. Politics, religion and education have felt this revolution. All have been modified by it, and none of the three more than education.

Education no longer means simply intellectual acquirements or training of the intellect. It means a great deal more ; it means now in a narrow sense preparation for life, in a broader sense it means life itself.

Universities have nearly always been the centers from which spring those influences that shape the destiny of man. They have been the nurturers and exponents of the greatest of all the possessions of man, freedom—freedom in thought, freedom in politics and freedom in religion. A remarkable instance of this fact is to be found at the present day in Russia, where the universities are doing more for that oppressed country than all else in the land.

The power of institutions of higher education permeates every nook and corner of a State. The students attending them are exposed in a transition period of their life to influences that mould their thoughts and destines, and therefore it behooves every university to cultivate those faculties of the mind of its students that will best subserve the interests of their fellow-men. It should send out from its halls young men ready to take an active part in life, ready to battle with wrong, ready to teach the truth, and ready to add their contributions to the welfare of their kind. This I believe to be the aim of all institutions of learning.

The most beautiful feature of the Christian religion is its doctrine of unselfishness and doing good to others. This doctrine is carried nearer to perfection at the present day than it has ever been before, and I firmly believe that I am right when I say that science has had more to do with this happy result than anything else. For centuries after the beginning of the Christian era the whole world presented scenes of war and famine, destitution and oppression. The mass of mankind was at the beck and nod of a few who had only their passions or desires to influence their conduct. It has been a long and difficult process to bring about our present condition, but the progress of the world has been sure and steady since the first glimmer of the natural sciences was brought into Spain by the Moors. The Arabian academies in Spain were thronged by students from the rest of Europe, and of these Roger Bacon, by his discovery of gunpowder, furnished the first great lever to lift his fellow-men from darkness to light, from slavery to freedom. From that time to this our conditions have been steadily improving, and as the sciences multiplied, and as men found other avenues for their intellects than the dead languages or metaphysics and the useless quibbling engendered by *their* study alone, they have been able to bring about an almost perfect realization of the dream of the early Christians.

One of the most striking effects of the sciences is their influence on other branches of learning. They have not only grown themselves and have ameliorated the lot of mankind, but they have also revolutionized all other studies. The methods of thinking first used in science have been applied with great good to the study of languages, to the study of psychology and the like. More is now known of Latin and Greek than has been known of them since they existed as living languages. While physiology has given an impetus to psychology that has sent it forward further in the past few decades than it had moved in the past 2000 years.

In short, science has opened up realms of thought that were formerly undreamed of; it has thrown down barriers that were considered insurmountable, and it has given to man everything that he holds most dear.

While the influence of science is felt everywhere in the world, yet some countries have been benefited by it more than others. On examination it will be found that those countries are most advanced intellectually and financially where the sciences are most cultivated. There is no doubt but that every trade and industry are the direct outcome of scientific discovery and invention. Nor can it be disputed that those countries are most advanced in every way where those trades and industries most do flourish. Wealth begets not only comfort for its possessors, but it also begets a higher degree of civilization and enlightenment.

It needs but a cursory glance at America to discover that the South is behind every other portion of the country in progress and prosperity. This is not because of inferiority in her people intellectually or otherwise. Everyone who has taught the young men here must know that they will bear comparison with any others in the world. They are quick to learn, steady in their application to study, and capable of becoming well trained in methods of thought. The climate here is not enervating on the mind. We are in the temperate zone, and besides experience has demonstrated that climate has no influence on the intellectual activity of man.

There is no doubt but that we are behind the age. No enterprise is undertaken here without resort to the North or West for capital to carry it on. No structure of any magnitude is built but that we send there also not only for money to build it but also for engineers to plan it and mechanics to construct it. No railroad is built without our getting engineers, mechanics, materials of construction and money from the North to put it in operation. No mechanical engineering feat of any kind is contemplated but that we seek the heads to plan and the hands to execute in any place but the South. Everything that requires expert knowledge for its completion seeks its experts elsewhere.

Were this all, we might still be consoled with the thought that our intellectual ability was recognized here and elsewhere. But is this true? How many men educated in the South, by their writings in the field of letters, of science, of religion, or of arts have attained a reputation other than provincial? They can be counted on the fingers of one hand.

Many of the most brilliant Southern men have sought their education away from their native land, and obtaining it, have chosen rather to live abroad than exert their talents where they were born.

There must be some radical evil that brings about this condition of affairs. We belong to the same Anglo-Saxon race as the rest of our countrymen; we are their equal intellectually, morally and physically; our land is as susceptible of improvement as theirs; we have as great natural resources in land, in water, in mineral wealth and the like; and yet we are poorer financially and intellectually; our trades and industries are in an embryonic state, and our intellects do not bear fruit that finds favor with the rest of the world.

I believe that the answer to this conundrum can be found in studying the condition of our institutions of learning. The universities of a country make the country. The South for many years has been dominated in educational matters by an institution that held up to its youth false ideas of what is best in education. It gave pabulum to their minds that was insufficient for their growth. It warped the natural bent of their intellects. It stunted intellectual progress. Instead of cultivating liberality of thought, it engendered a spirit of narrow-mindedness. This institution, instead of fostering the sciences, and thus conferring upon the land of the South all the advantages reaped elsewhere by its students, contented itself with making the classics the *sine qua non* of education. That science which was taught was bare and meagre in the extreme, and utterly inadequate to the demands of the age. This policy of this university has reacted upon itself. From being considered at the time of its incipiency among the best of American institutions of learning, it has fallen to a very subordinate place in the opinion of the educational world.

Were this the only result of this disastrous policy it would need to call forth no comment, but the results have been more widespread. Every educational institution of the South has been looking up to that for years, and has modeled itself more or less on the same false plan.

The consequence has been that we have had no institutions of learning worthy of the name, and our whole people have become impregnated with wrong conceptions of what is good and what is bad in education.

The South is an old country, relatively speaking. It was settled and populous before the West was thought of as a possibility. Therefore we have received but little immigration from other States or countries of men of intellectual attainments.

The West, on the other hand, has been built up by such men. They have established factories, metallurgical works, industries, etc., such as these same men were accustomed to in the land of their birth. Consequently the West is far beyond the South in progress and prosperity.

It is time that we should have a change. The South needs a new order of things before she can compete with the rest of the world. I believe the day is not far distant when we will drop our false ideas and take up those more in accordance with the requirements of the age.

The first place in which this movement must be inaugurated is the university. Already is the change in progress. Every young man who leaves the South for study abroad and comes back to live brings with him ideas that must influence those with whom he comes in contact.

We have to dispossess ourselves of the idea that Latin and Greek are the *sine qua non* of education and learning. I have nothing to say against the study of these two languages. They are useful in training the mind, as is every other study. But to say that they are an educational necessity is saying that which can not be demonstrated and which is contrary to common sense. It is no doubt well, or even necessary, that one should know more than one language; but German or French can be used as substitutes for Latin and Greek as intellectual training, while for practical purposes there is no comparison between them.

Because most educated men have studied Latin and Greek is no reason why they should still be considered a necessity. We must remember that it has only been a few years since it became possible to study other things than the ancient languages, mathematics and philosophy in institutions of learning. But since these other things have become possible, there has been growing a demand that other studies should be considered as at least equivalents to the ancient languages.

I wish to emphasize the fact that this demand does not mean the abolishing of Latin and Greek from the curriculum of our studies. It means simply that these two studies as an intellectual training should not be considered of more value than others.

One of the arguments adduced for the necessity of the study of these languages is that thereby one can become acquainted with the derivation of words and also with their meaning. Especially is it said to be of importance to the scientific man, whose whole vocabulary is made up of words derived from the Latin or the Greek. This has always appeared to me to be a very puerile argument, from the fact that a man can look up a derivation in an English dictionary and derive more instruction therefrom than if he had the meaning of the word already in his mind. Besides, scientific terms have derived meanings which bear no relation to the meaning of the original word. For example, what help is it to a chemist to know that eudiometer is derived from eudia, fair weather, and metron, a measure, or that barometer is from barus, heavy, and metron, measure? Neither translation offers us the faintest inkling of what the instruments really are.

Again, we are told that the study of these two languages will improve our English. I for one must confess that it is incomprehensible how languages so dissimilar in every respect can aid us in our writing of English.

Again, we are told that the beauty of these languages will more than repay one for his labor in acquiring them. The beauty in thought may be there, it is true, but a translation will give that just as well; and as far as beauty of expression goes, can anyone who is unable to think, or at least to speak, in a language, honestly tell whether or not an expression in that language is beautiful?

For the philologist a knowledge of these languages is essential. For others, let them be studied or not as one's choice inclines one. Tradition has much to do with our lives, and both Latin and Greek will be studied long after it has become recognized that neither is an essential to education. But let us dispense with such considerations. I believe that we can regard the whole question from a higher standpoint.

There are two aims in life than which nothing is nobler—they are the search after truth and the doing good to our fellow-men. It has always struck me that mere learning, however much it may benefit one's mind, is selfish and undesirable if it be useless for others. On the contrary, if the acquisition of knowledge can produce anything that will benefit the world, even in the slightest degree, the one who acquires that knowledge and proclaims it is more to be admired and respected than the possessor of all the useless lore ever known. For such aims as just mentioned the sciences present the most favorable opportunities. There is not one that does not present numberless opportunities for discoveries of facts or phenomena applicable to the necessities of man. There is not one of them that does not demand of its followers a quick understanding and an intellect well trained in many other branches of knowledge. Again, the ultimate aim of every science is the discovery of truth, such truth as is shown by the Creator in his making of the earth.

There can be no higher vocation in life than the pursuit of such knowledge. A scientist who has successfully followed his calling will leave behind him works that will live forever in alleviating the lot of his fellow-men or in administering to their necessities.

What the South lacks is this spirit of scientific research and scientific training. Without it she will never leave the ruts worn by years of false doctrines and misconceptions. As was said before, it is to her educational institutions that she must look for the bettering of her condition. It is the duty of the universities to instill into the minds of the students thronging their halls the importance of cultivating those studies that will most benefit themselves, their country and their fellow-men. Every opportunity should there be given for the pursuit of those studies for the lack of which the South has so long suffered. The sciences, both natural and exact, have made the world what it is, and therefore they are entitled to at least as much consideration as any other studies. A university should be the cherisher of all branches of study, but its first duty is to those studies that will do the most good and that most nearly reach truth.

In our universities we need schools of civil engineering, of mechanical engineering, of mining engineering, of electrical engineering, schools of physics, of chemistry, of geology, of mineralogy, of botany, of biology, schools of medicine, of pharmacy, of sanitary engineering and the like. We do not want these schools to be mere apologies of schools; we want them to be of the best, of such a character, in short, that their graduates will be able to undertake and successfully to accomplish any work pertaining to their chosen field.

Besides this, we want to have all our students to know at least something of the natural sciences, enough at least to give them a just appreciation of their value and to enable them to think and speak intelligently on scientific subjects.

Furthermore, we want our students so to choose their studies as to enable them to obtain an education most serviceable to them in their after life.

A young man is not formed like a piece of machinery. Students are not like army rifles, which all require the same cartridge. No young man who seeks an education resembles in mind and taste any other young man. It is unfair to all to require the same tasks from all. As much as possible should be left to the individual choice.

To accomplish these results we have to have first a just appreciation of the value of the sciences, and then money, and in no small amount. While the sciences confer the greatest prosperity on men, they require for their proper prosecution amounts far in excess of what is required for any other studies. Our laboratories and workshops should be thoroughly equipped and maintained. We must have no niggardly appropriations for the maintenance of these laboratorics.

Our people should be trained to sec these things in the proper light, and the place where this training must be acquired is at the universities.

We want liberality and not narrow-mindness; we want a liberal education and not a narrow one. Those institutions that to-day are doing the most good in arts, in letters and in science are the ones that pay the most attention to the last. Unfortunately none of these are in the South.

Finally, I wish to call to your attention for a few moments the relation between the State universitics and the States themselves. These institutions of learning have been founded and are maintained by the State. The State, it seems to me, has the right to expect that most prominence should be given to those branches of knowledge that will be most productive of good to its citizens. For this reason the university should put a premium upon professional studies of all kinds and upon the natural sciences, for to these must the State lock for a direct return of its outlays. Every first class lawyer, physician, geologist, engineer, physicist or chemist educated by the State can and will, repay the cost of his education many fold to the State.

Our institutions of learning, however, should not only afford opportunities for acquiring a knowledge of the practical applications of the various sciences; they should much more foster the pursuit of these sciences for the sake of the sciences themselves. They should encourage their students to devote their lives to those nobler pursuits which look for their reward only in the discovery of truths.

I trust that Texas, the newest of the Southern States, will be the first to realize the importance of the cultivation of the sciences. If she will then will she be the first to reap the benefit of her wisdom.

I conclude with the same words with which I concluded my address on the opening of the Academy of Science. We should encourage by every means in our power the study and prosecution of the exact and natural sciences, because on them rest our comfort, our welfare, our progress, physically, mentally and morally.

VOLCANIC DUST IN TEXAS.

By E. T. Dumble.

Read June 14th, 1892.

During the field season of 1891 a number of specimens of a material nearly white in color and of light specific gravity were collected by Messrs. Kennedy and Walker from different localities in the Tertiary area, over which they were working. From their general appearance they were supposed to be diatomaceous earth, and under the microscope several of the specimens proved to be composed of diatoms. Other specimens, however, did not show any such forms at all, but consisted of the flat transparent, sharply angular particles with striated or pitted surfaces peculiar to volcanic dust, and it was so determined by Prof. F. W. Cragin.

These deposits were apparently, but not certainly, all interstratified among the clays and sands which we have designated the Fayette beds, and which are probably of Miocene age. On a recent examination in Fayette county I found the same material under such circumstances as seem worthy of note, as deciding the point in that particular instance at least.

The Fayette beds were described by Penrose in the First Annual Report of this Survey, on page 47, and in general terms may be said to consist of two heavy beds of sands and sandstones separated by a great thickness of clays and lignites. He gives the section of Second Chalk bluff, showing the several beds of browncoal overlaid by sands and clays. These underlie the upper sandstone beds of Palm bluff and La-Grange bluff and overlie those of Sand bluff and Muldoon.

On the west of the Colorado river the topographic expression of these three series of beds is:

For each of the two sandstones (many beds of which are indurated, and some even quartzitic in places) a line of detached bluffs generally facing north, connected by lower ridges.

For the intervening clays and sands with browncoal, a valley eight miles or more in width, which is drained by Buckner's creek and its tributaries. The general trend of all is about south sixty degrees west, from the Colorado river, and the dip of the beds is very gentle to the south or southeast.

O'Quinn creek, a branch of Buckner, has its head near the base of the upper sandstones, and flowing northward to its junction with the larger stream has cut through the browncoal series, and affords, what is somewhat rare in this generally flat country, a satisfactory exposure and continuous section of the underlying beds.

In making this section I found about half a mile above the mouth of the creek, in a vertical bluff some twenty feet in height and probably three hundred feet in length, the following exposure:

1. Soil.
2. Yellow sand.
3. Brownish yellow sands with little clay, containing large quantities of plant impressions, roots or stones, converted into earthy browncoal, spiral rootlets, etc.
4. Browncoal, somewhat lignitic in places but generally compact and massive.
5. Volcanic dust, white to creamy white in color, with traces of roots or worm borings and a little sulphur.
6. Browncoal, somewhat variable, with small inclusions of members of the group of asphaltums.
7. Gray clays and sands, interbedded or interlaminated, weathering yellow, with efflorescence of sulphur on surface.

Under the microscope the material of No. 5 shows all the characteristics of volcanic dust, but the individual grains are much larger or coarser than those I have observed previously in other portions of the area.

Were it not for the fact that we have a similar series of lignites occupying relatively the same position to the upper sands as shown in the section of Second Chalk bluff already referred to, and were it not for the further fact that the section made was from a continuous exposure in which the connection was not lost or even obscured at any place, and that no faulting of any consequence was found, it might be argued that the series of lignites and volcanic dust were of later age than the upper sandstones and had been deposited in this valley subsequent to its first erosion.

The facts, however, clearly demonstrate that the stratigraphic position of this bed at least is in the browncoal series of the Fayette beds, and, if our correlation of these beds be correct, of Miocene age.

These deposits are locally known as "chalk," and are used as such in marking lumber, etc., and also to a less extent for polishing purposes.

THE DEVELOPMENT OF THE AMERICAN TROTTER—A STUDY IN ANIMAL PHYSICS.

By Geo. W. Curtis, M. S. A., Director Texas Experiment Station and Professor of Agriculture A. & M. College, College Station, Texas.

Read June 14, 1892.

The aim of all progressive modern thought and enterprise is toward a field of future promise—the accomplishment of great results in shortest time. As the world moves onward, one who lags behind must either learn to follow those of quicker thought and action, or be classed with those who, having eyes see not, and having ears hear not; human drones who live in memories of the past, yet think to claim a share—a full sized portion—of the fruits of modern progress.

As a nation the American people occupy the foremost rank of nineteenth century civilization. To America must be credited not alone the broadly liberal live and let live policy which has made our shores a landing place for so many million subjects of despotic royalty, but as well, and far more to her credit, let us place the rapid, healthy force of American brain and courage, which has made us what we are—the greatest nation of the world in all things most to be desired.

To such a people as our own we might expect to turn for practical solution of those great problems of the breeder's art, which, accomplished by Americans, have given to our people first place in the development and improvement of the modern breeds of domestic animals. Getting a basis for our work from established breeds of Europe, we have been able not alone to hold our own, but to steadily improve until the best individuals of nearly every breed of horses, cattle, sheep, and swine at present known to modern breeders are found on this side the Atlantic. Not only this—in the development of our own peculiar breeds, the American Trotter, the pacer, and the American saddle horse, we have proven two things: First, that artificial gaiting may be made permanent and become transmissible, or subject to the laws of heredity; and second, that by solution of the gaiting problem the new world has succeeded where the old world always failed, save in the single instance of the Russian Orloff—a breed in no way equaling that finished product of the breeder's art, the American Trotter. Besides a feeling of pride in the fact that our breeders have succeeded beyond their most sanguine hopes, a close study of the methods pursued by leading trainers, and the physical and mental characters of the winning horses at either gait, brings up matters of interest to all, and of especial moment to the student of animal physics.

Since the early years of the present century (1806) when a horse of unknown breeding trotted a full mile under saddle in the then almost incredible time of 2:59 (but one second better than three minutes), the records show a series of descending steps—each step a tablet to the memory of some once famous horse.

Flora Temple, the first to beat 2:20 in 1859, Dexter, Goldsmith Maid, Rarus, St. Julien, Jay Eye See, Maud S., and Sunol, the present queen of the trotting turf by virtue of her 2:08¼, have each in turn lowered the world's mile record at the trot; while among pacers the record drops from that of Roanoke—first to beat 2:20 in 1852—past Pocahontas, Billy Boyce, Sleepy Tom, Little Brown Jug, and Johnston, to the 2:06 of Direct, the black California wonder that has earned and now holds the world's mile record at the pace. And the end is not yet; better tracks, better trainers, better horses will be seen this year than ever before. With Doble to pilot Nancy Hanks, Williams behind Allerton, and Marvin to guide the peerless Sunol, we may expect to chronicle faster time than yet recorded at the trot; while Roy Wilkes, Johnston, and Direct will all be found in touching distance of the present world's mile pacing mark.

To one who watches closely it is no surprise to find that horses may be taught to carry such terrific speed at a gait not natural for extreme exertion; but to those who see the record only, knowing nothing of the methods used in blood lines or in training to accomplish the result, it can be little less than wonderful. By many it is thought the trainer's art should credit take for all the progress made; by others it is argued better tracks alone must be responsible; others still, not satisfied to credit track or trainer with the total good accomplished, claim a further reason in our better understanding of all those physical and mental traits of the individual animal which make selection possible and development practicable. Brain capacity in the horse is of vital moment to the trainer, as is brain capacity in the student to the teachers under whom he seeks instruction. The sluggish, stupid brain of dullard, horse or human, will never show that firm yet plastic nature fitted best to carry knowledge. The brain one-sided in its make-up may receive instruction fairly well, but when forced to execute beyond a certain limit falls by reason of its lack of balance, and fails to hold the mastery at the very moment when the muscles, strained beyond the power to respond in reflex action, most have need of mind control. A first essential for the horse that carries highest speed at artificial gait is a brain with ample room for strain in mental exercise—a perfect poise, that neither loses interest by lack of work in competition, nor overthrows its balance by undue excitement. The horse that "keeps his head" can be urged to greater effort and will break but rarely, catching quickly at the gait desired in obedience to the driver's will; while the horse with mental poise at best uncertain, carries his gait at moments to terrific speed, but just as surely follows up by breaking, losing time, and possibly a race, before he can be righted and held down to steady work.

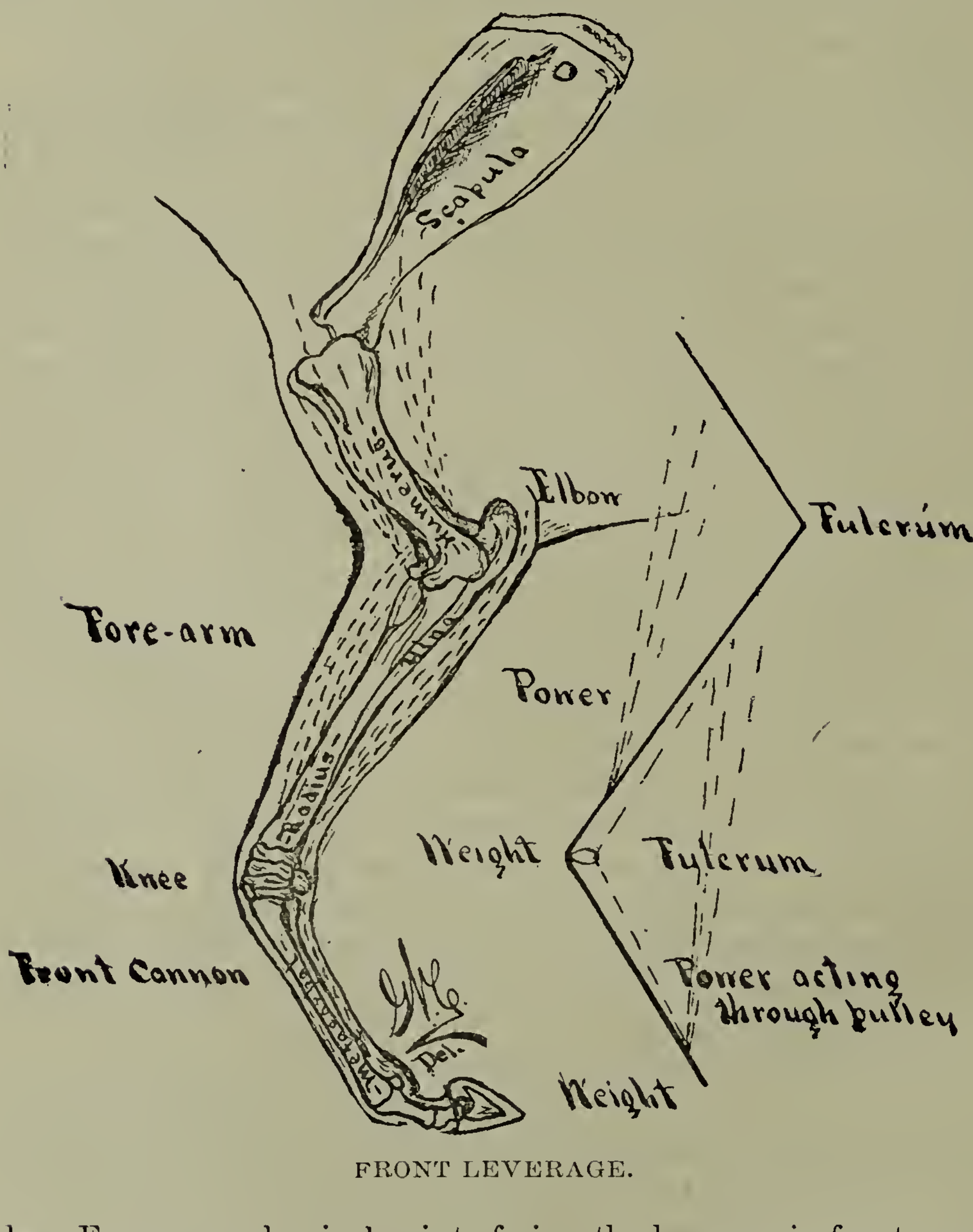
I have no patience with that narrow view which credits brain in so-called lower animals only as an "instinct." The horse that bears the highest training goes beyond an instinct and shows a true brain action at once receptive and controlling in its functions. It can not equal human mind 'tis true, but to call it "instinct" merely is an insult to the horse creation.

Admitting, as a first essential, brain in horse as well as human, we may ask, is there a second necessary—a sort of corollary to the first—wherein the tape-line and the practiced eye may be relied on to select a future winner at the trot or pace? Can we find, in other words, some standard shape, or measurement of certain parts, without which highest speed will be impossible? Perhaps no other subject in the breeder's realm brings forward such opposing forces as the proposition just advanced—nor can we say that either side is wholly in the wrong. Laws of motion, gravity and projectile speed, and strength by leverage of inert matter, have been investigated and are fairly known; but when applied to life and vital action something else must be considered, and the strongest rule, as based on theory of motion, may be proven only by the plain exceptions found. To say that quality and speed in trotters can be determined by the tape-line to a certainty would be absurd at best; but we may be able often to reject the horse that lacks capacity to trot at speed and thus save time, and spare ourselves the disappointment certain to result from training trotters that can never trot. Bear in mind that best of form must not be taken as a guaranty of speed at either trot or pace; but this much may be said with certainty, if he lack the form demanded, he may be fast and game, may even trot well down among the lower "teens" in seconds; but the records of the world will never be in danger, and the mark he does attain will be due to skill in training or to mental impulse, and can not be credited to shape or trotting leverage.

Severe exertion of the muscles, long continued, is only possible when the lungs are free in ample chest room. This we find best illustrated in the Thoroughbred or running horse, and here comes in an argument for the use of running blood in breeding trotters, which so many hold in favor. The highbred horse—the Thoroughbred—excels in this respect beyond all question, and the trotter that can stand the strain of long heat races must show the lung development of a Thoroughbred, with dilating nostrils and the clean fleshed throat that indicates the perfect freedom of the breath.

The muscles of the leg, aside from leverage, which depends on length of bone, must be developed to the point of balanced tension, and especially be trained to work at all times absolutely under brain control.

The leverage of motion in the horse rests almost solely in the quarters, front and rear. Front leverage is perhaps of lesser moment, from the fact that main propelling power comes from rear development; but the trotting leverage in front is still of great importance, since by it alone we may determine reach and stroke, or smoothness of the



FRONT LEVERAGE.

stride. From a mechanical point of view the leverage in front presents an interesting double or compound lever, lifting of the knee being due to a lever of the third class, where the power acts between the fulcrum and resistance; while the bending of the knee, or flexure of the cannon on the fore-arm, shows a lever of the same class, combined with pulley action of the tendons at the knee. If the fore-arm bone—the radius—be long, the lifting power of the muscles acting on the elbow as a fulcrum meets a greater weight resistance at the knee, the motion must be slower, and the knee will not be lifted high, as when the bone is shorter. If, too, the cannon bone be short in proportion to the fore-arm the necessity for high knee action is entirely overcome, and the horse will have an easy reaching stride that covers distance without seeming to exert, and saves the feet by striking lightly even at the highest speed.

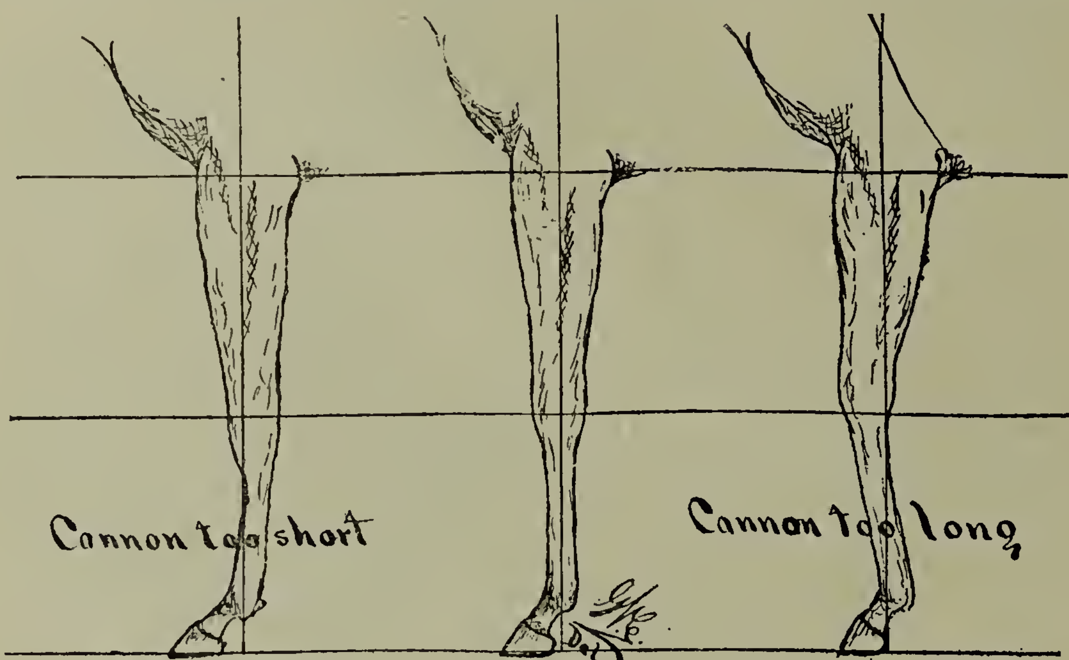
The reverse proportion—short fore-arm and relatively longer cannon bone—insures a high and pounding action of the knees that always tends to greater wear and waste of muscle energy, as well as damage to the feet and legs by heavy pounding when the horse is forced to travel fast.

Almost all the line descendants of old Hambletonian have this easy reaching action, and the measurements of leading members of the family show an uniformly long fore-arm and short front cannon, which, together, guarantee the smooth far-reaching action just explained. The Electioneers—descended from Electioneer, the greatest son of Hambletonian—show the feature strongest, and among them rest the records of the world at nearly every age from yearlings up. Hambletonian himself, the founder of the Hambletonian family, and the horse that should be credited as the actual founder of the trotting breed, had a cannon measurement of 11½, fore-arm of 20½ inches—a ratio of 1:1.783, and this ratio is exactly reproduced in his grandson Ansel, owned by Mr. Bonner and selected by him as the then best son of Electioneer. Sunol, the best daughter of Electioneer, measures 10¾ and 19½ inches respectively for cannon bone and fore-arm—a ratio of 1:1.823. Nancy Hanks by Happy Medium, another son of Hambletonian, measures 10 and 19 inches—a ratio of 1:1.9. Her knee action is perfection, and her mile in 2:09 on a regulation track is almost fairly equal to the 2:08¼ of Sunol on the Stockton kite.

The extreme of high knee action was illustrated in the gait of Smuggler—a converted pacer of undoubted courage and recorded trotting speed, but whose every motion carried a suggestion of a cyclone. He measured 12 and 20 inches — a ratio of 1:1.666. Helm credits Smuggler with raising the knee above the horizontal to an angle of 45 degrees, and states that he "strikes the ground with a force that is simply terrific." It should be borne in mind, however, that the heavy muscled shoulders, high withers and well set neck which made him pace by nature, made him also strike with added weight when speeding at the trot.

While the principle of speed with least exertion is a good one always to be kept in view, we should not forget that safety lies in middle ground of conformation. The extremely short front cannon, acting with the long fore-arm, amounts to drag or dwelling motion and may even spring the knees behind the vertical, resulting in a "calf-kneed" horse—which no one can admire and few will care to use. The horse with extra short fore-arm and long front cannon will finally be knee sprung almost to a certainty — "buck-kneed" and stumbling as he walks, a perfect picture of decrepitude. (See illustration.) For the stylish coach or carriage horse, the proud high stepper, with the short fore-arm and relatively longer cannon, will be greatly in demand; but for speed and stamina in long heat races, tie your fortunes to the horse that reaches out in front and moves the body forward on an even line at no great distance from the ground.

Rear leverage in the horse means something more than muscle force which gives propelling power. No horse can carry speed at any gait



"Calf-Kneed" — Normal — "Buck-Kneed"

with insufficient muscle, but the natural impulse of the horse to strike a gallop when he wants to travel faster may be so constrained by certain leverage in rear development as to make the artifical gait a second nature, breaking only when the brain is worried or the speed is carried past the limit which the horse can reach.

The motion of the hind legs, from the fetlocks up, is modified by four distinct true levers, each one more or less complex in action — one especially remarkable; the muscles from the haunch or hip bone and the Illiac fossa extend in two directions — downward to the stifle, and down and backward to the leg bone (Tibia) and the hock. The upper thigh bone (Femur) works at upper end against the lower portion of the Illium in connection with the other pelvic bones, and the muscles running downward from the hip, together with the bones of upper thigh and leg, form a double compound lever — really two in purpose—moving separate or jointly in obedience to the brain's direct or reflex action. The muscles of the lower thigh which flex the cannon on the leg present a simple lever of the third class (power between weight and fulcrum) combined with pully action of the tendons at the hock — exactly corresponding to the leverage in front which bends the cannon on the fore-arm. (See illustration—Rear Leverage.)

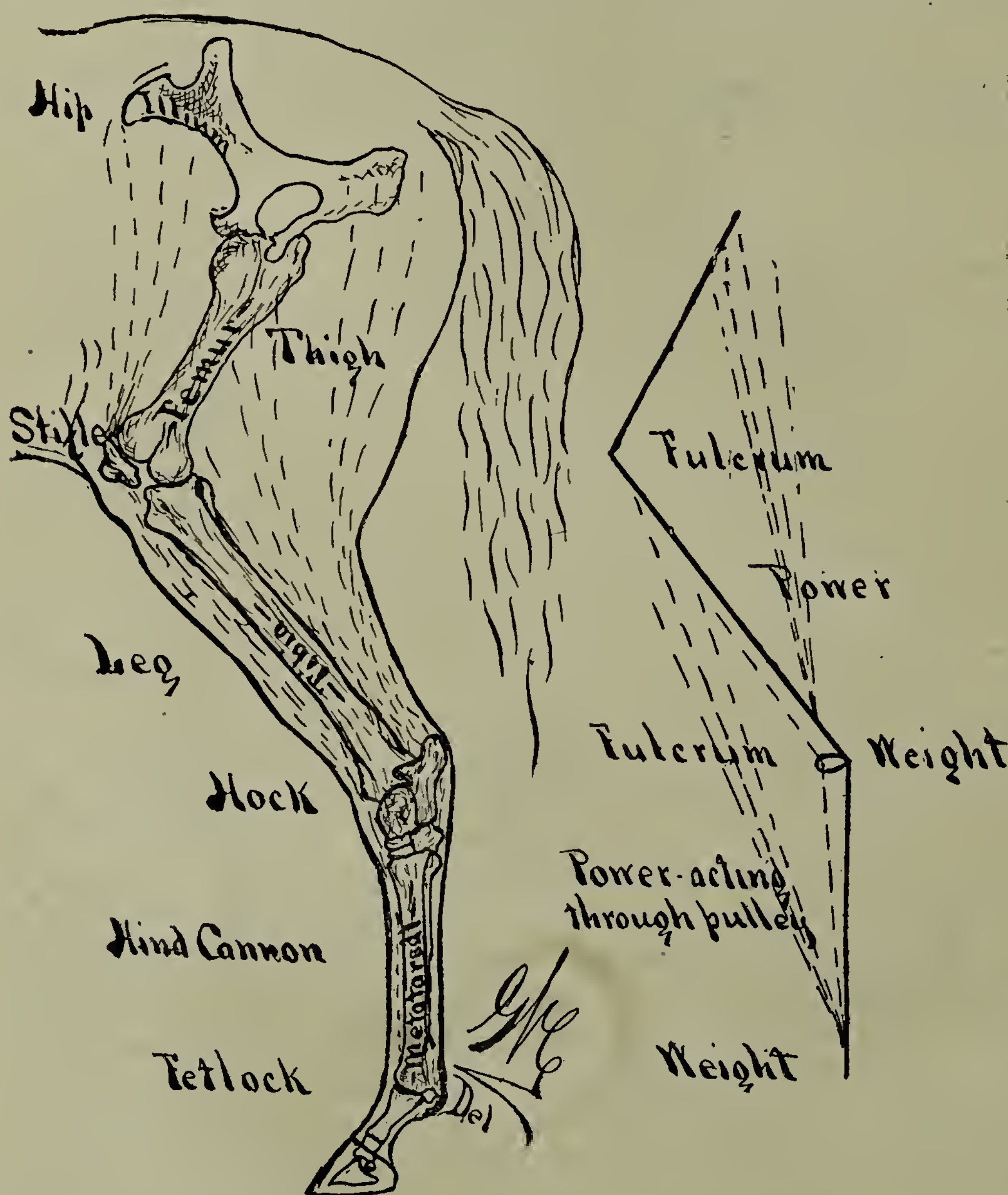
If the distance from the hip to hock be fairly long in reference to the lower thigh, the horse will stand with straighter leg at rest, and the hock will swing in trotting almost underneath the stifle, somewhat with the motion of a pendulum. Such are called "line trotters," and our best examples bear the blood of Hambletonian through his son Electioneer. Nearly all Electioneers reach out in front and trot directly on a line behind, the hind foot passing underneath the front, and placing squarely with the body.

The Knoxes of New England illustrate extremely narrow trotting, passing hocks in motion very close, and barely missing interference. The thigh is very short, the length from hip to hock is relatively long. They are descended from a horse called General Knox — standing 15 hands 2 inches, and with a thigh but 20 inches and a half.

The reverse of this proportion, longer thigh and relatively shorter length from hip to hock, compels the horse to travel wide behind — swinging out the hocks in motion to avoid necessity for greater elevation of the stifle. The extreme in wide hock action showed in Duroc, with a thigh 24½ as compared with length from hip to hock of only 39 — a ratio of 1:1.592. All of his descendants, to the present day, show Duroc blood in length of thigh, and travel with that open, straddling gait which such a conformation makes imperative.

Hambletonian showed the middle ground in ratio, both lines being long, but lengthened so that each might correlate the other's action and insure "line trotting" to perfection. His measurements were 24 and 41 respectively for thigh and hip to hock — a ratio of 1:1.708, and his best descendants show a similar proportion. Nancy Hanks, already mentioned as the daughter of a son of Hambletonian (Happy Medium), measures 21¾ and 38 — a ratio of 1:1.747. Ansel, by another son (Electioneer), measures 23½ and 40½ — a ratio of 1:1.723. Maud S. by Harold (one of Hambletonian's sons) measures 23¾ and 40 — a ratio of 1:1.684 — and is said to have an almost perfect action. Sunol, by Electioneer, has longer thigh and therefore has a longer stride, and carries speed at somewhat wider gait than most of the Electioneers. Her measurements are 24½ and 40 — a ratio of 1:1.632. Nearly all the offspring of the so-called "Star cross" in the Hambletonian family show the blood of Duroc through his son American Star. A horse "Star gaited" trots with well spread hocks and carries speed without a chance of interference, front or rear.

But by far the most important trotting leverage remains to be considered: length of Metatarsal bone (the cannon of the hind leg), as compared with length from hip to hock. As a rule the horse with hock placed low — that is, with short hind cannon — carries speed to some extent by nature at the trot; while the horse with hock placed high—that is, with long hind cannon—is a galloper from impulse. Do not understand by this that a horse with fairly long hind cannon can not carry trotting speed — far from it; many a horse that lacks the best essentials for perfection at the trotting gait, by long and careful training, proper balancing by shoes and toe weights, and restraint by



REAR LEVERAGE.

straps and hobbles, may be trained to trot at speed; but the time is past when trotting interests can be sustained by training and manipulation only. The impulse to trot — the "instinct" if you will — must be controlled in great degree by conformation of the parts concerned, combined with mental aptitude. Both these essentials for the future trotter may be fixed by well known laws of breeding and become established features of the future trotting breed.

That an animal with long hind cannon will be a galloper by nature, and with short, a trotter, is shown most clearly by a study of the measurements and gaits of those wild animals with which we are familiar. The elephant, whose gait is nothing but a trot, in spite of his enormous size and length of leg has hock placed almost on the ground — a cannon bone no longer than its breadth, and never to exceed 5 inches. A little study of the parts concerned will satisfy the most incredulous that the gait which he assumes by nature is a matter not of choice but of necessity—he could not gallop if he would. His leverage has been wisely placed to carry weight of his ungainly body and his speed becomes a matter wholly secondary. The long, strong muscles reaching from his hip to hock, run almost parallel to the bones of upper thigh and leg, and could hardly be expected to exert sufficient force for lifting such enormous quarters briskly as in galloping; the motion must be swinging — not propelling — a condition which the trot fulfills exactly.

The other extreme—the long hind cannon and the corresponding pushing or propelling gait, the gallop—may be found in all those animals of well known speed, as deer and antelope, jack rabbits and the like. Their natural gait, at anything beyond a walk in speed, is known to be a gallop, and the conformation correlates the gait. The prong-horned antelope (*Antilocapra Americana*) of Northwest Texas, rarely ever known to trot, although but 31½ inches high, displays a cannon measurement of 12½ inches as compared with length from hip to hock of 16¼, a ratio of but 1:1.3.

Just what ratio in this lower lever will be most conducive to the trotting gait can be determined only by a study of the measurements of well known trotting horses now before the public, noting the peculiar points of interest in their ways of going, and especially their tendencies to break when urged to highest speed. Sunol measures 17½ and 40 respectively for hind cannon and length from hip to hock, a ratio of 1:2.285. Her hock is very low, the cannon extra short, and her mile in 2:08¼ bears witness to her speed capacity. Ansel, also by Electioneer, shows nearly equal measurement, a ratio of 1:2.222. Delmarch, by Hambrino, measures 17¼ and 38½, a ratio of 1:2.232. Jack, the steady, gray campaigner owned by Mr. Forbes, measures 17½ and 37, a ratio of 1:2.114. Mary Marshal measures 18 and 39, a ratio of 1:2.167; and Allerton, the king of racing stallions, measures 17 and 39, a ratio of 1:2.294.

Nearly all the great celebrities at present on the track show cannon not quite half as long as length from hip to hock; a few exceptions only prove the rule. The horses named are all pure gaited trotters, bearing voice and whip if needed in a race without a skip, and straining every muscle in a keen desire to win. The record each has made is plainest evidence that trotting blood and brain and leverage combined will carry highest speed. Mary Marshal, 2:12¾; Jack, 2:12; Delmarch, 2:11½; Allerton, 2:09¼; Maud S., 2:08¾, and Sunol, 2:08¼, are proof potential of the progress made in breeding trotters since the days of Flora Temple.

And now a word in reference to trotting morals: The time is past when prejudice and narrowness of moral vision can obscure the good which carries with it often much of evil. The depravity of certain classes that frequent the turf and track must not be taken as essential features of legitimate sport. That depravity exists we cannot doubt, but that the trotting horse should bear the stain of man's depravity, and the trotting race be therefore banished from the list of noble sports, are statements that may well be challenged. While the Thoroughbred or running horse by some is looked upon as mainly valuable for sport with incidental usefulness, the trotter must be classed by all as being really useful. The horse that pulls with ease a wagon, coach or carriage at a lively trot will shorten time and can not fail to be of really greater worth than a running horse, of value mainly for the winnings he may earn. We should not overlook the evil which we know is often found, nor spurn the good because of evil which we know exists. Let us first be right ourselves, and then by effort and example right the wrongs we see whenever possible.

TRANSACTIONS

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The Bureau of Education, Washington, D. C.
The Department of Agriculture, Washington, D. C.
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The American Philosophical Society, Philadelphia, Pa.
The Franklin Institute, Philadelphia, Pa.
The Academy of Natural Sciences, Philadelphia, Pa.
The University of Pennsylvania, Philadelphia, Pa.
New York Academy of Sciences, New York, N. Y.
The American Academy, Boston, Mass.
The University of Virginia, Charlottesville, Va.
Indiana Academy of Science, Brookville, Ind.
Wisconsin Academy of Sciences, Arts, and Letters, Madison, Wis.
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Academy of Science, St. Louis, Mo.
Kansas Academy of Science, Topeka, Kans.
Colorado Scientific Society, Denver, Col.
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The Lick Observatory, San Francisco, Cal.

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ON SPHERICS

BY M. B. PORTER, SUGAR LAND, TEXAS.

[Read February 6, 1892.]

"Upon this supposition of a positive curvature, the whole of geometry is far more complete and interesting; the principle of duality, instead of half breaking down over metric relations, applies to all propositions without exception. In fact, I do not mind confessing that I personally have often found relief from the dreary infinities of homaloidal space in the consoling hope that, after all, this other may be the true state of things."—W. K. Clifford, Lecture on Philosophy of the Pure Sciences."

INTRODUCTORY NOTE.

The following is the substance of a paper read before the Texas Academy of Science, Feb. 6, 1892, and is an attempt to outline a synthetic treatment of the conic sections, by regarding them as degraded forms of the spherical ellipse. The advantages accruing from such a method, are, it is believed, greater unity in the conception of the properties and generation of these curves, by considering them as different aspects of one and the same curve; secondly, as affording a far more definite and satisfactory view of the line at infinity, so all important in the theory of planimetry, the theory of parallels, and the treatment of plane curves.

The principle of duality, which, to one unacquainted with Plucker's point and line co-ordination, might seem, *in plano*, wanting in that axiomatic certitude indispensable in a proof, occasions no difficulty in spherics, where the quadrantal correspondence of line and point has been made use of since the foundation of this branch of geometry. Quadrantal reciprocity, though a special form of the principle of duality, is of incalculable value in studying the metrics and graphics of the sphere, and, in showing that it may be considered, either as a point-aggregate or a line-aggregate, facilitates the realization of polar-reciprocity in its most general form. The principle of limits is systematically employed, and is to be regarded as an *assumption* by means of which it is possible to define the expressions, *length* of a curve, *area* of a warp, *direction* of a curve at a point, etc. No attempt is made to establish the graphical properties independently of metrical considerations; but rather to connect these as closely as possible. Hence the theory of projective rows and pencils is worked out from the more elementary properties of the conic. Van Staudt's symbol $\overline{\wedge}$ is used to indicate projective rows and pencils.

Besides the axioms laid down in Dr. Halsted's *Geometry* (*Spherics*), the following principles are made use of.

Defining the polar reciprocal of a curve to be the curve enveloped by the lines quadrantally polar to every point on the given curve; the area of any curve is equal to the area of the hemisphere, less the scalar perimeter of the polar reciprocal multiplied by a steradian.

This follows from the theorem in elementary geometry concerning polar polygons, by supposing the vertices (indefinitely near together) to be situated on the curve, whose area it is desired to measure. As the points approach coincidence they would form a polygon more and more nearly equal to the required area, and their polars would envelope a curve more and more nearly equal to the polar reciprocal.

Besides the point to line correspondence, there is a point to point correspondence also, for if two tangents, indefinitely near to each other, intersect, they determine a point corresponding to the polar of this tangent. That the polar of a circle is a circle is easily proven from the most elementary consideration, such as symmetry or congruent triangles. The remarks on projection have been added appendically to explain the terms *cyclic line* and *conic*.

SPHERICAL CONICS.

I.

1. In this paper, the *sum* of any number of sects means, the sect between the extreme ends of the first and last when they are all placed end to end along any line so that none overlap.

2. A spherical conic is the locus of a point which moves in such a manner that the sum of the two sects connecting it with two fixed points (foci) shall be equal to a constant sect. If the symmetrical conic be constructed by producing the focal sects one-half line, its foci will be Φ and Φ', and these points will be situated on the line through F and F′, the foci of the first, and one-half line from them. Both curves may be regarded as constituting one locus.

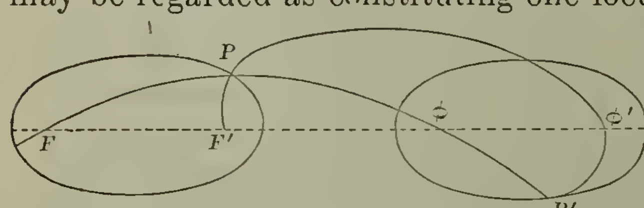

Fig. 1.

In figure 1, $FP + F'P =$ a constant and $FP \times \Phi P$ are equal to one-half line. Therefore the difference between F′P and ΦP is constant.

With respect to the foci F′ and Φ, the locus may be regarded as a spherical hyperbola. While from the above considerations it is clear that the locus is symmetrical with respect to four centers midway between F, F′, Φ, Φ', and with respect to three axes the line through FF′, $\Phi\Phi'$ and the perpendiculars to it at the midpoints of FF′ and FΦ'.

4. The polar reciprocal of the spherical ellipse is a curve enveloped by the base of a triangle of constant area whose vertical angle is fixed. In the case of the ellipse, therefore, the *sum* of the base angles is constant, and in the case of the hyperbola the difference. The lines polar to F and F′ are called the *cyclic* lines for reasons that will appear later.

THE TANGENT.

5. THEOREM. *A tangent to a spherical ellipse bisects the angle between the focal radii drawn to that point.* Let P be the given point, P′ a point very near the first, and let F′s and Ft be laid off on FP and F′P equal to FP′ and F′P′. In the right-angled triangles PP′t and PP′s we will have PP′ common and Pt equal to Ps. As the point P′ approaches P the arcs P′t and P′s will more nearly coincide with the perpendiculars and PP′ continually approach the bisector of angle tPF′. Conversely, it may be proved that if PT bisect the angle tPF′ it can have only one point in common with the curve.

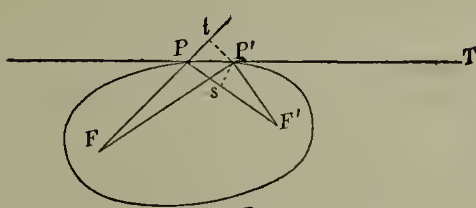

Fig. 2.

(a). In the reciprocal figure we have: the tangent intercepted between the cyclic lines is bisected by the points of tangency.

(b). From I., above, it follows that confocal conics intersect at right angles.

6. THEOREM. *If two tangent lines be drawn to the reciprocal curve they intersect the cyclic lines in four concyclic points, and the center of the circle is the pole of the line through the points of tangency.*

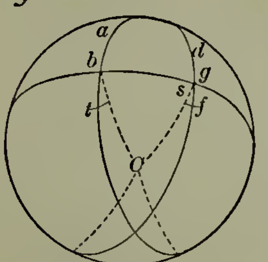

Fig. 3.

I shall prove the converse. In figure 3, $a+b=g+d$. If C is the center $f+d=t+a$, and if s is added to both sides, we get $a+b=g+d$. C is a quadrant from Φ and Φ'; where Φ bisects dg and C is on the perpendicular to the supplement of gd at its middle point.

(c). Passing back to the spherical ellipse. The four focal vectors drawn to any two points on an ellipse touch a circle whose center is the intersection of the tangents drawn at these points.

7. Many focal properties are readily deducible from [2 and 5]. In figure 4, produce TF so that TL=F′T. The triangle PF′T=triangle PTL and PL=PF′.

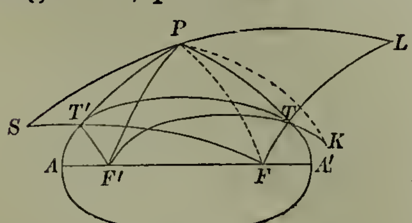

Fig. 4.

Producing FT′ so that T′S=T′F′; triangles PT′S and PT′F′ are equal and PS=PF′ =PL, so that triangles PSF and PFL are equal. Thus it follows that angle LFS is bisected by PF.

The part of any third tangent intercepted between these two fixed tangents subtends a constant angle at the focus equal to angle TFP.

8. If F′T is produced so that TK=FT, triangles FPS and F′PK are equal, PF=PK, PS=PF′ and FS=FT′+T′S=FT′+T′F′=F′K=AA′.

Thus angles FPS and F′PK are equal, and since FPF′ is common, SPF=KPF, or TPF=T′PF′.

9. From 8: If a system of conics touch two lines and have one focus on a third passing through the intersection of the tangents; the locus of the other focus is determined by 2°.

10. *For the reciprocal curve*, 1° above becomes: the intercept of any two tangents on the cyclic lines is bisected by their chord of contact. 2° becomes: if, from any two fixed points on the curve, lines be drawn to a variable third also on the curve; they cut off a constant sect on the cyclic arcs.

Hence five points determine the reciprocal curve; for two determine the reciprocal curve. 3° becomes: in any secant, the two short (long) sects cut off between the curve and the cyclic lines are equal. Figure 14. an=n′r.

II.

If any four points on the polar reciprocal are joined with a variable fifth point also on the curve, these lines determine on the cyclic lines two ranges of four points each, which are said to be *perspective*. Displace one of these ranges along its line, and the range on the other line may be so displaced that it will be perspective with the other (by 10. 2°). Further, if the range on the first cyclic line be arbitrarily chosen, and three elements of the range on the other be similarly taken, the fourth element is determined by the perspective relation, and will remain invariable, no matter how either range be displaced along its cyclic line. 2°. Let the polar of the perspective-center be drawn. It will make with the cyclic lines angles measured by the sect between the perspective-center and the poles of the cyclic lines. If lines, symmetrical to the cyclic lines with respect to the polar of the center of perspective, be drawn, these ranges will be projected into equal ranges on these symmetrical lines. If a reciprocal curve be traced through the center of perspective having for cyclic lines the lines symmetrical to the former ones, it may be shown, as before, that having assumed seven sects, the eighth is determined by the perspective relation. By 2° it is possible to vary the angle between the perspective ranges through all values, so that two *projective* rows will be placed in perspective, when three elements of one are perspective to these elements of the other, no matter what the angle is between them.

The functional relation which subsists thus evidently between these sects is called by Clifford their *cross-ratio*, by Chasles their *anhar-*

monic ratio. The word *projective* is used to denote that the two rows are *in some* position perspective, or are projective in the above sense to other projective rows.

Two pencils are projective when they can be arranged so that all the corresponding rays intersect on a geodesic.

3°. By this definition four points fixed and one variable determine, in the case of the reciprocal curve, a system of projective pencils; while on the ellipse four fixed tangents and one variable determine a system of projective ranges.

The Theorems of Pascal and Brianchon readily follow from either of these relations.

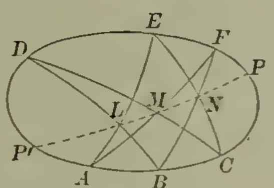

Fig. 5.

11. Thus figure 5. M. FNCB$\overline{\wedge}$C. FEDB$\overline{\wedge}$A. FE DB$\overline{\wedge}$M. ALDB. therefore M. FNCB$\overline{\wedge}$M. ALDB, and since three corresponding elements coincide, the fourth must also, L, M, and N are collinear. The line L M N determines the two 'points P, P such that A. P'DEF$\overline{\wedge}$D.P'ABC and A. PDEF$\overline{\wedge}$D. PABC. Pascal's line, thus, determines a seventh point, which taken along with any three of six given points is perspective to the remaining three and itself taken in a corresponding order. The problem has in general two solutions, but only one when the Pascal's line is tangent, and the problem is impossible when the line is without the curve entirely.

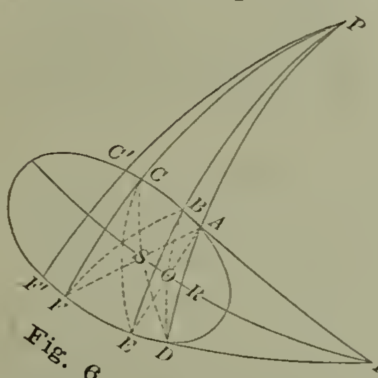
Fig. 6.

12. In figure 6, suppose (FC), (EB), and (DA) all to pass through the same point P; draw a line through DE to meet OMN (Pascal's line) at L. The ranges PBSE and PA RD are projective, while L. PARD$\overline{\wedge}$L. PBS E; so that D, E and L are on one straight line. Thus, if a secant turn about P the join (EC) (BF) is always on the line *OL*. This is called De la Hire's theorem of the pole and polar, P being called the pole, and *OL* the polar.

Cor. I. D. ABCC' $\overline{\wedge}$A. DEFF'.

Cor. II. This, together with Pascal's theorem, affords an elegant method for drawing a tangent to a curve of this kind, *on plano*, with a ruler only.

POLES AND POLARS.

13. From the method of generating the polar, it will be seen that the polars of all the points on any line pass through a certain point, the pole of the line and conversely; so that to every line there corresponds a point, and to every point a line. This is only a more general aspect of the principle of Duality, as hitherto employed (quad-

rantal transformation), the correspondence depending on the conic of reference.

13. If tangents are drawn at the vertices of the hexagon, figure 5, the intersection of the tangents at D, F; and A, C, will be on the polar of M, so for L and N; so that their intersection will be the pole of the Pascal's line. This is Brianchon's theorem, and may be thus enunciated: if the opposite vertices of a hexagon, whose sides touch a conic, be joined, the joins pass through one common point, the pole of the corresponding Pascal's line in the inscribed hexagram. Conversely Pascal's theorem may be deduced from Brianchon's.

From the above, since the conic and its polar reciprocal are generated in precisely the same manner, either by points or enveloping lines, the reciprocal curve is a spherical conic, and all the properties proved for this curve hold for the spherical ellipse.

Cor.: The reciprocal of one conic with respect to another conic is a conic.

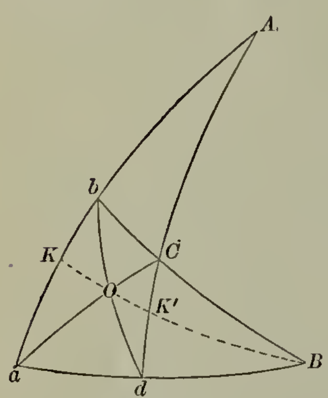

Fig. 7.

14. *The Conjugate Triad.* The six joins of four points determine three points called a conjugate triad, and if a conic is drawn through the four points, any one of the three points is the pole of the line passing through the other two. Thus, figure 7. A is the pole of BO, etc.

In figure 7, $aKbA \barwedge dK'cA \barwedge cK'dA$. Such a row is called *harmonic.* Thus the conic, the pole, and its polar divide any line through the pole in a harmonic range.

When the pole is at the center of the conic the polar is the trigonometric polar of the center, and the sect aK=Kb, while KA is equal to a quadrant. Conversely, in a harmonic range, abcd, if ab=bc, bd is equal to a quadrant, and in a four-ray pencil O. abcd, if angle aOb= angle bOc, angle bOd is measured by a quadrant.

15. By—[8]: if a tangent is drawn from the polar of the focus to the conic, the part intercepted between the curve and the polar of the focus (directrix) subtends a right angle; also, if a line be drawn cutting the curve and the directrix, and the focus be joined with the three points of intersection, the join of the focus and the point on the directrix bisects the angle between the other two.

In figure 7. If the angle at O be a right angle and turn about O while *Ad* and *Aa* remain fixed, the angular velocity of B about O is double the angular velocity of the sides of the right angle.

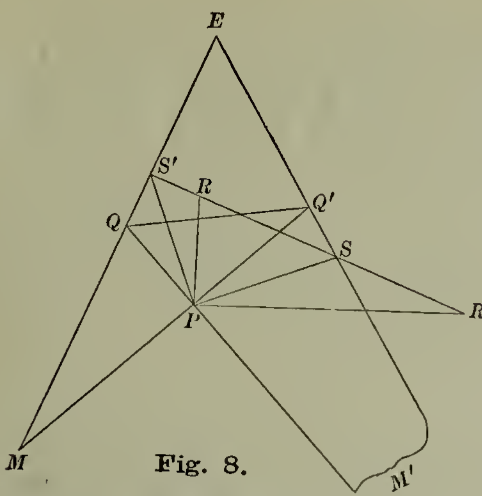

Fig. 8.

16. If a right angle turn about a fixed point P, and cut two fixed straight lines EM and EM', successively assuming the positions QPQ, S'PS and RPR', the points QRQ'R'M'M, where M and M', Q and Q' are the points of intersection of the legs of the right angle in its first position, will be on one conic, because Q'. R'M'MR$\overline{\wedge}$P. R'SQ'R$\overline{\wedge}$P. R'QS'R,$\overline{\wedge}$ Q.R'M'MR, 1°. This result shows that if a right angle turn about any point on a sphere, it intersects a spherical conic in four points, whose *joins* touch another spherical conic (II. 3°). The vertex of the right angle will be the focus of the second conic by 7, while the directrix, which passes through E and the intersection of QQ' and MM', is the polar of P with respect to the conic QQ'MM'RR'. 2°. If P is at the center of the conic, the envelope is a circle 3° if P is a point on the curve, the envelope becomes a sect which connects P and a certain point through which all the subtended chords pass. If the right angle turn so that one leg is tangent, the other is the normal, so that this property affords an elegant method of drawing a normal at any point of the curve. The reciprocal theorems are 1° if a quadrant be displaced along any line, and tangent drawn from its extremities to a conic, they intersect on a conic having this line for its cyclic line, which has the same pole with reference to both conics. 2°. When the cyclic line of the second bisects the angle between the cyclic lines of the first conic the locus is a circle; 3° when it touches, the first conic the curve becomes a geodesic.

17. By 13 Cor. The reciprocal of a conic with respect to another conic is a conic, and it is evident that there will be a point which will have the same polar with respect to all three, hence the reciprocal of one conic with respect to another having the same focus and directrix is a confocal conic with the same directrix. It is not difficult to prove that the chord of contact subtends a constant angle at the focus.

This reciprocated yields: If a constant sect be displaced along the cyclic line, tangents from its extremities intersect on a conic, and the chord of contact envelopes another conic, all of which have the cyclic line in common.

18. Many other interesting properties of the focus and directrix follow from the foregoing.

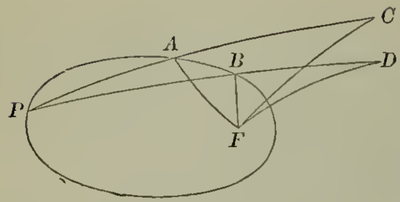

Fig. 9.

In figure 9. A and B are fixed points, P movable, and F is the focus.

Angle AFC=$\frac{1}{2}$ supplement of PFA (14.) and angle BFD=$\frac{1}{2}$ sup. of PFB; so that angle CFD=$\frac{1}{2}$ angle AFB.

The reciprocal is: if a variable tangent intersect two fixed tangents, and the points of intersection be joined with the pole with respect to the conic of the cyclic line, these joining lines determine an invariable sect on the cyclic line.

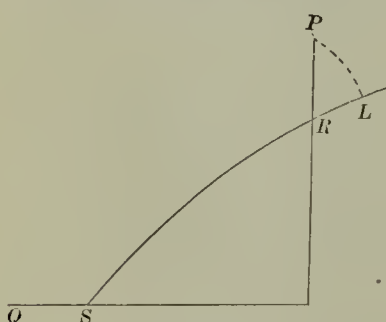

Fig 10.

19. In figure 10. Let P be a point and Q its quadrantal polar. If SL is a quadrantal sect always passing through R, and having its extremity on QS, the polar of P, L will trace a spherical conic passing through P and R, and whose cyclic lines are the quadrantal polars of P and R. Drop a perpendicular on QS from P, it will intersect at L, for SL would be equal to PS (a quadrant). Thus the locus of the vertex of a right-angled triangle whose base is fixed is a spherical conic.

Reciprocating this last, if a quadrant sect slide between any two lines it envelopes a conic.

By means of [11], it is possible to solve a number of problems relating to the construction of polygons inscribed in polygons and conics whose sides shall fulfill certain conditions. The celebrated problem of Pappus, generalized by Cramer and Poncelet, to inscribe in a conic or a polygon of w sides, a polygon of n sides, the sides of which shall pass through n given points taken in any assigned order.

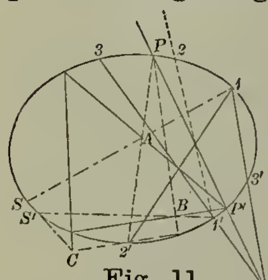
Fig. 11.

20. In figure 11, taking for simplicity the triangle, let A, B, C be the three points. Choosing any point at random on the curve, as (1), draw a line through (1) and A to cut the curve at s; draw through s and C to cut the curve again, and so continue with all the points in the order assigned, the last one cutting at (1′). Determine thus three points (1′) (2′) (3′), and find a fourth, such that O.1′2′3′4 $\barwedge$ O. 1234, (4) being a double point in the series 12341′2′3′4, is a vertex of the polygon. There are generally two solutions.

DESCRIPTION OF CONICS BY LINES AND POINTS.

21. Besides the methods already described (2, 3, 4, 11 . . . .), for the generation of a conic, the method of Newton is easily deduced from the property of projective pencils. Two constant angles turn about vertices A and B, if two of the sides intersecting trace a conic through A and B, the other two will trace another through A and B.

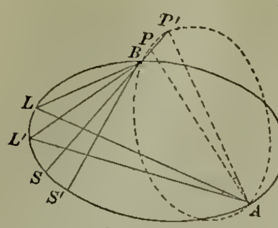

Fig. 12.

In figure 12. Let L, L', L'', L''' be four positions of the intersection of the legs tracing the conic A. LL'SS' $\barwedge$ B.LL'SS' $\barwedge$ A.PP'P''P''' $\barwedge$ B.PP'P''P'''. So that A, B, PP'P''P''' are on a conic.

CONDITIONS NECESSARY TO DETERMINE A CONIC.

22. 1°. Five lines or five tangents [11].

2°. The focus and three tangents, or the cyclic line and three points [5].

3°. The focus, the directrix, and one point; or a cyclic line, its pole and one tangent (another point could be determined as the harmonic conjugate and thus both cyclic line would be determined (22-4°)).

4°. The focus, the directrix, and one tangent (because the point of tangency may be found by (8)).

5°. A point, its polar, and three points (14).

6°. Two points, their polars, and one point on the curve.

THEOREMS OF GRAVES, MACCULLOGH, AND OTHERS.

23. (a) Figure 13 represents three biconcyclic conics. Let tangents be drawn to the inner one *C*. By a previous theorem the sects intercepted between the cyclic lines, and the curves will be equal, while the point of tangency will bisect the portion of the tangent line between the cyclic lines and between the curves B and C. In [4] it was shown that the two vertical triangles *Pab* and *Pa'b'* are equal, where *aa'* and *bb'* are tangents, and since the point of tangency bisects *aa'*, *bb'* the triangles must approach perfect congruence as *aa'* approaches *bb'*, while at the same time the vertical triangles cut off by the conic B, will at the same time approach congruence. In other words, the line tangent to *C* cuts off a constant space from B, because the increment caused by the tangent beginning to move is equal to the decrement. (b) On the contrary, considering the conics S and C, a similar reasoning shows that the same increment *Pmn*=*P'm'n'* is added to the space between the conics C and A, the fixed tangent M and any variable tangent that is added to the space between A, C' (the conic symmetrical to C) and the same tangents. In other words the differences between these spaces is equal to a constant space.

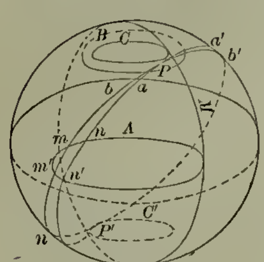

Fig. 13.

1°. The reciprocal of the first (*a*) is Graves' theorem.

If tangents be drawn, any point on a conic to a byconfocal conic, the sum of the arc (convex) and the tangent lines is constant, i. e., if a string be tied loosely about the inner conic and drawn tight with a tracing point, the point describes a conic byconfocal with the first.

1° contains Fagnani's theorem as a particular case, for if the tangents be drawn from the points where the major and minor axes cut the curve, the elliptic quadrant will be cut up into parts whose difference is expressible by a constructable line.

2°. The reciprocal of (*b*) is: When two byconfocal conics cut each other, if tangents be drawn from any point on one to the other their difference is equal to the difference of the arcs between their intersection and the points where the tangents touch.

Cor. If tangents be drawn at the point above the major and minor axes cut the curve, and a byconfocal conic be traced through their intersection, it will intersect the original conic in a point (Fagnani's), which divides the quadrant into two parts, whose difference, *in plano*, is equal to the difference between the axes.

24. By means of 2°, it is also possible to prove a theorem of Landen's. (See Williamson's Integral Calculus.)

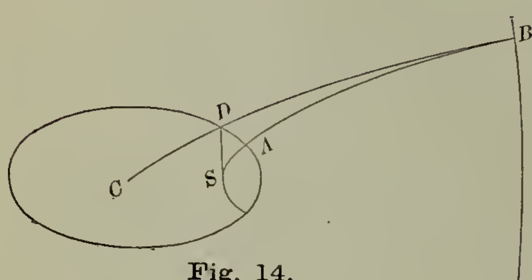

Fig. 14.

In figure 14, DS is a tangent at the vertex, and CB is a tangent from the center of the two conics. CB is a quadrant, and by 2° DB—DS=AB—AS, or adding CD and 2AS. CB—BS=DS—2AS+CD. This result is mainly interesting on account of its interpretation *in plano*.

THE PLANE.

If the sphere increases without limit, the tri-rectangular triangle becomes indefinitely large, while the quadrant becomes immeasurably long. This last is evident, because the reciprocal of a tri-rectangular triangle is a tri-rectangular triangle, hence from the relation existing between the sides and angles (area) of two reciprocal figures, the infinitude of one implies the infinitude of the other.

Since the area of a polygon is equal to the spherical excess, multiplied by the tri-rectangular triangle, if a polygon of finite extent be drawn on a sphere, whose quadrant is becoming indefinitely long, its spherical excess will have to approach zero as a limit, and over a *finite* area the assumption of parallels holds good, and the rules of planimetry apply. It is thus, by the measurement of the spherical excess of astronomical triangles, that attempts have been made to determine the curvature of our cosmical space. On the other hand, the rules of planimetry and similarity are applicable, on a finite sphere, to indefinitely small areas, and the rigorous proof of Graves' theorem, etc., requires it to be proven that the error is of the second order, which, however, presents little difficulty.

To reduce theorems in spherics to corresponding ones *in plano*, it is only necessary to consider the sphere to grow indefinitely large. It is often expedient, however, to select some particular point, as the center of the planar universe, and it is the quadrantal polar of this point that becomes the *line at infinity*. It will be noted in the reduction to the plane, that only the hemisphere is dealt with and the portion of the sphere beyond the line chosen to be *line at infinity* is disregarded. These considerations show why it is admissible to regard the *line at infinity* as having no direction, or rather any direction, as being the locus of the intersection of all parallel lines; why only one parallel can be drawn to a line through a point.

Many of the results obtained for spherical may be immediately stated for the flat conics by changing the word cyclic line to *asymptote*. But in 24 it will be found convenient take the polar of C to become the line at infinity; 24 then becomes an expression for the difference between the hyperbolic arc from the vertex to the point at infinity, and the asymptote between the center and the point at infinity. In 16, 1° let the line along which the quadrant is displaced be taken as the line at infinity, and it becomes the well known theorem: The locus of the vertex of a right angle, whose sides touch a conic, is a concentric circle. When AA′= a quadrant, the conic is the locus of a point equally distant from F and the quadrantal polar of F′; so that the *parabola* is said to be tangent to the line at infinity; the tangent can thus coincide with the line at infinity, and the lines joining its intersections with two fixed tangents to the focus would be parallel to the two fixed tangents respectively, and make a constant angle with each other; so that the in tersections of two fixed tangents, and a variable third, are concyclic with the focus. Conversely, if a series of parabolas touch three lines, the locus of their foci is a circle passing through the three points of intersection of the tangent, a theorem due to Lambert.

The property of the circle, in plano, that two points on a circle subtend a constant angle at any third point on the same circle, may be deduced in the same way. Considering the foci (10.2°) to coincide, the intercept on the polar of the center will be constant, and taking this line as the line at infinity, the theorem is evident. All graphical relations are, of course, quite independent of the selection of the *line at infinity*, so that Pascal's, Brianchon's, and the polar properties are proved at the same time for the sphere and plane. It is possible to pass by an inverse process from plane to the sphere, and, by supposing the plane to become uniformly bent in the third dimension, deduce from the properties of circles, *in plano*, theorems concerning conics on the sphere. The theorem of the circle, the vertex of any constant angle sliding around a circle generates a circle, while the chord of contact envclopes a circle which is concentric with the other two, may be thus stated: Any point in the plane being taken as the point which is to become the pole of the line which was the line of infinity, *in plano*, if parallels be drawn to the sides of the constant angle they will intersect the sides on the line at infinity, and contain between them a constant angle, while the sect intercepted on the line at infinity will be constant. If the plane be now supposed to assume a uniform curvature, the chosen center need not coincide with the vertex of the constant angle, because this property, on account of its graphical nature, must hold independently of the curvature. The line at infinity will now become the cyclic line, and the circles traced by vertex and enveloping line will become conics having the same cyclic line, which is the reciprocal of 17. Other results may be deduced in the same way. But the close analogy between these processes and the methods of projection is best shown in the following: Two spherical conics have cyclic lines intersecting in A and B. Let P, the pole of AB, be taken as a center, and the hemisphere be supposed to grow indefinitely flat, the two conics will become similar.

PROJECTION.

10. (2°) shows that a spherical conic is the projection of two circles, or that a cyclic cone has *two* circular sections, which are parallel to the cyclic lines on the sphere.

7 shows that if sections of the cone are taken perpedicular to OF (the focal line), O being the center of the sphere; O F will be the locus of their foci. A spherical conic is then a curve, the intersection of a sphere and a cyclic cone, whose vertex is at the center of the sphere. The cyclic arcs are determined by planes drawn through the vertex parallel to the cyclic sections, and the foci are the intersection of the sphere and the focal lines of the cone. Many of the foregoing results are easily deduced by projection from the properties of the circle and plane conic. Thus the reciprocal of 17 is deduced by projection from equal chords in a circle envelope a concentric circle. Of course all the graphical relations are true for their projections.

THE PILGRIMAGE AND CIVILIZATION OF THE TOLTECS.

By David Cerna, M. D., Ph. D.

Read June 19, 1893.

I need not state, perhaps, that of the three principal branches of the historical human races, the Hamitic, the Semitic, and the Aryan or Indo-European, this last one has always been considered as the most important in every respect. From it, undoubtedly, have sprung the peoples that have more largely contributed to the progress and development of civilization. The Semitic branch is especiallay noted for having given to the world three religions, each one of which proclaims, singularly enough, the existence of One, All-Powerful God, Ruler of the Universe: the Jewish, the Mohammedan, and the Christian. The Hamitic branch comprises chiefly the venerable Egyptians and the Chaldeans. To another Eastern nation the world is indebted for modern civilization, although not generally admitted, but nevertheless true. I mean, of course, China.

Regarding the contributors to modern human progress we shall not, nay, we can not stop here. We shall find, if we carefully consult and examine the annals of human existence, that two other peoples have also contributed to the common stock of civilization, and that these two peoples belong to our own Continent. As you may surmise, I have reference to the Peruvians and the Mexicans; especially to these latter tribes that once inhabited and held full sway over beautiful *Anahuac:* tribes to which belonged Netzahualcoyotl, the king-poet, and the poet-king of our primitive Continental literature; Guatimotzin the Aztec Philopœmen, the last and heroic martyr of his race, and a host of other brilliant stars that shall forever shine in the firmament of our own history.

There is no doubt that all these Mexican tribes contributed more or less to the establishment of the great Aztec Empire and to the origin and development of a wonderful civilization.

Whether all these ancient peoples had or not a common origin; whether they were aborgines or had sprung from Eastern nations, a topic in itself extremely interesting from a historical and scientific point of view, the matter remains unsettled, notwithstanding the many beautiful theories promulgated on both sides of the question.

It has been maintained that the Mayas and the Maya-Quiches, the races peculiar to Yucatan and Chiapas, perhaps the most ancient of American peoples, proceeded either directly or indirectly from Egypt and other Eastern nations, their appearance on this Continent being accounted for in different ways, but without the light of positive proof.

Be this as it may, these tribes differed in many respects from the rest of the Anahuac races. Without entering, then, into a discussion of problematical questions, permit me to relate briefly the story of these latter people, especially, for the present at least, that of the remarkable Toltecs, considered as the most ancient of the civilized Mexican nations.

History tells us that the Toltecs were among the first of the ambulent tribes to traverse the country and penetrate the beautiful and picturesque land of *Anahuac*. Other tribes followed, or preceded them, such as the *Chichimecs*, the *Colhuas*, the *Acolhuas*, the *Tlaxcaltecs*, the *Chiapanecs*, the *Zapotecs*, the *Olmecs*, the *Huastecs*, the *Otomies*, the *Tarascs*, the *Matlatzincs*, and others, the principal one of all these being that which formed, in the course of time, the most famous and powerful Empire of this Continent, and which, as you well know, succumbed finally to the Spanish Conquest. I refer to the Aztecs or true *Mexicans*.

The Toltecs lived within the limits of the territory situated on the northern part of the country, in a city founded, built and called by them *Tlapallam* or *Huehuetlapallam* of the *Tollan* kingdom. Their chief occupation had been the tilling of the land and the working of metals. They were especially advanced in agriculture.

The Toltecs, in this seclusion, lived many years of prosperity in Huehuetlapallam and other neighboring towns, but as the demands of their ever increasing population became greater and greater, they resolved to remove farther on towards the South.

After wandering hither and thither for several years, and having met with various experiences, they came across a better country where they resolved to settle, founding towards the year 552 the city of *Tlalpallanconco* or the *small* Tlapallam. Engaged in their favorite occupation, agriculture, that afforded them the principal means of support, the Toltecs continued to live in their new abode for a period of three years, at the end of which, under pressing circumstances, and especially through the advice of their wise and honored prophet *Huemac* or *Huematzin*, they again proceeded on their southern journey in their eager desire of finding the promised land.*

According to *Huematzin* (the word signifying "big hands," and also figuratively "intelligent, wise and powerful"), their chief adviser, the existence near by of a fierce and warlike tribe, the Chichimecs, was a hindrance to their peace and prosperity. Besides, the future greatness of the Toltec family was to be found in a land situated farther on, where they could reign supreme and give rise to a happy and prosperous nation.

Thus stimulated by the hopeful and eloquent words of the great *Huematzin*, the intelligent Indians, during the year 555, again abandoned

* It may be of interest to learn that the Toltecs, at the beginning of their long pilgrimage, made vows of chastity, vows which were to hold good for a period of twenty-three years. The object of such step can be clearly understood, and it is said that they faithfully kept their pledged word.

their last homestead, and, after a twelve-day journey, they arrived at a place named *Hueyralan*, or better still *Hueixallan* (near the sandy place), where a stay of four years was decided upon.

In the course of time, and a little farther on, they established themselves in the beautiful plains of *Xalisco*. There, under an excellent climate, and highly pleased with the exhuberant fertility of the surrounding country, they lived and prospered for a period of eight years. A city was built, and as a result of their incessant labors, the land was yearly covered with numerous and abundant crops consisting especially of corn or maize, cotton, beans, and pepper.

Again continuing their pilgrimage, the Toltecs arrived, in 567, at a place called *Chilmalhuacan* where they settled for a period of five years.

From Chilmalhuacan (the word signifying "a place where reside the owners of the '*chimalli*'" or shields) the Toltecs proceeded, in 572, to *Tochpan* or *Tuxpan*; thence respectively to *Quiahuiztlan* or *Quiyahuiztlan*, and *Zacatlan*. Other places were successively visited and occupied for short periods of time, such as *Totzapan*, *Tepetla*, *Mazapec*, *Xiuhcoac*, and *Iztachuexolla*.

In 645 they arrived at *Tollantzinco*. The Toltecs were still under the guidance of the great Huehuematzin and seven other Indian chiefs: *Zacatl*, *Chalcatzin*, *Tzihuacuatl*, *Metzotzin*, *Checatzin*, *Tlapalmetzotzin*, and *Cxhuatzon*.

Tollantzinco was a beautiful and fertile country, situated about fifty miles north of the future capital of the Mexican Empire, that is, the present City of Mexico. The country offered the best advantages, and the Toltecs, ever eager to improve their condition, resolved to make of the new place their home. They did so for a period of sixteen years, during which peace, happiness, and prosperity crowned all their efforts.

But the venerable Huehuematzin, who never abandoned the tribe that was to become the originator of a great civilization, with his continued counsel once more induced the wandering Indians to remove to another and better place, and finally in 661 the Toltecs arrived at Tollan or Tula, which was decided upon to be the termination of their long pilgrimage.

Although the exact point from which the Toltecs originally started in their wanderings is shrouded in speculation if not mystery, there is no doubt that the itinerary followed by them in their southern journey, as referred to by the Indian historian, IXTLILXOCHITL, is exact in some respects, if *not* in all. While the situation of Tlapallam or Huehuetlapallam, on the north, is doubtful, there remain Xalisco in the modern State of Xalisco, or Jalisco, as it is called at present, in Mexico. There is Tochpan or Tuxpan now in the State of Michoacan, and again in the State of Vera Cruz, where is also known to have existed Quiahuiztlan. In the State of Puebla there is the town of Zacatlan, while Huexutla, Tollantzinco, and Tollan or Tula can at present be examined in the State of Hidalgo.

The starting point of the Toltecs in their pilgrimage is summarily treated by EUSTAQUIO BUELNA* in a recent study. This writer traces such a point as far north as the territories traversed by the Colorado and Gila rivers, an opinion entertained by other ancient and modern writers. He believes that the tribes in their wanderings must have passed by the *Tulare* lake found between the modern cities of San Francisco and Los Angeles, in Upper California. Singularly enough the same name *Tulare* is still retained by a small town, in the county which also bears the same appellation, in that State. Nay, could not these wonderful people have come from farther north? I find that in the State of Nevada, in Elko county, on the northeastern portion, there is a little town called *Tulasco*. Be this as it may, again, in New Mexico, we come across with another place that bears the name of *Tularosa*.

All these terms have in common the prefix *tula*, which is neither of English nor Spanish origin. *Tula* is a *nahoac* or Toltec term, and comes from *tollin*, or *tule*, a name applied to a marshy plant, presumably abundant in the neighborhood of the first Tollan or Tula. The plant here referred to is not found about the Mexican Tula, and it is but fair to infer that the modern city derived its name from the ancient town.

Traveling South, then, the Toltecs must have arrived at the confluence or thereabouts of the two rivers mentioned, the Colorado and the Gila. Now, the word Gila is undoubtedly derived from *Xilla*, itself composed of *xilotl*, which drops the particle *otl* and takes that of *tla* or *la*, meaning "a country abundant in green corn." Once more, it may be inferred that somewhere in this vicinity the first Huehuetlapallam or Tlapallam must have been built, from the fact that this last term, *tlapallam*, signifies in the Toltec language "a place near the *red soil*."

The character of the ruins of ancient towns, discovered later in the regions just alluded to, points strongly to the probability of said towns having been the work of cultured races, and *not* of the numerous North American Indian tribes which have never shown any tendency to progress or civilization.

In the course of years, of centuries perhaps, the Toltecs in their passage from Gila to Anahuac must have followed a route by way of Sonora and Sinaloa, along the coast, until they reached the high tablelands of Mexico, founding the city of Tula first and of Texcoco afterwards.

Tula or Tollan, situated about forty miles north of the actual Capital of the Republic, and almost perfect as regards the excellency of the climate and the fertility of the soil, was looked upon by the Toltec family as their promised land. Indeed, Tula was the realization of their

* *Peregrinacion de los Aztecas*, Mexico, 1887.

happiest dreams. It seemed as if their desires, their hopes, and their ambitions were to be fulfilled; as if the gods, moved by the trials and tribulations of their children, tribulations and trials patiently endured for a period of over one hundred years of a wandering life, and as a reward for their perseverance, the gods, in lieu of all this, had at last answered their summons, opening to them a new but permanent field upon which to lavish their greatest energies for their own and for the good of future generations! The die was cast, and the Toltecs, elated at their promising prospects, resolved to settle definitely in the newly found land.

But the Toltecs were not, as some historians suppose, the sole founders of the new city and the other towns that afterward submitted to their rule. Other tribes were in possession of the land on the arrival of the new comers. The new capital, Tula, in fact had been the home of the Otomies, and was called by these *Mamemhi*. It may be said, therefore, that Tula is the most ancient city spoken of in the annals of beautiful Anahuac, and the Toltecs the first *historical* race of Mexico.

Once definitely established, the Toltecs converted Tula into the metropolis of the nation and the abode of future able rulers. The shrewd and intelligent Indians, after proper deliberations, and bearing in mind the absolute necessity of creating a common power to regulate and conduct their affairs on the one hand, and, on the other, to promote the welfare of the nation, which may be looked upon as the natural tendencies of a progressive and enlightened people, assumed a monarchial form of government.

The newly formed monarchy began to exercise its power in the year 667. The Toltecs elected *Chalchiutlotonac*, or *Chalchiuhtlanetzin*, as their first king. Under this monarch, naturally of a humane and just, and, at the same time of an energetic and progressive character, all the resources of the country were largely developed. The arts, agriculture, and science, all in their turn received from the monarch a decided and vigorous protection. It was during the reign of this ruler that a congress of the wisest men of the land, under the presidency of the most distinguished astronomer of those times, Huematzin, convened, and it was then that the great *Teomaxtli* or Divine Book was produced. The Teomaxtli came to be considered afterwards as the Bible of the Toltecs.

After a prosperous reign of fifty-two years the first monarch of the Toltecs abdicated the throne, according to law, in favor of *Ixtlilcuechahuac*, and retired into private life.

Ixtlilcuechahuac ascended the throne in 719. The reign of this monarch was attended by no remarkable event. Neither was that of his son *Huetzin*, who succeeded him.

After Huetzin the throne was occupied by Totepeuh, the fourth king. This monarch was an enthusiastic protector of the arts, and it was during his distinguished reign that the most costly cotton fabrics and the most imposing works of Toltec architecture and ornamentation were produced. The cities were embellished with magnificent edifices, particularly that great mystic town *Teotihuacan*, which in the native Toltec tongue signifies *habitation of the gods*. It was in Teotihuacan where the great temples of *Tonatiuh Itzacual* (house of the sun) and *Meztli Itzacual* (house of the moon) were raised.

After *Naxacoc*, the next ruler, the government was entrusted to *Mitlzin*. The new king, rich in personal and social virtues, ascended the throne in 979 amidst the joyous manifestations of the people. Mitlzin, or Mitl, patriotic and possessed naturally of a spirit of progress, spared no pains in promoting the welfare of his country. He soon conquered the admiration and love of his fellowmen by stimulating with undying enthusiasm progress in all conditions of life and society. Thus, industry, the arts, agriculture and science, all and each received protection, but that kind of protection that can alone contribute to the greatness and happiness of nations. Mitlzin was certainly the greatest of the Toltec rulers. The monarch, imbued with religious ideas, and solicitous of the religion of his ancestors and of his people, promoted and carried into effect the erection of a new temple which, for its gorgeousness, grandeur and magnificence, should surpass the many other sanctuaries already in existence, especially at Teotihuacan. That temple was the great *Teocalli*, dedicated to the Frog, the goddess of water. It was also during his reign that a seminary was founded for the assemblage of the most eminent men in the arts, literature, science and philosophy.

His period being about to expire, the king prepared himself to receive his successor, but his most loyal caciques and the people in general, in recognition of the monarch's important services to the country at large, laid aside for the first time the prescription of the law, and the king was urged upon to continue at the head of the government. The acceptance of a second term was hailed with universal satisfaction. Mitlzin continued in power amidst the most enthusiastic manifestations of private and public rejoicings.

During seven years of his second term the monarch continued to give complete satisfaction in the management of the government, when death came to cut short a most worthy life, a life consecrated to the good of the country he loved so well and of the people by whom he was so beloved.

According to law women were exempt from occupying the throne as rulers of the nation. But the Toltecs, true to the memory of the defunct monarch, grateful for his distinguished services, and as an honor they desired to confer upon the faithful and intelligent wife that had so aided her husband in the discharge of his high duties, once more disregarded the established statutes in order to entrust the government into the hands of *Xiuhtlaltzin*. The lawful heir to the throne, *Tecpancaltzin*, not only consented to conform with the wishes of the people, but promised on his part the most submissive obedience as a dutiful son and a loyal subject. There being no dissension, the distinguished widow, in 1038, took charge of the government as the first Queen of the Toltecs. Her reign, which only lasted four years, owing to the premature death of the sovereign, was an era of peace and prosperity.

During the latter part of these periods of peaceful and progressive government, the imposing pyramid of *Cholula* was built. This *teocalli* (house of God) which was dedicated to *Quetzalcoatl*, the god of the air, was so far the greatest addition to the numerous works of art already in existence throughout the kingdom.

On the death of Queen Xiuhtlaltzin, occurring in 1042, her son Tecpancaltzin, the rightful heir, was elevated to the throne. The new monarch followed closely the great path of progress and public good marked out by his worthy predecessors, and soon gave proofs of his ability as a ruler. But it was only during the first period of his eventful reign that the nation continued on its onward march of prosperity. Subsequent events, in which the failings, the weakness of the king, manifested themselves to a degree shocking alike to private and public morals, marked the beginning of the decline, final fall, and destruction of a great monarchy.

During the reign of Tecpancaltzin the beautiful legend of the discovery of *Pulque*, the Mexican national beverage, appears to have been invented. *Papantzin*, kindred to the king, had been able to extract from the *maguey* (*metl*) or century plant (*Agave americana*), a certain liquid said to have been identical with the one known at present as pulque. Papantzin communicated to his daughter *Xochitl* (flower) the secret, and both resolved to make the discovery known to the king. They did so, but Tecpancaltzin, more than with the new liquor, was taken with the surpassing beauty of the dark-eyed Xochitl. He became desperately and passionately enamored of the Indian maiden. Forgetting his high social position, his wife, his own dignity, and laying aside all scruples and moral principles, the monarch managed to abduct the innocent girl, and placed her in private apartments of the palace. Xochitl, in the course of time, intoxicated also with a strong love for the king, at last yielded to his entreaties, allowing herself to become the victim of a fiery and disastrous passion. As a result of these illicit relations there was born unto them a child. To it the name of *Meconetzin* was given, the word meaning "*son of the metl*," or maguey plant.

The queen consort soon afterward died of grief, overcome by the infidelity of her royal husband. As there was no legitimate heir to the throne, Meconetzin, under the name of *Topiltzin*, became in 1094 the ninth and last ruler of the Toltec nation.

The assumption of the governmental power by Topiltzin was looked upon with disfavor, and this sad condition of affairs continued until all respect for the new king was entirely lost among the people. Add to this, the conduct observed by the monarch himself, whose laxity of morals was upheld and even honored by a few of his caciques and court sycophants.

The curly hair, presenting the form of a tiara, which had been noticed on the head of the infant Meconetzin at birth, was turning out to be, as it had been expected, of an evil omen.

In the course of time immorality and corruption invaded all conditions of life and all grades of society. While the king and many of his caciques and court flatterers were leading a life of shame and vice, totally regardless of government and the good of the people, these were preparing a just vengeance, alone to be found in rebellion and war.

Internal dissensions gave rise to invasions by neighboring tribes; to confusion, anarchy, and a series of terrible encounters, all this lasting for a period of three years. In one of the most bloody battles the monarch's old father Tecpancaltzin and his mother Xochitl lost their lives, and Meconetzin himself escaped through flight. The fate of the last of the Toltec kings was never known.

According to ALFREDO CHAVERO,* the high priest Huemac, leaving Tollan with his followers, wended his way towards *Xaltocan*. The march was a direct one from North to South, traversing *Coatliyapan*, *Mepocatlapan*, *Tepetlayacac*, and *Huehuecuauhtitlan*. From here the emigrants followed a course from East to West, over the northern part of the Valley of Mexico, and passed through *Nepopoalco*, *Temacpalco*, *Acatitlan*, *Tenamitliyacac*, *Atzcapotzalco*, and *Tetlilincan*, where *Cihuatlatonac* was then reigning, and in his care they left the two infirm old men, *Xochiolotzin* and *Coyotzin-Teotlicuacomalli;* then, taking a southern course and turning towards the east, after going through *Chapultepec*, they arrived at *Culhuacan*, and there the wanderers, having abandoned the theocratic form of government, elected *Nauhyotl* as their ruler. But in the year *chicome tochtli*, 1122, Huemac, seeing himself abandoned by all his people, the Toltecs, hung himself in *Chapultepec* at a place known as *Cincalco*.

Desolation and total devastation of the country was the final result of such disturbances and changes. A most terrible famine soon followed, which gave rise to an enormous loss of life. The populous nation was soon converted into a desolate cemetery.

Thus perished a great people; thus disappeared from the face of the

***Mexico a Traves de los Siglos*, Tom. I, p. 384.

earth, after a prosperous reign of a little over four hundred years, the great Toltec nation, one of the most powerful and civilized monarchies that once inhabited the imposing regions of Anahuac.

A great people passed forever, it is true, but their civilization was the foundation of that of the other nations that followed and that were, with the Toltecs themselves, destined to excite the wonder and admiration of future generations all over the world.

The preceding paragraphs relating to the pilgrimage of the Toltecs are based chiefly on the writings of IXTLILXOCHITL.* The first history, however, that treats of the wanderings of the Toltecs and of the genealogy of the Toltec kings is that of TORQUEMADA.† Later writers, such as CLAVIGERO, VETANCOURT, and VEYTIA follow closely the works of IXTLILXOCHITL and TORQUEMADA.

CHAVERO‡ in his recent excellent work, after examining very carefully all previous researches, takes issue with most of these, especially those of IXTLILXOCHITL. CHAVERO says that, according to VEYTIA who followed the chronology presented by IXTLILXOCHITL, the Toltecs, after founding their city, established a monarchical form of government, electing *Chalchiuhtlanetzin* their first king, through the advice of Huemac. Chalchiuhtlanetzin was the son of *Icuauhtzin*, emperor of the *Chichimecs*. According to Toltec law, the reign of a monarch was limited to fifty-two years. Chalchiuhtlanetzin occupied the throne from 719 to 771, at the end of which term he died, and was succeeded by *Ixtlecuechahuac*. Then followed the son of this latter, *Huetzin*, who reigned until 875. Huetzin was succeeded by *Totepeuh*, who also ruled fifty-two years, that is, till the year 927. The fifth king was *Nacaxoc*, who reigned up to 979. Nacaxoc was followed by *Mitl*, who so distinguished himself in the management of public affairs that he was allowed to rule until his death, having reigned till the year 1035. His wife, *Xiuhtlatzin*, was then made queen, but this sovereign was only four years in power, when she died, and the government was placed in the hands of her son *Tecpancaltzin*. After the fifty-two years' rule Tecpancaltzin was succeeded, in 1091, by his natural son *Topiltzin*, the last of the Toltec kings, the monarchy having come to an end in the year 1116.

CHAVERO finds contradiction in these historical relations. Thus he says that TORQUEMADA took the names of Tecpancaltzin and Topiltzin, for *one* king only. The name of *Quechaocatlahinotzin* is given by that writer also to Chalchiuhtlanetzin; and Ixtlilcuechahuac receives not less than five other different appellations, that is, *Izacatecatl*, *Tlaltocatl*, *Tlilquechahuac*, *Tlachinotzin*, and *Tlilquechaocatlahinotzin*. Mitl is known

**Relaciones historicas de la Nacion Tolteca;* also *Historia Chichimeca.*

†*Monarquia Indiana.*

‡*Loco Citat.*, p. 358.

likewise under the name of *Tlacomihua*. Queen Xiuhtlatzin is sometimes also called *Xiuhquentzin*, and at others *Xiuhcaltzin*; and, in fact, TORQUEMADA took her for a king. The name of *Iztaccaltzin* is often given to Tecpancaltzin, and, finally, *Meconetzin* is the allegorical term applied to Topiltzin.

CHAVERO, therefore, considers as false the chronology of IXTLILXOCHITL, and places more reliance in the historical data furnished by the *Anales de Cuauhtitlan* (Annals of Cuauhtitlan). According to him these annals are authentic and of the highest importance. The original document was written in the Mexican language, between the years 1563 and 1569, according to AUBIN, or in 1570 according to RAMIREZ, the Mexican historian. These Annals were translated into Spanish by FAUSTINO GALICIA CHIMALPOPOCA, and are at present known as the *Codex Chimalpopoca*.

According to this history, the occupation of Tollan by the Toltecs took place in the year 674. Their first king was *Mixcoamazatzin*, who reigned from 700 to 765. The monarchs that followed were *Huetzin* and *Totepeuh*, the government of the latter lasting up to 887. The fourth king, *Ilhuitimaitl*, occupied the throne till the year 925; and the fifth monarch, *Topiltzin Quetzalcoatl*, till 947. After this came the succession of the following kings: Sixth, *Matlacxochitl*, up to 982; seventh, *Nauhyotzin*, to 997; eighth, *Matlacoatzin*, up to 1025; ninth, *Tlicoatzin*, to 1046; tenth, *Huemac*, to 1048; and eleventh, the second *Quetzalcoatl*, and last of the Toltec rulers, up to 1116, in which year the city of Tula was destroyed and an end put to the Toltec dynasty.

The principal differences between the data furnished by the Annals of Cuauhtitlan and those given by IXTLILXOCHITL consist in that in the the latter the governmental periods were chiefly conventional, that is, each one placed at fifty-two years; in the former instance they are spoken of as occurring in a natural order. Again, IXTLILXOCHITL refers to nine kings only; the Annals give the names of eleven distinct monarchs. The names of the rulers, common to both sources of information, are only four: Huetzin, Totepeuh, Topiltzin, and Xochitl. The latter, however, with a different attributive radicle in the Annals (Matlacxochitl?) is here spoken of as king.

Of the civilization of the Toltecs much can be said, but I will only mention for the present some of the most important points.

Society.—Three classes of society predominated among the Toltecs: The *Nobility*, the *Priesthood*, and the *Populace*; this latter included the artisans and hard-working people.

The priests represented the intellectual portion of society. They comprised the privileged class. They were the lawyers, the physicians, the scientists, the educational mentors, and, above all, the only holders of the sacred offices, the interpreters of the divine word; the only ones, indeed, to intervene in and direct the practice of their peculiar religious rites. As among the nobility, there were among the priests certain distinctions of rank.

The priests passed most of their time within the temples, engaged in prayer. They usually went barefooted, with eyes cast down, showing in every way a condition of the greatest humility. They never married, but lived in absolute chastity. They usually wore white or black tunics, long enough to reach the ground; their heads were covered with white caps, and their hair, arranged in rolls artistically twisted, hung gracefully over their backs. The priests were wont to fast and do penance for a certain number of days at the beginning of the month and year. They spoke but little, and when not in religious meditation or in the discharge of sacred duties, they engaged themselves in the education of the youth, who were generally taught according to their social ranks.

Marriage bore, it may be said, a Christian character, and polygamy was severely punished.

Government.—As may have been observed, the form of the Toltec government was a hereditary and absolute monarchy. Each monarch, according to law, could only reign for a period of fifty-two years, which number comprised the Toltec century. If the sovereign survived the period allotted by law, he was obliged to deliver the government, at the expiration of his term, to his successor. If he died within the period, a member of the nobility was appointed to exercise provisional power for the rest of the term, when the rightful heir would assume the control of the government. The existence of this law of fifty-two years is denied by CHAVERO, based on the Annals of Cuauhtitlan.

Although the scepter was always wielded by the royal family, the priesthood exercised a powerful influence in the management of public affairs.

The king wore the most gorgeous costume. This consisted of a plain white or gray mantle, over which was placed the tunic, *xicalli*, bearing the most brilliant colors and adorned artistically with golden trimmings and precious stones. The collars, similarly arranged, completed the whole attire which, hanging gracefully to a little below the knee, is said to have been simply superb. The shoes, species of sandals, made of some woven cotton stuff, had soles of metal, this being generally pure gold.

The royal palaces were grand in every respect, and so spacious as to contain gardens for the cultivation of the numerous rare plants, and the keeping of the different kinds of animals. The Toltecs were great naturalists, and I may here state that many of the medicinal plants, properly classified and used by them in the treatment of diseases, have come down to us and are yet employed as valuable drugs.

The monarch slept but little, and usually rose at an early hour. Meals were served to him twice a day only, at midday and at night. He spoke but little also, following the example of the priests, and did not allow himself to be seen except on great occasions, and especially when these bore a national character. Dead, he was buried with all royal magnificence in the corresponding *teocalli* or temple.

The king was the representative of the Supreme Being. Here we have, singularly enough, put into practice the principle of divine rights, a principle in existence among the most ancient theocracies the world over. According to the Toltecs, the kings were immortal, and when these died, they were transformed into gods or changed into the heavenly planets.

Agriculture.—Although the tilling of the land may have been practiced by previous races, the Toltecs seemed to have attained a high degree of perfection in agricultural procedures. They introduced the cultivation of maize and cotton especially, but they also raised many other useful plants, such as the different kinds of pepper, beans, tomatoes, and other vegetables. Certainly, agriculture constituted among the Toltecs one of the principal sources of the nation's wealth.

Arts and Manufactures.—In the practical arts and manufactures the Toltecs were quite proficient, especially in the preparation, through spinning and weaving, of cotton textures, in the dyeing of which they employed the most brilliant colors. The fabrics varied in kind, from the coarse linen to the finest cloths resembling damask, velvet, and even satin.

The different artisans, such as carpenters, blacksmiths, architects, and so forth, excelled in their respective trades, particularly the mozaic and feather manufacturers, whose exquisitely delicate workmanship remains unrivaled to the present time.

The Toltecs were familiar with the working of the metals and the cutting of gems and precious stones, and were well acquainted with the qualities and virtues of those products. This extensive knowledge is exhibited in the stone, silver, and gold ornaments used in their dresses and in the interior of their houses, palaces, and temples.

The Toltecs were great lovers of the fine arts, and although of a primitive nature, their architectural designs, exhibited in the constructed roads, cities, and monuments, evince a high order of taste and a high degree of civilization.

In Teotihuacan, which may be considered as the Jerusalem, the holy city of the Toltecs, were built by order of King Totepeuh the great temples of *Tonatiuh Itzacual* and *Meztli Itzacual*, already referred to, whose colossal proportions gave them the character of two sentinels placed there to guard the security of the kingdom. The edifice consecrated to the Sun measured at its base about 250 yards in length and nearly 200 yards in width, having a height corresponding to these measurements. It contained a huge model-idol made of a very hard stone, and literally covered with gold. It represented the deified king of day. In a concavity, upon the breast, was placed an image representing the Sun and was made of the purest gold.

The temple dedicated to the Moon exhibited measurements a trifle smaller than those of its companion. It likewise contained a colossal statue, covered with gold, to represent the mythological queen of night.

Each building was composed of four great compartments, with as many stairways, made of polished stones, and within them were scattered here and there numerous statuettes, covered also with gold plates, representing various other minor deities. Around these temples small pyramids of about ten metres in height were constructed to represent the stars, according to their knowledge and their traditions. These pyramids, however, appear to have been used as tombs for the dead members of the nobility.

Religion.—The primitive religion of the Toltecs consisted in the adoration of the sun, the moon, and the stars. The fecundating force of the sun was personified by *Tonacatecuhtli.* To this god they made yearly offerings of flowers, fruits, and sometimes animals. It appears that they also entertained a religious veneration for fire. This primitive religion, born of their observations of the heavenly bodies, induced them to admit the existence of twelve heavens. Upon the highest of these heavens resided *Ometecuhtli* and *Omecihuatl*, man and wife, the rulers of the twelve heavens and of the earth. The Toltecs held, in their superstitious philosophy, that all things were subject to the great Ometecuhtli. This deism mixed with astrology was, however (due no doubt to the influence exercised by the conquered and other neighboring tribes), gradually transformed into a polytheism as we see it in the religions of later nations. The principal divinities of the Toltecs were these: *Tonacatecuhtli*, the Sun; *Tezcatlipoca*, the Moon; *Quetzalcoatl*, the Evening Star; *Tlaloc*, the God of Rain; *Chalchiuhtlicue*, the Goddess of Water; *Xiutecuhtlitletl*, the God of Fire; *Centeotl*, the Earth, and *Xochiquetzalli*, the Goddess of Love.

With regard to their religious rites, these were at first peaceful, and simply consisted in the assemblage of the people within the temples and at certain periods of time to do homage, under the direction of the priests, to the different deities. Afterwards, however, the Toltecs assumed the custom every year to sacrifice very young girls in honor of the god Tlaloc, or *Tlalocatecuhtli.* Their little hearts were taken out, offered to the god represented by a huge model, and their little bodies properly buried afterwards. Again, at certain periods of the year, they would select the most notorious criminal, place him between two big stones, and thus crush him to death. This sacrifice, called *Tetlimonamiquian* (the crushing of the stones), was also performed in honor of the same god. Here we have, it may properly be said, the foundation of the human sacrifices so extensively practised by later tribes, especially by the Aztecs, or true Mexicans.

Science.—The Toltecs had a profound knowledge of astronomy and of hieroglyphics. They are said to be the people to have *first* arranged or measured time according to astronomical knowledge, that is, according to the movements of the planets. Their magnificent calendar is a monument of their science. They knew and classified the principal stars of the firmament, named them, studied their relations, and were almost thoroughly acquainted with their movements. But, like most of the ancient peoples, the Toltecs applied their astronomical knowledge to the formation, largely, of astrology to suit their religious and traditional ideas.

The Toltecs were the first to introduce into Anahuac hieroglyphical writing, whether they invented this themselves, or whether they acquired it from pre-existing races. Their language was the *Nahoa* or *Nahuatl*, which afterwards came to be known as the Mexican.

As a whole, the Toltecs were of a good moral character, little addicted to war, and great admirers of virtue; they detested lying and deceit. They were singers, musicians, and great dancers. In their private as well as their public festivities, wooden instruments and drums were abundantly used. They were devout, good orators, and great conversationalists; polite, courteous, and of attractive manners.

In their hieroglyphical writings they inscribed religiously their history, their customs, and manners; in fact, their whole system of civilization, a civilization of which I have endeavored to give a general idea.

In one word, agriculture, the arts, science, and all that evidence which afterwards served to throw distinction and lustre upon the subsequent inhabitants of the beautiful valley of Mexico, were due chiefly to the influence of the Toltecs. They were so noted in the different arts and in science that the name of Toltec, given to the distinguished of later nations, was held as a great honor. Their paintings and hieroglyphics are remarkable for the general knowledge they contain. Whosoever studies the history of these ancient people will find that they were a progressive and enlightened race, the founders of the subsequent civilizations of Anahuac. They were the first people to raise in that magnificent garden of this continent, Mexico, imposing monuments to be compared only to those of Egypt and India. The great ruins of Cholula and Teotihuacan especially are immortal proofs of the existence of the first civilized nation of America.

It has been maintained by some, let me repeat, that the Mayas and the Maya-Quiches, the races peculiar to Yucatan and Chiapas, perhaps the most ancient of the American peoples, proceeded either directly or indirectly from Egypt and other Eastern nations; that the Mayas and the Maya-Quiches gave origin to the Toltecs, and that thus the series of other tribes came gradually into existence. But be this as it may, certain it is that the Mayas and the Maya-Quiches differed in many essential characteristics from the rest of the Anahuac nations. Other tribes may have existed during and even prior to the time of the Toltecs, but none have left the brilliant records of this great people.

Undoubtedly the Toltecs were the first race to disseminate over the virgin regions of the American continent the true germs of civilization. If nothing else, it was the first historical race, the representative of the most primitive nations of Mexico, the same race, in point of fact, that was met by the Spaniards under the great Aztec monarchy. But the Toltec, all in all, and embracing as it does the sum of all the knowledge found in the most ancient human history of the American continent—the Toltec, may be regarded as the *golden era* of ancient Mexican civilzation.

ON RAINMAKING.

By Alexander Macfarlane, D.Sc., LL.D., Professor of Physics in The University of Texas.

Read December 31, 1892.

In this paper I propose first to state briefly what is known about the formation of rain, and then to discuss in the light of that knowledge the different methods of rainmaking which have recently been tried or proposed. While the text books and memoirs of physical science contain a great amount of sound knowledge on the subject, we nevertheless see and hear of professional rainmakers who are no better than the medicine man of the Indians, and we also witness government appropriations expended in operations very suitable to the fourth of July, but useless as means of extending our knowledge of the formation of rain in the atmosphere.

If a dish filled with water be placed inside a glass receiver, vapor will rise from the water until there is a certain amount of vapor in each cubic inch of the air; the evaporation then stops. The amount of vapor per cubic inch which is sufficient to saturate depends on the temperature of the enclosure; the higher the temperature, the greater is the amount of vapor required; not only so, the amount required increases more rapidly than the temperature. But the amount required to saturate is independent of the density of the enclosed air; when the air is rare, saturation takes place quicker, but there is finally just the same amount of vapor in each cubic inch. This is true even when the enclosure is free of air. For every temperature of the air there is a certain maximum amount of aqueous vapor which it can hold per cubic inch; and conversely, for a given amount of aqueous vapor per cubic inch there is a certain temperature at which the air can just hold it. If the temperature is further lowered, some of the vapor condenses, and the condensed vapor may appear as fog, cloud, mist, or rain.

In what ways may a portion of the air of the atmosphere be cooled? It may come into contact with another portion at a lower temperature, and lose heat by convection and conduction; or it may radiate some of its heat into space or to colder bodies; or it may use up some of its heat in expanding to a larger volume. The last, called dynamic cooling, may be observed in the working of an ordinary air pump. At the beginning the glass receiver is full of air having the temperature and moisture of the air of the room. After a few strokes made in rapid succession a cloud forms inside, and drops of water trickle down the inside surface of the glass. The air left after a stroke expands to fill up the whole enclosed space, and in doing so it draws upon its internal heat. The loss may be so great as to chill the enclosed air below the temperature at which the moisture saturates; if so, a cloud of particles of water appears.

The conditions which determine whether the condensed vapor will take the form of fog, cloud, mist, or rain, were investigated first of all by Mr. John Aitken, of Scotland, in a brilliant series of experiments which commenced in 1880.*

What is meant by *fog*, *cloud*, *mist*, *rain?* The particles composing a fog are so fine that they scarcely fall through the air, a cloud is a little coarser in the grain, while a mist is still coarser in texture, and rain is any one of these while falling, whether it be a wetting mist or a drenching rain. Mr. Aitken showed that the dust particles in the air act as nuclei upon which the vapor may condense; if these are present in air cooled below the temperature corresponding to the moisture, condensation takes place immediately. If the dust particles per cubic inch are very numerous, there are many centers of condensation and little water for each; hence fog. If the number is smaller, the nuclei being fewer get a larger share of water; hence clouds. If they are fewer still, mist ensues; and if they are very few, so much water condenses on each nucleus that a heavy drop is formed; hence rain. If the air inside the receiver has been thoroughly freed from dust, and then cooled by expansion below the dew point, a sudden shake in the operations will cause rain to form, the mechanical disturbance taking the place of the dust nucleus. If there were no dust in the atmosphere, the rain would fall from a nearly cloudless sky, a phenomenon which has been observed at some places on the globe.

The dust which is effective as a nucleus for the vapor in the atmosphere does not consist of the coarse motes which may be seen in the path of a sunbeam; it is microscopic, becoming visible only when its size is greatly increased by the load of water. Mr. Aitken said in his first paper:

"In all probability the spray from the ocean, after it is dried and nothing but a fine saltdust left, is perhaps one of the most important sources of cloud-producing dust. It is well known that this form of dust is ever present in our atmosphere, and is constantly settling on every object, as evidenced by the yellow sodium flame seen when bodies are heated."

He further said: "The composition of the dust will also be of great importance in determining its power as a cloud producer, as it is evident some kinds of dust will have a greater attraction for water vapor than others. Fine sodic chloride dust, for instance, we should expect would condense vapor before it was cooled to the saturated point, on account of the great attraction that salt has for water."

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* Transactions of the Royal Society of Edinburgh, Vol. XXX.

"Some kinds of dust (page 365) have such an affinity for water that they determine the condensation of vapor in unsaturated air, while other kinds of dust only form nuclei when the air is supersaturated; that is, they only form free surfaces on which the vapor may condense and prevent supersaturation."

In 1888 Mr. Aitken invented and developed a method of counting the number of dust particles in any sample of air. These particles are invisible to the highest powers of the microscope; they become visible when loaded with vapor from the supersaturated air in which they were floating. In order to make the number small enough to count, the sample of air to be tested was diluted with pure air 200 times before being drawn into the receiver of an airpump; a plate of silver with a ruled surface had been placed horizontally at a convenient distance from the top of the receiver; the air was cooled by exhaustion, and the density of the vapor kept up by evaporation from water in a dish inside; and the number of drops that fell on the plate was counted. The following results were obtained:

Source of air.	Dust particles per cubic inch.
Outside, raining	521,000
Outside, fair	119,000
Room	30,318,000
Room, near ceiling	88,346,000
Bunsen flame	489,000,000

Subsequently the pure air at the top of Ben Nevis was found to contain 34,000 per cubic inch.

Suppose, then, that we attempt to produce rain, not in a small portion of the atmosphere cut off from the rest by means of an airtight receiver, but on a large scale in the unbounded atmosphere. If the air operated on is at a temperature higher than its temperature of saturation, it must be cooled down to that temperature. Further, when the moisture condenses it gives out latent heat, which tends to arrest the process; this latent heat evolved must be removed. It is not, as some rainmakers have imagined, "Pull a trigger; Nature will do the rest." The only trigger pulling which experiments warrant as possible consists in supplying the necessary fine dust for nuclei, so that condensation may take place without delay when the air is cooled to its temperature of saturation; or in supplying fine dust from such a substance as common salt, which has a chemical affinity for water, and may be able to accelerate slightly the falling of a shower.

Suppose we take a cubic mile of the air upon which Dyrenforth operated on the night of Friday, November 25, 1892. The record at the weather office in San Antonio at 8 p. m. gave the temperature of the air as 72° Fahrenheit, and the dew point as 61° Fahrenheit. To cool down a cubic mile of that air to the dew point would require the abstraction of as much heat as would raise 88,000 tons of water from the freezing point to the boiling point. To cool it down another 11 degrees would require as much more heat to be abstracted. The amount of water set free would be 20,000 tons, which spread over a square mile would give about 1.4 pounds per square foot, or 27-100 of an inch of rainfall. The amount of latent heat set free by the condensation of that amount of water would raise 100,000 tons of water from the freezing point to the boiling point; and it would be necessary to absorb this heat in order that the rainmaking might go on. I have supposed the cubic mile of air to be kept constant; if the air operated on is constantly changing, the task becomes one of infinitely greater difficulty.

Let us consider now how the different rainmakers propose to accomplish this remarkable feat.

1. *Melbourne.*—In Kansas there is a Professor Melbourne, who has taken contracts to make rain. For the slight sum of $500 he contracted to cause a rainfall of half an inch over a circle of country 100 miles in diameter. He is called the Australian rain maker. I recollect that some twelve years ago there was an account in the newspapers of attempts at rainmaking in Australia. The country was suffering from prolonged drouth, and I believe that the firing of cannon was actually tried. Probably it was then that Melbourne discovered his method, or borrowed it from the Bushmen. He came to Temple, Texas, hired a shanty on the outskirts of the town, shut himself and an assistant in, and all observers out. All that could be observed from the outside was the issue of some colored gas through a small pipe in the roof of the shanty. The proceedings of this impostor were gravely discussed by intelligent people; so great is the ignorance of physical nature.

2. *Espy.*—Mr. Dyrenforth in his article in the North American Review, October, 1891, refers to a plan proposed by Professor Espy, which was considered by the government of New South Wales:

"In 1837, Professor Espy, at that time a well known scientist, proposed a method of compelling nature to loose the moisture which she holds suspended aloft. His plan was to kindle great fires which would produce a powerful upward current of hot air, and this rising to a great height where, owing to diminished pressure, it would expand, by the expansion would be cooled, thereby condensing and eventually precipitating its moisture. The Australian government proposed in 1884 to make a test of Espy's theory; but when Mr. H. C. Russell, the government astronomer of New South Wales, demonstrated that it would require 9,000,000 tons of coal burned daily to increase by 66 per cent the rainfall of Sydney, where the average humidity is 73, the project was forthwith abandoned."

Mr. Dyrenforth leaves out one essential point in the calculation. Over what area was the 9,000,000 tons of coal to be burned daily? Anyhow the result given by the calculation ought to have staggered him in the belief that he could accomplish a comparable result by means of a few insignificant explosions. It is evident that to heat the air produces, in the first place at least, the opposite effect to what is desired; and in any case the subsequent cooling by expansion must first abstract all the heat supplied from the coal before it can take out the further heat required to reduce the air to the temperature of condensation. If moist air could be made to ascend by a process which does not heat it, such process would be more effective and less expensive.

3. *Powers.*—In 1870, Mr. Edward Powers, of Delavan, Wisconsin, published a collection of statistics in a volume entitled, "War and the Weather." By means of these random statistics he establishes the remarkable truism, that battles are followed by rain; but he nowhere proves that battles are necessarily accompanied by rain, or that a day of battle is followed more quickly by rain than is a day of no battle. His investigation is a glaring example of the fallacy of *post hoc ergo propter hoc*, further vitiated with the fallacy of neglecting to consider rains which do not follow battles. Without having tested his hypothesis on a small scale, he petitioned Congress to make an appropriation to test it on a large scale. Two hundred seige guns which lie idle at the United States Arsenal at Rock Island, Illinois, were to be taken to a suitable locality in the West, and one hundred rounds to be fired from them in each of two operations, the estimated cost of the two operations being $161,000. This shows anyhow that Mr. Powers had some slight idea of the expensiveness of rain making. He does not explain how the sound and heat due to the firing of the cannon are to take the heat out of the air in order that the vapor may condense. He does not show how the condensation is to start, but he makes the gratuitous assumption that the latent heat developed by condensation will help on the process instead of retarding it.

Compare Aitken and Powers. The former devises crucial experiments and reasons from the results; the latter deals in so-called facts and cranky arguments. The one puts a distinct question to nature; the other deals in one-sided and random statistics. The one believes that truth may be found by experimenting on the air in his cellar at his own expense; the other lectures and lobbies to get the National Congress to test his crank theory on a large scale at a cost to the country of $160,000. In the one we have a philosopher; in the other a crank.

4. *Ruggles.*—In 1880, Daniel Ruggles, of Fredericksburg, Virginia, patented a process for producing rain. The invention, as described by Mr. Ruggles, consists of "a balloon carrying torpedoes and cartridges

charged with such explosives as nitro-glycerine, dynamite, gun cotton, gun powder, or fulminates, and connecting the balloon with an electrical apparatus for exploding the cartridges.''

Suppose that we have a mass of supersaturated air in the atmosphere, no nuclei being present on which the moisture can condense; Aitken's experiments lead us to believe that the mechanical shock due to an explosion inside or near the mass of air would cause the excess of moisture to condense. But suppose that a cloud has already formed; that fact means that condensation has already started, and that there is no want of nuclei. When the excess of moisture has already condensed, we have no reason for believing that a shock such as that intended by Mr. Ruggles would cause more moisture to condense; for the temperature of the air must first be reduced, and the direct effect of the explosion is to elevate, not lower the temperature.

5. *Dyrenforth.*—As the result of the agitation of Mr. Powers, Congress voted $2000 to make a preliminary test, and the inquiry fell to the scientists of the Department of Agriculture. They reported that there was no foundation for the opinion that days of battle were followed by rain, any more than days of no battle. It was then that Mr. Dyrenforth came forward with Ruggles' plans and offered to make some tests. An additional appropriation of $7000 was placed at his disposal for a series of practical tests, which were made at Midland, Texas, in August of 1891. A further government appropriation was expended in tests at San Antonio in November of this year.

So little does Dyrenforth understand the nature of the problem, that his plan of operations is as much as possible an imitation of a battle. The ground explosives were fired off in a line facing the advancing clouds; the chloride of potash supplies the place of the smoke from the gun powder; shells are projected into the air at frequent intervals; the general and his lieutenant even wore cavalry boots. Instead of using a balloon to carry up solid explosives and touching them off when aloft by an electric current, he used cheap balloons filled with hydrogen and oxygen in the proportion required for forming water, and the combination was started by a time fuse attached to the balloon itself. He changed from an explosive to an implosive agent, without apparently being aware of any difference. But there is an important difference. The heat of combination of the oxygen and hydrogen is increased by the falling in of the atmosphere into the empty space produced; while the heat of combination of a solid or liquid changed to a gas is diminished by the cooling of the gas in expanding.

The largest balloon used had a content of nearly 1000 cubic feet. The combination of the hydrogen and oxygen produced as much heat as would raise 1300 pounds of water from the freezing point to the boiling point; a very insignificant transformation of energy when compared with the heat required to be abstracted in order to cool one cubic mile of the air to the temperature of saturation (page 75). Not only so, it is a transformation of the opposite kind to what is required; for what is required is cooling, not heating. The effect of the falling in of the atmosphere was to develop an additional amount of heat, sufficient to raise fifteen pounds of water from the freezing to the boiling point.

What was accomplished with this government appropriation? The test of Friday was made while the atmosphere was threatening to rain; eight balloons, 150 shells, and 4000 pounds of rosellite were fired off; result, an explosion of a balloon inside a black rain cloud does not bring down a shower. The test of the following Wednesday was made with a clear sky; ten balloons, 175 shells, and 5000 pounds of rosellite were fired off; result, the sky remained clear. No more tests were made, but the rainmakers the night following, heedless of the probable deluge, fired off twelve balloons, 150 shells, and several thousand pounds of rosellite merely to get rid of them. There was no care taken to observe what might be looked for with some show of reason; the party expected a physical miracle, and they were disappointed.

6. *Chicago inventor.*—At the time of the San Antonio fiasco, another patented plan of making rain was published, and it was said that Senator Farwell, who has been the main supporter at Washington of rainmaking appropriations, was more satisfied with it than with the concussion plan. It consists in freeing liquified carbonic acid in the portion of air from which it is desired to extract rain. The carbonic acid in vaporizing and expanding must be supplied with heat, which it will extract from the surrounding air. Here we have the proper kind of agent; but there is the financial question to consider. The amount of heat abstracted by one pound of liquid carbonic acid in volatilizing, and taking the temperature of 72° Fahrenheit, would change 68 pounds of water by one degree Centigrade of temperature. To reduce the cubic mile of air we considered (page 74) to the temperature of saturation would require 129,000 tons of carbonic acid; to reduce it the other 11 degrees Fahrenheit would require an equal amount; and to absorb the latent heat would require an additional 150,000 tons. If we take the price of a pound of liquefied carbonic acid at one dollar, the cost, supposing no waste or change of the air, of a rainfall of 27-100 of an inch over a square mile would be more than $400,000.

7. *Pitkin.*—In March of this year I received from Mr. Pitkin, of Kansas City, a newspaper cutting in which he describes two mechanical methods of rain making. "The first plan is to use two large canvas tubes or conduits of unequal lengths, their lower ends to be connected over large rotary fans run by steam power; their upper ends attached to

balloons, which carry the conduits into the proper strata of air. By the action of the fans the cold air is drawn down one conduit and forced up and out of the top of the second conduit directly into the humid current of air, thus causing one upward and one downward current of air.''

This plan supposes that a tube such as described can be held in the air by balloons held captive by ropes, the one at a height of perhaps 2000 feet, the other at a height of 1000 feet. This is rather a difficult postulate to realize. But suppose that it is practicable, it is safe to say that the amount of rain precipitated even under favorable conditions would not suffice to run the steam engine.

''The second plan is to use a large sheet of canvas, properly strengthened by netting. The canvas is to be supported in midair (by balloons) at a right angle to the course of a humid current of air; the lower corners of the canvas are to be controlled by ropes, which reach the earth, by means of which the sheet can be drawn to act as an inclined plane. The currents striking against this inclined plane will be deflected from their paths and carried up. They will expand as they ascend, and will be brought directly into contact with the colder air above. This should cause rain, as in the case of mountain condensers. The humid air deflected by a sheet 200 by 400 feet would be over four billion cubic feet an hour, if the current striking it travelled ten miles an hour. This volume cooled should yield considerable moisture, in addition to which the cumulative effects of precipitation should yield much more.''

Mr. Pitkin has calculated the amount of air which would be deflected upward per hour by his vertical sail supported by balloons; but he has not calculated the pressure which this frail structure would have to stand. With the wind blowing at ten miles an hour and striking the sail perpendicularly, the pressure would be equal to the weight of one hundred thousand tons. The atmosphere can not be controlled so easily; it would simply flatten out the sail. A mountain ridge can withstand the pressure; but who can stand the expense of building a mountain ridge?

8. *John Jacob Astor.*—Mr. Astor has an invention for making rain which he thus describes: ''In the sketch I have shown an air tower erected upon an eminence, such as a cliff or a mountain, and I place in the valley a blower of large capacity, which communicates with the air tower by means of an air trunk of suitable size; and I drive the blower with any convenient power. In the present case I have represented an engine house which encloses the blower, and an engine for driving the same. In lieu of such an arrangement I may provide a tower of sufficient height to convey the air directly from the lower to the higher level, and I may arrange the blower and the driving mechanism in the base of the tower; or I may arrange the blower upon the eminence and extend

the suction pipe to the lower level, and connect the discharge pipe of the blower with the air tower. The capacity of the apparatus need not be greater than is required to produce the initial disturbance, or the nucleus of the storm, as when the precipitation of rain begins the storm will increase from natural causes. To augment the amount of moisture in the air trunk I divert the exhaust pipe of the blower engine into the trunk, thereby surcharging the air in the trunk with the exhaust steam of the engine.''

The proposed air tower would be comparable in height to the Eiffel tower, and therefore comparable in expense. Mr. Astor has got the cranky idea that he has only got to pull a trigger and nature will do the rest. It would certainly be advisable to deal economically with the exhaust steam of the engine, for it would probably contain more water than the arrangement could bring out of the atmosphere, notwithstanding the enormous expense of an Eiffel tower.

MATERNAL IMPRESSIONS AND TRANSMISSIONS OF MUTILATIONS.

By James E. Thompson, M. B., B. S., London University; F. R. C. S., England; Professor of Surgery in the University of Texas.

Read December 31, 1892.

In bringing forward this subject, I have been actuated, not so much by the desire of putting any new light on it as of presenting in a concise form the consensus of opinion on these various questions.

Maternal impressions have excited public notice from the very earliest times.

Hippocrates and Galen were firm believers that certain impressions received by the mother during pregnancy would be followed by certain abnormalities in the child.

Spartan women when pregnant were required by a law of Lycurgus to look upon the statues of Castor and Pollux, in order that their children might be beautiful. That this belief was widespread, we have abundant evidence.

Thus in Genesis, chapter 30, verses 37, 38, 39, we find the following:

"And Jacob took him rods of green poplar and of the hazel and chestnut tree, and pilled white streaks in them, and made the white appear which was in the rods.

"And he set the rods which he had pilled before the flocks in the gutters in the watering troughs when the flocks came to drink, that they should conceive when they came to drink.

"And the flocks conceived before the rods and brought forth cattle, ringstreaked, speckled, and spotted."

The literature of the middle ages teems with instances, and this stream of folklore pours down to the present day.

Sir Walter Scott, in the "Fortunes of Nigil," attributes the terror that James the First experienced at the sight of a sword to the fact that his mother, when present at the murder of Rizzio, was pregnant with the future king of England.

Oliver Wendell Holmes founded his story of "Elsie Venner" on a maternal impression.

Every practitioner of medicine can quote numerous stories of this nature; and midwives and mothers are still a more prolific source.

It is not my intention to quote in detail more than a few cases of this nature, but these, I hope, will serve as types to illustrate my meaning.

Many tales are so preposterous that they can be eliminated on a superficial examination: Thus, cases of harelip being attributed to the mother during her pregnancy being frightened by a hare running across her path; also cases of clubfoot being attributed to some real or imaginary sprain of the mother's ankle. Such cases, and they are by no means rare, deserve the utmost contempt.

On the contrary, other cases occur where the connection between cause and effect seems too close to be ascribed either to imagination or to a mere coincidence. Such cases are two that fell under my personal observation.

A lady, the wife of one of my medical friends, during her first pregnancy, was observed by her husband to be continually scratching her left wrist. This habit was watched by her husband with the closest interest, as his wife knew absolutely nothing about maternal impressions. A healthy child was born at full term, with a capillary nævus on the left wrist in a spot corresponding to that scratched by the mother.

During the next pregnancy the same habit was repeated, only this time she scratched her forehead. The second child was born at full term with a capillary nævus in this situation.

The other cases occurred also during a first pregnancy. A lady during the sixth month of pregnancy accidentally saw a baby whose forearm had suffered intra-uterine amputation. This sight seemed to have left a lasting impression, for she often referred to it, wondering if her own baby would be similarly afflicted. The baby was born at full term, and the right forearm, just above the wrist, had been amputated in utero.

These cases I can absolutely vouch for, and although I do not accept them as absolute proof of the maternal impression, still they can not be relegated to the domain of coincidence.

That many cases are the result of coincidence there is no manner of doubt. Such a one is quoted by Ballantyne, where a pregnant woman, being frightened by a dead frog which a friend threw at her, gave birth to an anencephalic monster, and even repeated the same feat at her next pregnancy.

One could of course quote multitudes of cases which bear on this subject, but without coming one whit nearer the main point at issue, which is, Do maternal impressions have any influence over the development of the fœtus? We must first prove this to our satisfaction before we can with advantage inquire into the *modus operandi* of such a process.

Absolute proof of the dependence of fœtal defects on maternal impressions are not forthcoming, unless we accept the enormous mass of quasi evidence which loads medical journals of to-day as well as those of earlier date.

However, the subject is of such importance from an æsthetic and hygienic point of view, that full attention ought to be paid to all such cases, to elucidate them and put them on a true scientific basis.

The age of the pregnancy should be carefully noted, as by this means some developmental peculiarities, which can only occur in the early months, will not then be ascribed to impressions received by the mother at a later date. Thus it would be manifestly absurd to ascribe a case of hypospadias to a maternal impression received in the eighth or ninth month of pregnancy.

Allowing for a moment that there exists a distinct connection between the impression and the fœtal deformity, how does it work?

It is excessively difficult to understand how a maternal nervous disturbance can affect the growth of a child in any particular direction. No nervous connection has been demonstrated between the fœtus and the mother; therefore the *modus operandi* must be searched for in an entirely different channel. It is well known that certain emotions and thoughts on the mother's part can so alter the uterine circulation that the fœtus is deprived of its necessary blood supply, with the result that abortion or premature labor may occur. But this deficiency affects the fœtal circulation in its entirety, and not in a partial manner.

How the blood supply to any particular fœtal organ, such as the head, arm, genital organs, can be so altered by certain maternal vaso-motor changes, is what at present baffles all our research and ingenuity. It seems to us that the fœtus must suffer in toto or not at all. Dareste's well known experiments on the artificial production of monsters throws some light on this subject. He found that conditions affecting the blood supply of the embryo are inevitably followed by developmental peculiarities. These conditions are: the application of heat in the neighborhood of the cicatricula, or the production of a temperature slightly above that of normal incubation. The errors of development varied of course in each individual experiment. These researches are exceedingly interesting, and point to a possible explanation in the circulatory apparatus; but we are confronted with the same difficulty, viz., to account for the similarity between the fœtal deformity and the maternal impression.

Hoist, in Keating's Encyclopædia of Diseases of Children, throws out the hint that the results may be due to the action of ptomaines and leucomaines on the fœtal organs, these products resulting from deficient oxygenation of maternal blood supplying the placenta. This theory has, however, very little to recommend it. How is it possible for a vaso-motor disturbance in the mother to establish a vaso-motor change in an exactly analagous region of the fœtus without the existence of some complex nervous apparatus? If this apparatus exist, it has certainly escaped the observation of all workers in this line.

I here repeat what I have before insisted upon, that a vaso-motor disturbance must affect the placental circulation in toto or not at all.

The mode of development of a particular ovum is determined from the moment of its fertilization by a spermatozoon. It then receives certain tendencies which will affect cell segmentation up to its latest stages. It has qualities imparted to it which will produce certain results, even to the shape of the nose, color of the eyes and hair; aye, even qualities which become manifest in functions, such as tricks of manner, speech, expression, gait, and a thousand other peculiarities.

On contemplation, it seems to me preposterous that an impression received by the mother after the ovum has received its stimulus to develop can in any way alter any of these tendencies, either functional or structural, so as to give a distinct connection between the impression received by the mother and the defect resulting in the offspring.

As, on the other hand, I would like to put before you an unbiased view of the subject, I will give an epitome of Dabney's views on the subject.

The cases collected *seem* to show that neither mental nor bodily defects are often caused by maternal impressions.

That the defects may be due to errors of development, or marks, such as nævi, moles, etc., which may be caused by circulatory or inflammatory disturbances.

That the defects due to errors of development have been as a rule attributed to impressions received at a period of pregnancy when such errors are likely to occur.

That other effects, such as marks, nævi, etc., have occurred at a later date, when inflammatory affections are more liable to occur.

That, in a large number of cases, there is a striking similarity between the impression received and the resulting fœtal defect.

That it is not necessary for a woman to be conscious of the impression or to expect a defect for such defect to occur, although in many cases the defect has been anxiously awaited.

That the impressions are usually of an emotional character, and often unpleasant.

That an impression of considerable violence may produce an effect in a few hours, although as a rule a much longer time is required.

In concluding this section, I wish to say that the question is still sub-judice. The difficulties in coming to a definite conclusion are so great and so numerous that it would be rash to occupy a positive position without further evidence of a more definite scientific character being laid before us. Unfortunately, mothers and some medical men are a little too credulous and too much inclined to find some cause for a result, even if they have to search into the depths of their own romantic minds. Until we can be sure that fact and not fiction is speaking, we are powerless to decide.

TRANSMISSION OF MUTILATIONS.

The subject of "transmission of mutilations" has often been confounded with that of maternal impressions, without, in my opinion, due regard for the innate causes at work and the mechanism by which each particular process exerts its influence.

A true maternal impression, in the strict definition of the term, exerts its influence on the fœtus, and not on the ovum before the act of impregnation has been accomplished; with one exception, that in certain cases the maternal impression has been so lasting that its effect has reached over into the following pregnancy, producing an analagous fœtal deformity in both cases.

On the contrary, a transmitted mutilation presupposes that, in consequence of an injury received by the parent (either male or female) at a variable period before pregnancy, the offspring comes into the world inheriting the same condition that the parent acquired.

This proposition formed the basis of Lamarck's theory of transformation of species. He thought that changes in structure resulted from changes in the conditions of life, forcing the animal to assume new habits. Certain habits increased or decreased the activity of various organs; those organs subject to disuse underwent retrograde changes, whilst those whose activity had increased acquired new importance.

By such a theory Lamarck was able to account for the length of a swan's neck, owing to its custom of seeking food at the bottom of the water; also for the disappearance of the eyes of animals or fishes inhabiting caves or subterranean lakes and seas.

This theory necessarily assumes that of "transmission of acquired characters," and Lamarck accepted this as a matter of course.

So did Darwin a few years later, but he added to it the theory of "natural selection," which in the hands of such a truthful, laborious genius, forms one of the grandest discoveries of the century.

It is outside of my province to enter deeply into the subject of natural selection, for I should commit myself to controversies which would occupy more time than I have now at my disposal. I will content myself with insisting, that, whilst the doctrine of natural selection is full of truths and wonders, that of transmission of acquired characters is not proven. The supporters of Lamarck's doctrine rely mainly on cases of transmitted mutilations to prove their case.

We find on scanning the literature of the subject that Darwin put forth certain cases in support of this view. In the "Descent of Man," (pp. 200-311) we find that he attributes the narrowing of the long central tail feathers of the Motmot to the effect of habitual mutilation. These birds have a habit of biting and removing the feathers from this spot, presumably to improve their appearance. On the other hand the feathers are naturally narrower in this situation, and this narrowing extends even higher than the habitually denuded part. Is it not natural to assume that the feathers were originally narrower; that this proved a sexual attraction, which was intensified by habitual mutilation?

Dr. Prosper Lucas quotes a long list of inherited injuries, all of which are unsatisfactory and bordering on the romantic. I give a few of his cases as samples. He says: "Many girls are born in London with no breasts, owing to the injurious effects of corsets worn by their mothers." He quotes the case of a Jew who could see to read through the thick covers of a book, and whose son inherited this acuteness of vision.

A case is quoted by Richter of a soldier who lost his left eye from inflammation, and who had two sons, each with the left eye malformed (microphthalmic). The explanation of this case is, that the father was micropthalmic, and consequently subject to inflammation, and the sons inherited this constitutional condition from their father, and not from the effects of inflammation.

Darwin quotes a case which is mentioned by Ball as being the most conclusive and convincing. It is that of Brown-Sequard's epileptic "Guinea pigs," who were born with the absence of some of the toes, owing to their parents having gnawed off their own gangrenous toes when anæsthetic after division of the great sciatic nerve. This case, however, is imperfectly reported, and it is not claimed that the deficiency was on the same side of the body, or exactly analagous in both parent and offspring.

Darwin's own explanation of this condition is, that during repair of the injured part in the parent, all the representative gemmules, which would develop or repair or reproduce the injured part, are attracted to the diseased surface during the healing process, and are there destroyed. In other words, that a something which is needed to bring about the formation of any particular part in the child is withdrawn from the germ cells of the parent, and in consequence a failure of this part to attain adult development. "A very pretty and simple process forsooth!"

A new school has lately sprung up in our midst which has revived the doctrines taught by Lamarck. It bases its doctrines on certain changes which occur in mammalian teeth as the result of mechanical agencies, e. g., rubbing and wearing down of the crowns of teeth from habit or accident. This process goes on during the life of the parent, and is believed to produce similar changes in the offspring. If we grant this fact, we prove nothing except that the offspring is able to acquire characters which the parent was unable to; for the shape of the teeth is predetermined before they burst through the gum, and before they are subjected to any mechanical agencies whatever.

A few years ago a number of tailless cats were shown before the association of German naturalists at Weisbaden. They were said to have inherited their taillessness or rudimentary tails from the mother, who was reported to have lost hers by injury. This history, however, was not proven; so it can not be accepted as evidence. An interesting series of cats without tails, or with rudimentary tails, was discovered some years ago at Waldkirch, in the Black Forest. The mother had a normal tail, the father was unknown. As it was suspected that these cats were the results of transmitted mutilations, further investigations were made, resulting in the discovery of a male Manx cat in the neighborhood. I quote these two cases to show the absolute necessity of close and careful observation before accepting a mere rumor as scientific evidence.

It may be asked in this connection, how came it about that tailless cats are found in the Isle of Man and in some parts of Japan. Tailless cats are popularly thought to be better mousers than others, and so are more highly prized. This being so, it is just probable that artificial selection was added on to a process of natural selection, preserving and perpetuating a race of cats whose tendency was to a gradual diminution in tail length.

Some very interesting researches were made by Bonnet on the rudimentary tails of dogs who were born of parents whose tails are habitually mutilated. Occasionally, but very rarely, from such parents, a pup is born whose tail is shorter than normal and whose tail is represented by a membranous curled-up appendage surmounted by a tuft of hair.

Bonnet found that the rudimentary tails depend upon the absence of several vertebræ, together with abnormal ossification, and sometimes anchylosis. The cases varied, and here I quote in detail, for the subject is important. In the two first cases the reduction occurred in the distal end of the vertebral column, the more or less malformed vertebræ being anchylosed; a membranous appendage extending beyond the rereduced caudal vertebræ and forming the so-called soft tail. These characters were shown to be inherited from the mother. In a third instance from four to seven caudal vertebræ were absent, and the caudal column was characterized along its whole length by a premature tendency toward anchylosis. In addition, the last three or four vertebræ were placed transversely to the long axis of the tail, which was greatly curved.

Now are these changes such as would be expected as the result of maternal or paternal mutilation? Would we not rather expect that the terminal vertebræ would be absent altogether? Investigations have shown that a similar deformity is present in the much prized tailless cats of Japan.

As the holders of the Lamarckian theory base their views almost entirely on transmitted tail mutilations, Weissman (Essays on Heredity), to settle this question, experimented on 901 white mice which were the direct descendants of seven females and five males. Of these 901 young, produced from five generations of mutilated parents, in no single instance was there an example of an abnormal tail. Of course even a larger number of experiments like the foregoing prove nothing definitely. It would be necessary to carry them to infinity before one could say with certainty that a mutilation could *not* be transmitted.

This law of transmission of mutilations would entail the existence of a mechanism of a wondrous nature; a mechanism so complex that we are fain to imagine that nature, who in her methods is usually simplicity itself, does not foster it. Each alteration of the body of the parent would (under such a law) produce a change in the germ; this change would consist, not alone in structural differences, but would be entirely functional, causing, say at the 1000th cell generation, an increased or decreased growth of cells; this increased or decreased growth in the offspring being at a spot corresponding precisely to the overgrowth or deficiency in the parent. Now, although it is impossible to prove the absolute non-existence of such laws, it is excessively difficult to imagine how they work; nor should we expect the results to be as rare as they are. Nature's laws are not made to be useless, and to become manifest by caprice. They act invariably and continually. If such a law exist, how is it that Jews, among whom mutilation of the prepuce has been practiced from time immemorial, are not oftener born without this appendage? How is it that certain species of sheep, whose tails have been habitually mutilated for centuries, so very rarely bear lambs without tails or with rudimentary tails? How is it that fingerless, armless, and legless children are not a more common result of paternal accidents in our manufacturing districts.

In conclusion, I consider that this doctrine is not only not proven, but stands on no foundation whatever.

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HOW THE NEW MATHEMATICS INTERPRETS THE OLD.

By George Bruce Halsted, A. M., Ph. D., Member of the London Mathematical Society, Professor of Mathematics in the University of Texas.

Read March 4, 1893.

Sylvester told a story of C. G. J. Jacobi, that, having accepted the profuse hospitality of Cambridge University, having at dinner consumed astounding quantities of Trinity Audit Ale, the renowned man was asked: "Who are the greatest living English mathematicians?" and roared out: "*There are none!*"

This happened about half a century ago, a decade before Rowan Hamilton published the first of his two monumental works on Quaternions; when Sylvester, Cayley, Boole, were youths; now they are immortals, one at least outranking the greatest of the Jacobis.

I will not recall the creation of the vast Invariantive Algebra, or the Algebra of Matrices, or Quaternions, or even the Algebras of Logic. But Clifford attributes to Sylvester and Cayley the basis for assigning the true nature of arithmetical propositions. However that may be, we now know that it is objectionable to say, "And the units and the measured things are *concrete numbers*," as is said in the most ambitious of American algebras; or to say, "And the whole answer to the question *how many* is twelve apples, or twelve and two-thirds yards. Such numbers are *concrete numbers;* and concrete numbers may be defined as measured quantities," as is said, 1892, in Jones' Drill-Book in Algebra (Cornell).

We now know that "such numbers" are no numbers at all.

Number is of essence abstract. Number is primarily a characteristic or quality of a collection or group. A number-symbol may be used to represent an operation which obeys exactly the same formal laws as the number, yet no number is primarily an operation. Still that imperfection of the past hangs on as far as Byerly's Integral Calculus, 1891, though Gauss made all the world familiar with $\sqrt{-1}$ or i as a *number*, an independent number-unit like the number 1. I call it *neomon*, and such numbers *neomonic*.

In nature, each distinct thing is perceived as an individual. Each distinct thing is a whole by itself, a unit. The individual thing is the only whole, or distinct object, which exists in nature.

But the human mind takes like individuals together and makes of them a single whole and names it. Thus we have made the concept a flock, a herd, a bevy, a covey, a drove, a family, a genus, a species.

These are artificial units, discrete magnitudes; the unity is wholly in the concept, not in nature; it is of human make.

From the contemplation of the natural individual in relation to the artificial individual spring the related ideas "one" and "many."

A unit thought of in contrast to "many," as not-many, gives us the idea *one*. A "many" composed of "one" and another "one" is characterized as two. A many composed of "one" and the special many "two" is characterized as "three." But the young mind is very slow to pass from the knowledge of one and two on to the distinct recognition of the quality three. If I should judge from my two little boys, who should hereditarily be not inapt, their ancestors for four generations being Princeton graduates, I would not be surprised if it took a year to pass naturally from a distinct recognition of one, two, and many, on to the equally distinct recognition of three.

Numerals applied thus each to a special kind of discrete magnitude are called *cardinal numbers*. Their names are easily learned by a child. He may repeat the names readily up to ten and beyond, long before he knows the quality three.

Then teaching him to count, or pair each name with a natural unit of the specific artificial unit to be counted, we teach him to transfer to the artificial unit that name at which the count ends.

Ordinals are these numeral words modified in form or sound and applied successively each to a natural unit of the artificial unit. An ordinal will designate a natural unit among the arranged natural units of an artificial unit or group.

Number is a creation of the human mind, and only applies primarily to the artificial wholes created by the human mind—discrete aggregates.

The numerical symbols are first pictures of all groups having the designated quality; the freer from other qualities the better the symbol, since it is to symbolize something wholly abstract; it needs to represent the individual existence of the elements of the group, and nothing more; to that alone the numerical quality pertains.

Just as a woman buying a ribbon, in order to convey the desired color, would produce a scrap having that color, so a savage would hold up three fingers in describing a group of bears he had seen. Such pictorial reproductions are the primitive numerals I, II, III, IIII, V. The numeral words are the names of the hand-pictures used in conveying the abstract numeric quality.

In Eskimo "hand me" is tam ut'che, "shake hands" is tal lalue, "bracelet" is tale gow'ruk, "five" is talema.

Our word *five* is cognate with the Latin quinque, Greek *pente*, Sanscrit pankan, Persian pendji; and in Persian penjeh or pentcha means an outspread hand.

A word of the same sort as our word "to score" is the old Greek word for counting *pempazo*, to finger-fit-by-fives (or hands).

To five would be the method of races poor in number sense, e. g., the Romans; *to score* would be the method of barefooted or sandaled races, for example Mexicans. But most counting used as base the ten digits, and so our arithmetic is decimal. It is not that a decimal system, in so far as decimal, is a good system. That is one of the widespread errors taught to our children. Twelve would have been unquestionably a better base. If only our ancestors had had the good fortune to sprout another finger on each hand, there would now be no decimal system, and a vast simplification in arithmetic would have occurred. But the ten fingers of our ancestors have so grown into our brains, that I think all hope of relief now from decimality is chimerical. But this hopelessness of our hereditary imperfection is no adequate reason for lauding "decem." Do not attribute to ten the positional notation for number made possible by that splendid invention of the Hindoos, the zero, nought, cypher, which a *digital* point empowers to run down as easily as up.

The very ease and facility thus attained for cyphering prepared the way for an extension of meaning to number, or rather the attribution to it of a second distinct but allowable meaning.

From the time of Euclid the world has had an exquisite scientific treatment of the exact relation of any two magnitudes comparable by apposition of their multiples. This relation, their ratio, Euclid always pictured as the fingers picture number, by exhibiting another group also possessing the quality; he pictured the ratio of any two magnitudes by the ratio of two sects (definite pieces of a straight line).

The modern era of the world, the scientific, dates from 1637, when Descartes published his system of conditions which we now interpret as giving to every point in a plane a distinct name consisting of two numbers, and to every pair of numbers a point. His conventions, though for his use explicable, and by him explained, as a geometric algebra operating with sects, yet get their dual power only when seen as setting up a unique one-to-one connection between number-pairs and points, so making algebra talk geometry, and inversely, geometry talk abgebra. For example, the equation $Ax+By+C=O$, representing each pair of numbers which jointly satisfy the equation, pictures now an aggregate of points, which are *on* a straight line, while number is discrete, but which *are* the straight line if number be continuous. Descartes perhaps never passed beyond Euclid's representation of the ratio of two magnitudes by two other magnitudes, never reached the conception of the systematic representation of the ratio of two magnitudes by one magnitude, a step like that from picturing the numeric quality of a group by another group, to personifying, individualizing that quality as a self-existent discrete number.

In regard to just this point a common error is still widespread, which we see in the following, read before Sections A and B of the American Association for the Advancement of Science, 1891:

"The doctrine of Descartes was, that the algebraic symbol did not represent a concrete magnitude, but a mere number or ratio, expressing the relation of the magnitude to some unit. Hence that the product of two quantities is the product of ratios, . . . ; that the powers of a quantity are ratios like the quantity itself," etc.

That every statement here quoted is a mistake will be instantly seen from the following, taken from pages numbered 297–9 of the *original edition* of Descartes' Geometrie, 1637, a copy of which (perhaps unique on this continent) I have had the good fortune to possess since my student days (1876).

"Et comme toute l'Arithmetique n'est composée, que de quatre ou cinq operations, que sont l'Addition, la Soustraction, la Multiplication, la Diuision, & l'Extraction des racines, qu'on peut prendre pour vne espece de Diuision: Ainsi n' at' on autre chose a faire en Geometrie touchant les lignes qu'on cherche, pour les preparer a estre connues, que leur en adiouster d'autres, ou en oster; Oubien en ayant vne, que ie nommeray l'vnité pour la rapporter d'autant mieux aux nombres, & qui peut ordinairement estre prise a discretion, puis en ayant encore deux autres, en trouuer vne quatriesme, qui soit a l'vne de ces deux, comme l'autre est a l'vnité, ce qui est le mesme que la Multiplication; oubien en trouuer vne quatriesme, qui soit a l'vnc de ces deux, comme l'vnité est a l'autre, ce qui est le mesme que la Diuision; ou enfin trouuer vne, ou deux, ou plusieurs moyennes proportionnelles entre l'vnité, & quelque autre ligne; ce qui est le mesme que tirer la racine quarrée, ou cubique, &c. Et ie ne craindray pas d'introduire ces termes d'Arithmetique en la Geometrie, affin de me rendre plus intelligible. * * *

"Mais souuent on n'a pas besioin de tracer ainsi ces lignes sur le papier, & il suffist de les designer par quelques lettres, chascune par vne seule. Comme pour adiouster la ligne BD a GH, ie nomme l'vne a & l' autre b, & escris $a+b$; Et $a—b$, pour soustraire b d' a; Et ab, pour les multiplier l'vne par l' autre; Et $\frac{a}{b}$, pour diuiser a par b; Et aa, ou a^2, pour multiplier a par soy mesme; Et a^3, pour le multiplier encore vne fois par a, & ainsi a l' infini; Et $\sqrt{a^2+b^2}$, pour tirer la racine quarrée d' a^2+b^2; Et $\sqrt{C.\ a^3—b^3+abb}$, pour tirer la racine cubique d' $a^3—b^3+abb$, & ainsi des autres.

"Ou il est a remarquer que par a^2 ou b^3 ou semblables, ie ne concoy ordinairement que des lignes toutes simples, encore que pour me seruir des noms vsités en l'Algebre, ie les nomme des quarrés, ou des cubes, &c."

Thus what Descartes really did was to make what we would now call a new algebra, the third algebra, calling the algebra of discrete number the first algebra, and that geometric algebra the second in which the product of two sects was a rectangle, the product of three sects was a cuboid, and in which we might now call the product of four sects a tesseroid. In Descartes' algebra the product of two sects is a sect, of three sects still a sect, etc.

In the second algebra, add to each sect the compound quality direction, and Grassmann's algebra emerges, in which the product of two directed sects, or vectors, is the parallelogram they determine, and the square of a vector is zero.

Add direction to each sect in Descartes' algebra, and you have Quaternions, or else a sixth algebra, according as the square of a unit vector is taken equal to minus or plus the number one.

Thus notice that even before the conception of *continuous number* had come into anyone's head, the world had multiplication of magnitudes, which certainly were not abstract numbers; and it is wholly from studies of such multiplication that our present knowledge of the operation has come.

Yet our Cornell friend, Mr. Jones, on page 6 of his Drill-Book, tells us, "The product of two concrete numbers is an absurdity." On page 2 he has given us as an example of a concrete number $12\frac{2}{3}$ yards.

Now $12\frac{2}{3}$ yards multiplied by itself gives as a product in the second algebra a rectangle containing $160\frac{4}{9}$ square yards; in Descartes' algebra, a sect, $160\frac{4}{9}$ yards; in Grassmann, zero; in Quaternions, $-160\frac{4}{9}$; in the sixth algebra, $+160\frac{4}{9}$.

An Algebra is an artificial language composed of symbols, with their laws of combination, and possessed of peculiar advantages in giving of actual relations representations which can be manipulated according to rules of operation and procedure, experimented upon to give new knowledge, according to organized processes. The first algebra was slowly formed throughout centuries, to investigate the properties of numbers. The digital numerals differ in origin from the operational signs of algebra, in that the numbers are contracted pictures of the quality they now represent; while the operation signs were gradually introduced for *words*. Modern algebras embrace all organized systems of symbols combining according to definite laws, and so extend to subject-matter of which number constitutes but one element, or in which this element is entirely absent.

Notice the thought wrongly attributed to Descartes, "A mere number or ratio." Now "number" was never thought of by anyone as synonymous with ratio until long after 1637.

This radical innovation, the creation of the epoch-marking paradox, *continuous number*, is due to Newton. Newton makes this vast step explicitly and consciously. The lectures which he delivered as Lucasian professor at Cambridge were published under the title "Arithmetica Universalis."

At the beginning of his "Arithmetica Universalis," he says:

"Per Numerum non tam multitudinem unitatum quam abstractam quantitatis cujusvis ad aliam ejusdem generis quantitatem quae pro unitate habetur rationem intelligimus. Estque triplex; integer, fractus, et surdus: *Integer* quem unitas metitur, *Fractus* quem unitatis pars submultiplex metitur, et *Surdus* cui unitas est incommensurabilis. * * * * *Quantitates* vel Affirmativæ *sunt seu majores nihilo, vel* Negativæ *seu nihilo minores*."

Here we have at once the whole continuous system of real number, containing not only the absolute negative, but the general irrational, for notice that here a "surd" is not a "root," but the abstract ratio to the unit sect of any possible sect incommensurable with the unit sect.

In a proof-sheet recently sent me by that sound geometer Hayward of Harrow, I read: "Number is essentially *discrete* or *discontinuous*, proceeding from one value to the next by a finite increment or jump, and so can not, except in the way of a limit, represent, relatively to a given unit, a continuous magnitude, for which the passage from one value to another may always be conceived as a *growth* through every intermediate value."

But the moment we accept Newton's definition of number it is no more discrete than is a line-segment or sect.

After Newton it was possible to use "number or ratio" as synonymous, perhaps up to the time of Gauss. But what the English language still needs is any adequate explication of this very idea "continuous."

Mathematicians who write in English really attempt no definition of continuous; adopting with Clerk-Maxwell (Matter & Motion, Art. XXV) the holding up of a scrap supposed to have the quality, or quoting Aristotle's inadequate "the boundary separating two contiguous parts is common to both." [Can a number have a boundary?] Then they hasten to say that the geometric magnitudes are continuous; and then *the entire system of real numbers* or ratios, inasmuch as it contains an individual number to correspond to every individual point in the continuous series of points forming a straight line, *is continuous*.

This word "continuous" is even introduced at the very beginning of some elementary geometries (W. B. Smith, Introductory Geometry, p. 3), though no adequate idea can be attached to it before the demonstration of incommensurability. Most people live and die without ever knowing or conceiving that lines, even pieces of the straight line, exist, which can have no common unit of measure, try units as small as you choose.

Such an idea is contrary to their preconceived notions, and appears to them to contradict the testimony of their senses.

So their straight line possesses no more continuity than the series of rational fractions. What do you gain by holding up your colored scrap to the color-blind?

No one before Pythagoras, no one since Pythagoras, untaught, questions the possibility of expressing all size-relations among lines in terms of rational number.

The text-books of America, like those of France and Germany, have lost Euclid's masterful pure geometric theory of proportion for the study of size-relations without reference to measure. Following Newton's paradox without knowing it, they make a ratio, not a proportion, the primary idea, and define a ratio as a quotient, a number. No wonder that Dedekind says this doctrine of ratio can only be clearly developed after the introduction of irrational numbers. Newton, leaning on Euclid's Fifth Book, got his irrational number, by an innovation, from Euclid's geometric doctrine of proportion. American books get their proportion from the general irrational number, and then get their irrational from this proportion. To see that this *argumentum in circulo* fails in both directions around the circle, we have only to meditate on the obvious fact that for a great part of the science of space the continuity of its forms is not a necessary presupposition.

In illustration of this, Dedekind gives the following example:

If we take any three non-collinear points, with only the specification, that the ratios of the sects AB, AC, BC, are algebraic numbers, and consider as present in space only those points M, for which the ratios of AM, BM, CM, to AB are likewise algebraic numbers, then the space consisting of these points is throughout discontinuous [it lacks all points D, for which a ratio, as AD to AB, is a transcendent number such as *pi* or *e*]; yet despite the discontinuity, the perforation, of this space, all constructions occurring in Euclid are in it just as achievable as in perfectly continuous space. The discontinuity of this space would therefore never be noticed, never be discovered, in Euclid's science.

"Um so schoener erscheint es mir, dass der Mensch ohne jede Vorstellung von messbaren Groessen, und zwar durch ein endliches System einfacher Denkschritte sich zur Schoepfung des reinen, stetigen Zahlenreiches aufschwingen kann; und erst mit diesem Hülfsmittel wird es ihm nach meiner Ansicht moglich, die Vorstellung vom stetigen Raume zu einer deutlich auszubilden."

But this is just what has never yet even been attempted in any textbook in the English language.

All geometries, the best and the worst, make congruence their basis for comparison in size. One magnitude is said to be greater than another when this other is congruent to a piece of the first.

No two magnitudes have a ratio unless one can be congruent to, greater than, or less than the other.

But which American geometry points out that, since no part of a circle, no arc, can be congruent to any sect, so no part of a circle can be equivalent to any sect in accordance with the definition of equivalent magnitudes as such as can be cut into pieces congruent in pairs? But it follows that no circle has any ratio to its diameter from the assumptions in Euclid's geometry. The very attribution to a circle of ratio to its radius makes new assumptions.

High authorities (*e. g.* Duhamel) maintain that attributing measurability to curves, that the very ascription of length to a curve (that is, ratio to the unit sect,) involves the particular idea of a limit which itself involves the true conception of an infinitesimal.

THE NON-METALLIC MINERAL RESOURCES OF THE STATE OF TEXAS.

By W. H. Von Streeruwitz, of the State Geological Survey.

Read December 31, 1892.

Last February I had the honor to demonstrate to the Academy the probability of the existence of precious metals in the Central District of Texas, which comprises Llano county, part of Burnet, Lampasas, San Saba, Mason, Gillespie, Blanco, and Menard counties; and in Trans-Pecos Texas, covering about 35,000 square miles between the Rio Grande and the Pecos river. I advanced reasons based on the experience of centuries, and mentioned that the probability is strengthened, even made a certainty, by numerous outcrops and floatpieces; in short, by indications which can not be misunderstood by mining experts. Moreover, I stated that the existence of workable and successfully worked ore deposits in Trans-Pecos Texas is sufficiently proved by some existing mines. I also brought forward the more conspicuous reasons why the mining industry is so sadly neglected in our State.

The mineral resources of Texas are not confined to the deposits of ores of base and precious metals, but there is in the State an abundance of other minerals, not regarded ores, but nevertheless of great value. Some of these are partly appreciated and utilized, but only to a very limited degree. The existence of others, and that they might be of practical value, is known, but up to the present time they are not utilized; of others still, the existence is known, but their value is not even suspected by the greater part of the people.

Among the first class are the stone coal and brown coal deposits of Texas.

The value of stone coal is too well known to make necessary a demonstration; and coal mining in Texas, though in its infancy, is carried on more vigorously and in more places than ore mining.

This is not the case with a fuel next in value to the stone coal—the brown coals, or, as they are here commonly called, the lignites.

It is now pretty well ascertained that the greater part of the Tertiary belt of Texas abounds in brown coals, mostly of good quality, many of them far superior to such as are used in Europe to great advantage for domestic and manufacturing purposes. Since many of our Texas brown coals and lignites are superior to the European, there is no tangible reason why they should not be used here as well as in Europe (as I recommended in the August bulletin of H. S. A., 1888,) in their natural condition on the well known Treppenrost, or why they could not be used in the shape of briquettes just as well as they have been used in Europe for more than forty years, or why they should not be used in gaseous form likewise, as they are used in Europe.

The lignite of Solenau, in the province of Austria, with 13.5 of ashes and 35.00 of moisture, resulting in only 2400 caloric units, is used for domestic and manufacturing purposes; in Bohemia the lignites of Brunnersdorf, with 12.00 ashes and 21.00 moisture, resulting in 3333 caloric units, and the brown coal of Raudnitz of 3842 caloric units, are used very advantageously under steam boilers and in stoves.

For the same and similar purposes are used the lignites and brown coal of Moravia, Styria-Gallicia, Carinthia, Tyrol, Hungary, in short of nearly all the Austrian provinces. So, to mention only some, the lignites of Dubnian and Ratisch-Kowitz in Moravia, with 13 and 15 per cent of ashes and caloric effects of 2500 and 2685 units. The lignites of Rein in Styria result in 2836 caloric units; an Eocene brown coal of Sonnberg in Carinthia 3834 calories. The lignites of Welkagoriza in Croatia result in 3285 caloric units, and these, as well as at least 150 more lignites and brown coals, are burned to heat dwelling house and kitchen stoves, to raise steam, to make glass, pottery, and chinaware. They are also used for many metallurgical operations, for instance to roast ores, and to heat puddling furnaces.

The best of these European lignites or brown coals reach a caloric effect of perhaps 5000 heat units. Many of our Texas lignites (and not the best ones) contain from 50 to 60 per cent of carbon, which, if we neglect the heating effects of the available hydrogen (the hydrogen in excess of the amount that combines with the oxygen present to water), is equal to respectively 3900 and 4680 caloric units.

Specimens of better sorts of Texas brown coal, which I analyzed, resulted as much as 65 carbon and 25 available hydrogen, equal to 5655 heat units. My own analyses and observations, carried on since 1883, are continued by the analyses made in the laboratory of the Geological Section of our State Agricultural Department, of which, to mention only a few, four typical specimens from different localities produce respectively 5030, 4933, 4831, 4070 caloric units.

Experiments which I made eight years ago towards coking Texas lignites gave negative results, except under such a high pressure as would make coking for practical purposes very expensive, and at the same time too dangerous. But powdered and mixed with bituminous Pittsburg coal I got with 5 per cent of bituminous coal coherent coke; with 10 per cent of bituminous coal a ringing coke of sufficient coherence to adapt it for blast furnace use.

It might be objected that these were laboratory experiments, and that practical tests on a larger scale were not made, or if made, that they were a failure; for instance, the tests carried on in some of the cotton compresses in Houston, 1887. I was present at these experiments from the beginning to the end. I studied carefully and noted the conditions and results, and it was admitted by the engineers and firemen (with whom the decision rested) that the heating power of the lignites from the banks of the Brazos near Calvert was a *little* more than half of the heating power of the bituminous coal generally used under the boilers of these compresses. This experiment was carried on on a large scale; it covered fully three days, and it was not a failure, but a full success for the following reasons: The quantity was estimated by the volume and not by weight; the lignite was taken from near the river bank, where it had been exposed to leaching by the frequent rises in the river, and consequently had deteriorated; and last, but not least, it was burned on grates and in furnaces constructed for the use of bituminous coal, and in the flour mill test in a furnace built for wood firing. Or in other words, the lignites were tested under the worst conditions for the development of their heating power. I am positive that Texas lignites of average good quality, in furnaces built for this kind of fuel, can and will develop from two-thirds to four-fifths the heating effect of Pittsburg and Indian Territory coal.

Engineers and firemen may object to the brown coal, because it requires more shoveling and greater care to keep up the fire; but as hinted above, this objection will be lessened if the furnaces will be adapted to the fuel, instead of expecting that the fuel will adapt itself to the grate and furnace.

When I said the greater part of the Tertiary belt of Texas is underlaid by brown coal, I did not intend to say that all this brown coal is available. Local conditions require the same consideration in coal mining as in mining in general. To go into details on this subject would require more time than the present session of the Academy would or could allow. I had to be somewhat explicit in speaking of this subject in order to meet and refute beforehand the objection, that the want of suitable fuel would prevent the utilization of other valuable minerals.

We find in Texas fire clays which favorably compare with the world renowned Stourbridge clay and the clays of Alt Almenrode.

The experiments which I made in 1878 in behalf of Mr. Dillon with the fire clays of Limestone county, resulted in a fire brick resisting changes of temperature better than the Mt. Salvage brick and the imported English fire brick. Expansion and contraction were practically nothing, and their resistance to fusion equal to that of the best in the market. I formed by hand, of the same clay, a crucible, and fused in the same cast iron without destroying the crucible. Fire clays of equal quality are found in many localities together with the lignites in Texas.

Texas has also an abundance of kaolin, or china clay; deposits of excellent quality; the quality not estimated from laboratory results and analyses alone, but acknowledged by the practical experts of the most renowned porcelain factories of Europe, to whom I had sent specimens of Texas kaolin in 1884. We have any amount of excellent kaolin in close proximity to fuel, but no porcelain factories.

The use of kaolin is not, however, confined to the manufacture of porcelain. Mixed with lime in proper proportion, it makes cement equal to the best. Some experiments which I made with mixtures of lime and kaolin resulted in hydraulic cements of great strength, requiring only a short time to set, though I had no opportunity to expose the materials to the full heat necessary for a thorough combination of the constituents.

Many of our Texas kaolins are also sufficiently pure for manufacturing ultramarine colors.

That some of the marly limestones of Texas make a good quality of cement is successfully demonstrated by the cement factory of San Antonio.

The hydraulic qualities of dolomite were discovered nearly seventy years ago by McLeod and Vicat; and closer investigations of this subject made about thirty years later by Deville, Redtenbacher, Pasley, and others proved that dolomitic limestone, under certain conditions, can be converted into very good building mortar. But during the last five or six years the albolith, a hydraulic lime made of dolomite, is manufactured in Austria and brought into market in large quantities. There is any amount of dolomitic limestone and dolomite in Texas—the raw material for manufacturing the albolith—which, though it has very valuable qualities, is up to now hardly known in the United States. It settles and sets slower than the other hydraulic cements, but, once set, it is nearly impenetrable to water, and makes, therefore, an excellent mortar for cisterns and covering of walls. It also resists better than common cements the dissolving action of sea water.

The salt deposits of Texas are partly known and utilized, as the salt beds near Colorado City, other deposits in Southwest Texas, and the salt lakes at the foot of the Guadaloupe Mountains in El Paso county. But there can be hardly any doubt that in the eastern part of the State there also exist extensive salt deposits, and that they will be found 100 to 200 feet below the lowest lignite beds.

The existence of rock salt deposits in the vicinity of the headwaters of the Double Mountain Fork and the Salt Fork of the Brazos River is more than probable, judging not only from the geological character of the country, but also from the character of the waters of these tributaries of the Brazos River; and I think it is safe to predict that besides, probably above the purer chloride of sodium (common salt), the more valuable potash salts (the "Abraum Salze" of Stassfurt) will there be discovered.

All the gypsum used for plastering and other purposes is imported into Texas, though there is hardly any State or Territory of the Union that has more or larger gypsum deposits than our State. Some of these deposits are on railroads or in close proximity to such, and some of them consist partly of very fine alabaster.

Heavy spar, which is extensively used in paints; feldspar, used in enamels and in glazing porcelain; quartz and quartz sands, eminently fit for fabrication of glass; substances for coloring glass, among them the high-priced uranium, can be found in Texas, and in sufficient quantities. The existence of asphaltum beds, deposits of ozokerite, the presence of oil and natural gas in many localities, is well known, at least mentioned in the geological reports; but little has been done to develop and utilize the same.

The excellence of Texas granite and syenite is sufficiently demonstrated by the material of our State capitol in Austin; not less the good quality of our limestones used in its foundation, and for the full construction from foundation to roof of other buildings in Austin, San Antonio, and many other places. The red sandstones from the quarries on the Pecos are used not only in the State, but also shipped over the boundary lines of Texas, though the industry of quarrying these stones is still in its infancy. Sandstones from other localities are acknowledged good building stone, and commonly used all over the State.

We import marbles from the north, though it is partly known that marbles of good quality, coarse and fine grained, of various and pleasing colors and shades, uncolored, striped, and mottled, could be quarried in the State. I found a white marble that, considering grain, hardness, and clearness of structure, seemingly must be classified as statuary marble.

The beauty, variety of color, and capacity for polish of some of the western porphyritic rock, and its qualification for ornamental work, is scarcely superseded by a few; and so on.

The character of some of our Trans-Pecos formations indicates that precious and semi-precious stones may be expected among the non-metallic mineral resources of Texas; and I found a good outcrop of opal matrix in the Apache Mountains and opal float in the Van Horn and Wiley Mountains; also a piece of turquoise in the Sierra de los Dolores.

Sardonyx and agates I found in Presidio county, and moss agates of exquisite colors and structure near the Sierra Rosillas.

I shall not strain your patience much longer, but only mention that Texas has also hot and cold mineral springs, clay for pottery and bricks, common lime and building sands, and that our greensands and marls are recommended by some as fertilizers, which recommendations, however, I can not endorse. But without this fertilizer, the metallic and non-metallic mineral resources alone would class Texas among the richest States of the Union, even though the State had not immense agricultural resources, and in spite of the undeniable fact that stockraising is on the decline. But in order to develop the vast resources of Texas, there is required a little more knowledge, a good deal more energy and enterprise, and the three things which Frederick the Great said were required to carry on a war, viz., money, money, and once more, money.

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THE TEXAS ACADEMY OF SCIENCE.

October 12th, 1894.

INAUGURAL ADDRESS BY THE PRESIDENT OF THE ACADEMY,

DR. GEORGE BRUCE HALSTED.

ORIGINAL RESEARCH AND CREATIVE AUTHORSHIP THE ESSENCE OF UNIVERSITY TEACHING.

That which is most characteristic of the present epoch in the history of man is undoubtedly the vast and beneficent growth of science.

In things apart from science, other races at times long past may be compared to the most civilized people of to-day.

The lyric poetry of Sappho has never been equaled. The epic flavor of Homer, even after translation, comes down to us unsurpassed through the ages.

Dante, the voice of ten silent centuries, may wait ten centuries more before his maedieval miracle of song finds its peer.

The Apollo Belvidere, the Venus of Milo, the Laocoon are the glory of antique, the despair of modern sculpture.

To mention oratory to a schoolboy is to recall Demosthenes, and Cicero, even if he has never pictured Caesar, that greatest of the sons of men, quelling the mutinous soldiery by his first word, or with outstretched arm, in Egypt's palace window, holding enthralled his raging enemies, gaining precious moments, *time*, the only thing he needed to enable him to crush them under his dominant intellect.

There is no need for multiplying examples. The one thing that gives the present generation its predominance is science. The foremost factor in modern life is science.

All criticisms of the scope of life, of the essence of education, made before science had taken its present place, or attempting to ignore its prominence, are obsolete, as are of necessity any systems of education founded on pre-scientific or anti-scientific conceptions.

Unfortunately there are still some people so dull, so envious, so unscientific, so stupid as to maintain that the highest aim of a university should be the *training* of young men and young women, where they use the word "training" in its repressive, inhibitive sense.

The most profound discoveries of modern science unite in replacing this old "training" idea of education by one immeasurably higher, finer, nobler.

We now know that the paramount aim of teaching at every stage, and preeminently of the final stage, at the university, should be to *help* the developing mind, the developing character, the developing personality.

Judicious, delicate, sympathetic *help* is now the watchword. Even horses and dogs worth owning are no longer "broken;" they are "gentled."

What has brought about this glorious change?

Science, the greatest achievement of human life, the one thing that puts to-day, the present, in advance of all past ages.

Not only by having subjugated the forces of nature to the dominion of mind, but also by its intellectual influence, science is remodelling the life and thought of modern humanity.

Though science is the purest knowledge, yet even our estimate of knowledge has been changed by science.

Mere acquirement is now considered an unworthy end or aim for endeavor.

Action, production alone now receives our homage, now gives a life worth living; and therefore each must aim either at the practical application of his knowledge, or at the extension of the limits of science itself. For to extend the limits of science is really to work for the progress of humanity.

This is a fitting crown to the sweet and symmetrical evolvement which true teaching aids—the unfailing spring of pure pleasure which it affords.

The laws of physical, but above all of mental health made clear by science let every one realize how now our truest education stands ready to aid, to save, to satisfy, endangered or craving bodies or minds.

Nothing is more beautifully characteristic of young children than the desire to know the why and wherefore of everything they see. This natural spirit of inquiry needs only proper direction and fostering care to give us scientists.

But no one can teach science who does not know it. For a teacher, however subordinate, to have the true informing spirit to vivify his book-knowledge, even of the very elements, it is found almost uniformly essential that he should have been in direct personal contact with some one of those great men whose joy it is to be able to advance the age in which they live, and lead on mankind to unexpected victories in the progressive conquest of the universe. But it is the highest function of a university to help the gifted young man on his way toward becoming one of these glorious creatures, these men who make and who honor the age in which they live.

A university should wish to feed the mental leaders of the next generation.

For this nothing can take the place of contact with the living spirit of research, original work, creative authorship.

Without fostering and requiring such work of students, and still more of all its professors, no institution can be a university of the first class. Intimate contact with a producer of the first rank is worth more than the whole world of so-called training by use of retailed convictions.

The most inspiring teacher must have known how to acquire conviction where no predecessor had ever been before him; to show others how to conquer new regions, he must himself have broken barriers for human thought. As Rector of the University of Berlin, Helmholtz said: "Our object is to have instruction given only by teachers who have proved their own power to advance science."

There is no honest test or proof of scholarship or acquirement but production. The characteristic quality of all the highest teaching lies in the fact that it comes from a creator.

No more convincing demonstration of my thesis could be wished for than the work of Sylvester for America. On page 233, I, of his hochere Geometrie, 1893, Felix Klein, as high an authority as any living, says: "Sylvester hat noch 1874 als 60 jaehriger Mann den Mut gehabt an die Johns Hopkins University in Baltimore ueberzusiedeln und durch eine ganz specifische durch 10 Jahre fortgesetzte Lehrthaetigkeit hochere mathematische Studien auf amerikanischen Boden zu initiiren."

The birth of higher mathematics in America will always date from Sylvester's advent at the Johns Hopkins. Then and there with his mighty head he raised the whole western continent and made it a worthy associate in the profoundest thought-life of our world. But few know that this epoch-making period was not Sylvester's first advent in the United States. The immortal glory now belonging to the Johns Hopkins University might have been anticipated by another, and with the very same instrument.

An adequate life of James Joseph Sylvester has never been written, and probably never will be while he lives. At Cambridge he was most impressed by a classmate of his own, the celebrated George Green, who had already then produced the remarkable Green's Theorem, and much of the work which still stands as a foundation stone in the edifice of modern electrical science. As Sylvester would not sign the thirty-nine articles of the Established Church, he was not allowed to take his degree, nor to stand for a Fellowship, to which his rank in the tripos entitled him.

Sylvester always felt bitterly this religious disbarment. His denunciation of the narrowness, bigotry, and intense selfishness exhibited in these creed tests was a wonderful piece of oratory in his celebrated address at the Johns Hopkins University. No one who saw will ever forget the emotion and astonishment exhibited by James Russell Lowell while listening to this unexpected climax. Thus barred from Cambridge, he accepted a call to America from the University of Virginia.

The cause of his sudden abandonment of the University of Virginia is often related by the Rev. Dr. R. L. Dabney, as follows: In Sylvester's class were a pair of brothers, stupid and excrutiatingly pompous. When Sylvester pointed out one day the blunders made in a recitation by the younger of the pair, this individual felt his honor and family pride aggrieved, and sent word to Professor Sylvester that he must apologize or be chastized.

Sylvester bought a sword-cane, which he was carrying when waylaid by the brothers, the younger armed with a heavy bludgeon.

An intimate friend of Dr. Dabney's happened to be approaching at the moment of the encounter. The younger brother stepped up in front of Professor Sylvester and demanded an instant and humble apology.

Almost immediately he struck at Sylvester, knocking off his hat, and then delivered with his heavy bludgeon a crushing blow directly upon Sylvester's bare head.

Sylvester drew his sword-cane and lunged straight at him, striking him just over the heart. With a despairing howl, the student fell back into his brother's arms, screaming out, "I am killed!" "He has killed me!" Sylvester was urged away from the spot by Dr. Dabney's friend, and without even waiting to collect his books, he left for New York, and took ship back to England.

Meantime a surgeon was summoned to the student, who was lividly pale, bathed in cold sweat, in complete collapse, seemingly dying, whispering his last prayers. The surgeon tore open his vest, cut open his shirt, and at once declared him not in the least injured. The fine point of the sword cane had struck a rib fair and caught against it, not penetrating.

When assured the wound was not much more than a mosquito bite, the dying man arose, adjusted his shirt, buttoned his vest, and walked off, though still trembling from the nervous shock. Sylvester was made head professor of mathematics of the Royal Military Academy at Woolwich, a position which he held until the early period set by the English military laws for conferring the life pension.

He thus happened to be free to accept a position at the head of mathematics in the Johns Hopkins University at its organization. With British conservatism, he stipulated that his traveling expenses and annual salary of five thousand dollars should be paid him in gold, and this fixed, he came a second time to America.

The fame of his coming preceded him, for by this time he was ranked by Kelland in the Encyclopædia Brittannica as the foremost living English mathematician. The only possible sharer of this proud pre-eminence was his life-long friend Cayley.

Appointed among the first twenty fellows at the organization of the Johns Hopkins University, and having an intense desire to study Sylvester's own creations with him, I became alone his first class in the new University. Sylvester gives in his celebrated address a graphic account of the formation of that first class as illustrating the mutual stimulus of student and professor.

The text-book was Salmon's Modern Higher Algebra, dedicated to Sylvester and Cayley as made up chiefly from their original work.

The professor broke every rule and canon of the Normal Schools and Pedagogy, yet was the most inspiring teacher conceivable. Everything, from music to Hegel's metaphysics, linked into the theory of Invariants, combined with the precious personal data, and charming unpublished reminiscences of all the great mathematicians of the preceding generation.

Such a course in the creation of modern mathematics, with most precious, elsewhere unattainable, historic indications, will perhaps never be paralleled. It went on not only at the appointed hours, but the professor would send for his class late at night, while at other times they took excursions together to Washington. The incidents of those two formative years spent in most intimate association with one of the great historic personages of science can never be forgotten. It was during this period that Sylvester founded the American Journal of Mathematics, and it is due to his particular wish that it was given the quarto form.

Then began a new productive period in his life, the astounding activity and marvelous results of which can be faintly estimated by consulting the pages upon pages taken up in the Johns Hopkins Bibliographia Mathematica merely to enunciate the titles of the memoirs and papers produced. The very complete and profound historic and bibliographic account of the theory of Invariants given by Meyer in the Berichte of the deutsche mathematische Gesellschaft indicates very fairly Sylvester's final place in the history of that all-pervading subject. His original contributions to many other parts of the vast structure of modern pure analysis are of nearly as great weight.

Sylvester was completely of the opinion that no teaching for a real university can be ranked high which is not vitalized by abundant original creative work. He maintained that it was the plain duty of any mature man holding a professorship in a real university to resign at once if he had not already been copiously and creatively productive.

He believed that without unceasing original research and published original work there could be no real university teaching, and that any university professor who, without such a basis, pretended to be a good teacher, was, consciously or unconsciously, a selfish fraud.

On page 6 of his Address, delivered on Commemoration Day, 1877, he speaks of a university "under its two-fold aspect as a teaching body and as a corporation for the advancement of science." He there continues: "I hesitate not to say that, in my opinion, the two functions of teaching and working in science should never be divorced.

"I believe that none are so well fitted to impart knowledge as those who are engaged in reviewing its methods and extending its boundaries. . . . . May the time never come when the two offices of teaching and researching shall be sundered in this University!"

This was spoken of the Johns Hopkins. Since then no university has voluntarily professed an ideal not equally noble and exalted.

Science, penetrating ever deeper, makes clear the conditions of progress, of true education, of finest teaching.

Only those who have produced can adequately fulfill its present motto: "I serve, I help."

PRESENT NEED OF ENGINEERING EDUCATION IN THE SOUTH.

(*Read Before the Texas Academy of Science at Galveston, December 31, 1894.*)

THOMAS U. TAYLOR, C.E.

Before considering the needs of engineering education in the South, it will be well to look at the map of the whole country, with a view to locating the center of engineering education. As the civil war had such a material effect upon the destinies of the South, and as it destroyed the old civilization where the cavalier had his impress upon our institutions and customs, it took time for our ideas and thoughts to crystalize under the new order. This period, then, forms not only a good dividing line, but a necessary dividing line, in discussing the needs of any kind of education of to-day. Before the war the center of engineering education was far to the north, and held there with a tenacity that was not disturbed by a few isolated efforts in some of our colleges. The Virginia Military Institute, from 1840, did much to draw this center nearer the Gulf, and the brilliant success of her graduates in engineering brought this "West Point" of the South as much renown as that daring band of cadets did by their gallant stand at Newmarket. To the Virginia Military Institute, about 1840, came Thomas Williamson, a West Pointer, a man who impressed his individuality upon his students, and who for twenty-five years delivered the only lectures on engineering that were delivered in the South. The whole course was almost an exact reproduction of the course at West Point in nearly all its details—notably the case in engineering, in military science and its method of working. That the work was well done in engineering is well attested by the conspicuous place taken by the Virginia Military Institute graduates in civil life before 1860, and later by the many military engineers that helped the South during the struggle. But the Virginia Military Institute was practically alone in its efforts to train engineers. The main engineering belt was confined to that line of States from Massachusetts to Ohio.

As to the causes that retarded engineering, and in fact all industrial education in the South, they were many. The Southern civilization was one of *otium cum dignitate.* It was the civilization of the Cavalier rather than the Puritan. But when all this was destroyed, a newer life rose, phœnix-like, from the ashes, and girded itself for a new duty. Engineering education in the South, with the exception of the Virginia Military

Institute, is a *post bellum* plant. I shall not attempt to follow the progress in the whole country, which is marked by many of the finest engineering schools in the world, but shall confine this preliminary survey to what is known under the general term of South. As soon as the Southern universities had re-collected their faculties, many introduced engineering courses, although some of their courses were simply adjuncts to the chairs of mathematics or physics, and received no more attention than secondary subjects generally do.

In 1868 the University of Virginia added to its already first-class schools the school of applied mathematics, and Leopold J. Boeck was assigned to this school. After a service of six or seven years, Prof. Boeck resigned, and his mantle fell upon the most brilliant alumnus the University of Virginia had upon her rolls, that most remarkable educator and mathematician, William M. Thornton, the present chairman of the faculty and head of the department of engineering.

Washington and Lee also added engineering courses, in charge of special instructors. In 1865, just after the war, Gen. R. E. Lee was elected President of Washington College, and the courses of instruction were reorganized under his direction, and he is said to have taken special interest in organizing the engineering department. On General Lee's election to the presidency, William Allan was placed in charge of the department of engineering, and at once brought the course up to the highest standard—a standard that has been maintained even to this day by such men as Custis Lee, Percy and Humphreys. Virginia, then, can claim three institutions that have done much in the line of engineering work. It will be noticed that both the University of Virginia and Washington and Lee have special departments of engineering co-ordinate with the law departments.

Another institution that has done much to bring the center of engineering education further south is Vanderbilt University, and, if we include Missouri in the South, we can add two other institutions, Washington University at St. Louis and the State University at Columbia—the former of which is one of the leading engineering schools on the American continent. If to this short list we add the University of Texas, at Austin, the list of universities that offer engineering courses will be nearly complete. However, it is well to note that all these universities—University of Virginia, Washington and Lee, Vanderbilt, Washington University, University of Missouri—in fact, all, save the University of Texas, have a separate department of engineering, notwithstanding the fact that the University of Texas is better equipped for engineering work than any one on the list except Washington University at St. Louis:

If to this list of universities we add several agricultural and mechanical colleges that have engineering courses, we shall have a complete list of all the forces at work.

Then, summing up, we see that the vast belt of Gulf States, from Virginia to Texas, and those south of Ohio, is occupied by about a half-dozen universities that offer engineering courses. To those who would be disposed to extend this list, I would say that I have purposely omitted those institutions that have a course in engineering attached as a rider to the chairs of mathematics or physics. I have mentioned those that seriously offer courses in engineering subjects.

Having given this review of the forces that have done their work in the past and are still in the field, I come to a consideration of the needs of engineering education in the South. The number of engineering schools is insignificant when considered in connection with the area covered and the resources of this region. Many of our Southern States have State universities with well equipped law departments, but few of them have a corresponding engineering department, notwithstanding the fact that upon the engineer must always fall the responsibilities of developing the resources of the State or nation. We complain of having to ship our cotton to New England and buy it back in its fabricated state, but until the South takes the problem in its own hands by establishing engineering and industrial schools, we shall depend upon Northern mills to work up our raw material, and upon Northern trained men to superintend our industrial enterprises. When Thomas Jefferson was having his long fight in establishing the University of Virginia, he urged upon the legislature of the Old Dominion the necessity of higher education, and assigned as the principal reason for its creation the now self-evident truth that no State could hold its place in the onward march unless it provided means for training the statesmen that practically make the State. It can be added with just as much truth that no country or State can keep its place in the commercial world that does not provide within its own borders means for developing its raw material, whether of mind or matter. For the last twenty years Japan has had some of its subjects in nearly every prominent engineering school in the world, and, in addition to this, about ten years ago she called an American, J. A. L. Waddell, a Troy man, to the chair of civil engineering in the Royal University at Tokio. She sent her students to England to study law, to Germany to study military science, and to America to study engineering; and what is the result? Read the daily dispatches for the last three months, and you will see that no further argument is needed as to the necessity of engineering education. We trust that no such martial reason will ever require us to enter the lists; but we are fighting for commercial supremacy, and as long as we depend on other people to educate our industrial leaders, why, we'll continue to fight without any tangible result in sight.

Is it not more logical to spend the money of the commonwealth in training men to bridle the forces of nature, to blast our rocks and dam our rivers, to make the waste places of the Southwest glad with a perennial stream from the Rio Grande, than to spend money in educating men in other fields, whose after efforts can be no more than the efforts of a private citizen? The profession of engineering in the South (and it is a distinct profession) has been fed from every English-speaking clime under the sun, and the recruits, having fulfilled their special appointments, have left the land as dearth of resident engineers as it was before their advent. We must apply the same principles to our industrial enterprises that influenced Jefferson when he was working for higher education in Virginia. We must stop bringing our engineers from other climes, and we must depend upon ourselves for our own leaders. It is folly to rethresh the old dry straw about State's rights; to uphold the doctrine that the State is able to direct its own affairs and to control its own commercial destiny, and then follow this argument by a refusal to provide for the training of our young men in the engineering branches. I don't suppose any one will understand me to limit the term engineering to the ordinarily accepted meaning, which is usually restricted to civil engineering. I use it in its broadest sense, and in this sense it includes all industrial education; in fact, wherever mathematics is applied to utilize the forces of nature for man's benefit. It should commence in the city high school, if not in the lower grades, in the shape of manual training.

Almost every day we read in the papers about some bridge disaster, some water tank failure, or the collapse of some public building. Our own State is covered by a system of iron highway bridges, 10 per cent of which would not pass any board of expert bridge engineers that could be named. Right here is an argument of everyday life that ought to appeal to every county commissioner in the State. A bridge of a certain span is to be erected. The commissioners court receives several bids, and generally accepts the lowest. The highway bridge companies are represented by drummers who "skin" the bridge, yes, even take off the flesh, and in some cases take out essential bones, and by so doing underbid other companies. Every drummer submits plans that he thinks will win, and these are often arranged to catch the eye. To such a demoralized condition has highway bridge lettings descended that reputable bridge companies have withdrawn from that branch of the trade.

An agent (not an engineer) recently sent the following telegram to several bridge companies: "*Wire me at once the lowest price for which you will deliver a highway bridge—span 100 feet, and width 14 feet, factor of safety 4.*" And this under the shadow of our great capitol! Bids were even submitted based on these "wild cat" outlines.

County commissioners who are in other respects shrewd business men adopt methods in dealing with county bridges that do not obtain in other business affairs. In erecting public buildings a design by some well known architect is adopted, and after this is adopted bids are invited upon a specific structure. It would be just as reasonable to ask for bids to erect a court house one hundred feet square, with a certain number of rooms, with no other specifications, as to ask for bids for a bridge to span a certain creek. Again, it would be as reasonable to buy a horse simply because he is sixteen hands high and weighs one thousand pounds, as to buy a bridge of one hundred feet span and sixteen feet in width. Let our commissioners have their bridges designed by competent bridge engineers, with a complete set of drawings, and after these are obtained, invite bids for the erection of this particular bridge, according to specifications and under the supervision of the designer, or of a good engineer. The ordinary bridge drummer or agent is about as capable of designing a good bridge as a saw-and-hammer carpenter is of designing our State capitol at Austin.

It is a patent fact that a larger per cent of students go north to study engineering than any other professional course, and for the simple reason that we do not, at the University of Texas, dignify our engineering course by making it co-ordinate with the law department.

I claim that the State, as a matter of safety to itself, must offer higher education in law, and medicine, and engineering. When trained men go out from our law department, and when their influence is felt in the counsels of the State, we will not witness two co-ordinate branches of our higher courts giving diametrically opposite decisions as to the valadity of a common law marriage. When engineering is placed on a footing of co-ordinate importance with law and medicine, and when students, in inspecting our catalogue, can see that we dignify that profession that must be the pioneer in all industrial enterprises, then the current of Northern-bound engineering students will stop, and not before.

Discussion by Chas. Corner, engineer of the State Railroad Commission, and Dr. G. B. Halsted, President of the Academy.

Mr. Charles Corner, associate member, Institute Civil Engineers, said: "I don't know that there is much more to say on the subject. The Nineteenth century development is made largely what it is by civil engineering. It is unfortunate that engineering education is not more encouraged. Our highways and our bridges are faulty. If we have to put up a water supply, or develop the resources of the State, there is hardly any one able to take the work in hand. We must train our youth, and protect them."

Dr. Halsted: "Civil engineering was a branch of my own school. There was no such department when I came here. I was elected Professor of Pure and Applied Mathematics. I pushed at once for the appointment of a man who should be specially adapted in this particular line. It was a long time before I got recognition. The place was made an adjunct to the chair of mathematics. My idea was to make it independent, and that all supervision should be entirely removed. Professor Taylor succeeded in getting a special appropriation of $4000 from the Twenty-third Legislature to equip the school of applied mathematics. The next move is to raise this to a separate Department. Now we should have an engineering department second to none in the South. Our aim is to raise the dignity of this profession right here in the State of Texas. We are now in the midst of a battle. You know that science always wins. [Cheers.] The people know a good thing is desirable. Put the department where good can be done to science in general.''

Dr. Keiller expressed his good wishes for the department of engineering, and hoped the battle will be a victory. '' We hope to turn out men able to superintend great industrial works. I think it a great disadvantage to have us of the Medical College separated from the rest of the University. It tends to make us more one-sided. We are particularly obliged to Dr. Halsted for coming down once a year to Galveston."

Professor Taylor: ''I have just been told by Dr. Clopton that he was approached last fall by a young man who wanted to take a course in civil engineering, and he asked Dr. Clopton's advice as to what university he should enter. The doctor recommended the University of Texas, but the young man said he would not go there, as civil engineering appeared to be a subordinate branch as given in our catalogue. This emphasizes clearly the necessity of making our engineering course prominent in our catalogue in order to show what we are actually doing.''

THE PHONETIC ARITHMETIC OF THE ANCIENT MEXICANS.

BY DAVID CERNA, M. D., PH. D.

Demonstrator of Physiology and Lecturer on the History of Medicine in the Medical Department of the University of Texas, etc.

The value of the forms of speech in determining the relation and descent of nations has been steadily increasing as the correct principles of application have been more clearly defined and its positive results recognized. The proper comparison of language must be instituted from two directions—the one, the similarity of their words, or *lexical identity*; the other, the similarity of their formation of sentences, or *grammatical structure*.—BRINTON.

Not strictly as an original investigation, but as an introduction to the subject therein treated of, I offer this paper to the Academy, that in view of it some of the fellows or members of this scientific body may institute further studies in an almost inexhaustible field, particularly those students especially interested in philology.

What a series of striking similarities, indeed, exists between ancient western civilization, as exemplified by the Mexicans and the Peruvians, and eastern civilization of old, as met with among the various races of that part of the world. Could there have been at one time a direct communication between the West and the East, particularly between this continent and Asia? Speaking of the subject with special reference to the ancient Mexicans, Chevallier has said: "It may be conceived that Asia, the common mother of all the civilizations of the ancient world, had contributed in some part to furnish the elements of Mexican society, or had at least supplied a contingent to the religious notions and to the science of Anahuac nations. Traditions, which come near in various points to our Biblical revelations, and which are to be found, sometimes with a slight modification, in the religions of Asia, would seem to have reached them from thence. * * * At the epoch when China, having more vitality than at the present day, felt the need of room—though since that its every effort has been for segregation—the spirit of commerce and religious propagandism impelled men to track that immense causeway of more than three thousand miles long—sometimes submarine, and at others making its appearance in archipelagos stretched along the surface of the waters—which connects the most beautiful regions of Asia with the New World. Two hundred years before the Christian Era, the Chinese annals mention the mystical expedition of Tain-Chi-Houang-si, who explored the Oriental seas ' to find an elixir that confers immortality to the soul.' These trading and seafaring nations possessed of old the mariner's compass. We are then, perhaps, warranted in conjecturing that some, at least, of their navigators found their way to the New Continent.''

When we examine closely the physiognomy of the Asiatics of the far East, we are struck by the resemblance between these peoples and the ancient Mexicans, a resemblance that is really remarkable. And, as Humboldt has observed: ''We cannot refuse to admit that the human species presents no races more allied than those of the Americans, the Mongol, the Mantchoo, and the Malay.''

The number of analogies is great between the Mexicans and some of the peoples of the Old Continent; for instance, the Basques, descendants of the Vascons, a tribe of Iberians, who are believed to be the oldest inhabitants of Spain. It is affirmed by some writers that the Basque has no relation with the rest of the European languages; and yet, singularly enough, it is closely related with the American languages, especially with that of the Nahoas, or the *Nahuatl.* The Basque is said to be an incorporative language. A striking similarity, even in the nasal pronunciation, between the Chinese and the Otoml, one of the most extensive languages of Old Mexico, has been established. Again, the arithmetical combination of the numbers 4 and 20 of the Nahoas is also met with in the arithmetic of the Basques. We are reminded, once more, of the same combination in the four twenties of the Irish and of the French, both of which peoples, undoubtedly, derived it from the Celts, and these from still more ancient races. But, be all this as it may, the relations between Western and Eastern civilizations are worthy of being studied further, not only historically, but scientifically also.

It would hardly be necessary for me to remind this audience of the origin of the modern arithmetical system of numbers. Suffice it to say, that to attribute this system to the Arabs, as is sometimes done, is not correct. The Arabs learned the system from the Hindoos, and the Arabs themselves refer to the true origin of the notation. Of the ten numerals the cipher represents nothing *per se*; but when placed to the right of any one of the other numbers once it increases its value tenfold; when placed twice, a hundredfold; when placed thrice, a thousandfold, and so on. No doubt this system was based on the fingers, which give us its base, the number 10. The Romans, it will be remembered, employed seven characters to express certain numbers, that is I, one; V, five; X, ten; L, fifty; C, one hundred; D, five hundred; and M, one thousand. The Greek system used letters. The decimal system of notation used now by all civilized communities, was, undoubtedly, derived from the Hindoos.

Still another system, the so-called duodecimal, must not be forgotten, In this we may count by means of the thumb, upon the upper, middle, and lower row of phalanges of the other four fingers. Thus, the first row of phalanges would give us 1, 2, 3, and 4; the second row, 5, 6, 7, and 8; the third row, 9, 10, 11, and 12. The advantage of this system lies in the fact that easy calculations by divisions can be made, which give as the result a whole number, whether the division be made by 2, 3, or 4. That there is advantage in this, is apparent from the fact that, for instance, we divide the foot into 12 inches, the inch into twelve lines, and the line into 12 points.

In studying the system of phonetic arithmetic employed by the ancient Mexicans, we first have to deal with the Nahoas, among the first, if not the first, of the civilized races inhabiting Anahuac of old. The Nahoas were a polysyllabic race, whose historical record bears the impress of its having had a foreign origin. Absolutely ignorant of this origin, the only thing we possess, so far, is a more or less accurate knowledge of the civilization of the Nahoas, the predecessors of the great Toltecs, from studies of their hieroglyphical writings.

Orozco y Berra, who follows Gama on the subject, states that the formation of the numerals among the Nahoas originated in the five fingers of one hand. By computing, afterward, the fingers of the other hand, the number 10 is obtained, and counting, again, the toes of both feet, the number 20 is formed.

To designate the first four numbers single words are used; thus, 1 is known as *ce* or *cem*; 2, as *ome*; 3, as *yei* or *ei*; and 4, as *nahui*. Above these four numerals, for each succeeding number, as far as 9 inclusive, a compound term is employed. Thus, 5 is called *macuilli*. This name, to follow Gama, is derived from the compound verb *macueloa*, the latter word in turn being composed of *maitl*, the hand, and the simple verb *cueloa*, to double or bend upon itself. Orozco y Berra, again, believes that the word *mapilli* is derived from *maitl*, the hand, and *pilli*, child or son; and thus it signifies, figuratively speaking, the children or the appendices of the hand. Now, *macuilli*, formed from *maitl*, the hand, the verb *cui*, to take, and *pilli*, or simply *illi*, referring to the appendices or digits, would mean *the fingers taken with the hand*, or the fist. This author, then, entertains the idea that the first five units are counted according as each finger of the hand is being bent upon itself, until the fist is formed. He finds, also, that the words *xopilli*, toes of the feet, and *macpalli*, palm of the hand, have a similar origin.

The numbers 6 to 9 inclusive, are expressed likewise by compound terms, thus: *checuace*, 6; *chicome*, 7; *chicuei*, 8; and *chiconahui*, 9. According to Gama, *chicoace* or *chicuace* is formed from the verb *chico*, which means *by my side*, and the preposition *huan*, meaning *near another*, the whole term *chicohuance*, of which *chicoace* is a contraction, signifies *one* *along side* or *near the others*. Sometimes the term *chico* means *half*, as in the words *chicocua*, *chicocahua*, *chicocuatic*, etc. The particle *a*, among its various significations, has that of *like;* so that *chico-a* means *half of the hands*, or *like one-half of the hands*. Therefore, *chico-a-ce*, *chicu-ome* (*chicome*), *chicu-ei*, and *chicu-nahui*, being the first four numerals added to the word *chocua*, signify respectively, the *half of two hands*, or, *one hand plus one*, *one hand plus two*, *one hand plus three*, and *one hand plus four*, that is, 6, 7, 8, and 9.

The number 10 is expressed by the term *matlactli*, from *maitl* and *tlactle*, meaning the *body of man from the waist upwards*, or *the superior extremities of man*. *Maculli* is, then, a closed hand; *matlactli*, two closed hands. The next four numbers are formed by adding to the word *matlactli* the four fundamental digital expressions linked by the syllable *on* or *om* in the sense of *more*, thus: *matlactli-on-ce*, two hands plus one, 11; *matlactli-om-ome*, two hands plus two, 12; *matlactli-om-ei*, two hands plus three, 13; and *matlactli-on-nahui*, two hands plus four, 14.

The word *caxtolli* or *caxtulli* is used to express the number 15. The numbers 16, 17, 18, and 19 are formed in a similar manner to the ones just described, that is, by uniting to the word *caxtolli* the four fundamental digital numerals by means of the ligature *on* or *om*, thus: *caxtolli-on-ce*, 15+1, 16; *caxtolli-om-ome*, 15+2, 17; *caxtolli-om-ei*, 15+3, 18; and *caxtolli-on-nahui*, 15+4, 19. But Orozco y Berra gives no explanation as to the meaning of the word *caxtolli*, simply stating that it stands for 15.

For the number 20 the word *cempohualli* is employed. It is composed of *cem*, one, and *pohuailli*, a count, that is, it means *the putting together of twenty individual units*. A further analysis of the term would seem to give *cem*, one; *poa*, to count, and *pilli* or *lli*, the appendices, the whole term, *cem-poa-tli* or *cempohualli*, then, meaning *a count of the appendages*. Therefore, says Orozco y Berra, the number 20 is the number par excellence of the Nahoas; it is the I, the individual, composed of four parts, that is, two hands and two feet, each one of these parts having five appendices, or 5 multiplied by four.

More recent investigations, however, do not seem to support the conclusions arrived at by Gama and Orozco y Berra. For, if we examine carefully the true origin of the words used, that is, their etymology, or again, take into consideration the logical reason, so to speak, of their application, it becomes evident that such conclusions are not entirely correct.

The studies of Ramirez, and especially those of Chavero, furnish probably the only correct interpretation of the phonetic system of arithmetic used by the Nahoas; a system which, when considered otherwise than phonetically, differed materially from that of the Hindoos. For example, among the Hindoos, it will be remembered, 10 is the principal number, the basis. Their perfect series was from 1 to 10. This 10 was again considered as the first term for later progressive series, and constantly used as the multiplier. Among the Nahoas the essential numbers were four and five, this leading to the perfect series from 1 to 20. The 20 was the result of 5 multiplied by 4, and for later progressive series the 20 was employed as the common multiplier; but in the development of their progressive series the last term was only 80, or 20 multiplied by 4.

Again, unlike the symbolic numbers of the eastern nation, which were the 3, 5, 7, 9, and 10, the symbolic numbers of the Nahoas were the 2, 4, 9, 13, and 20, all these being formed on a combination of the 1 and the 4. Thus: 1+1=2. The two was represented by *Ometecuhtli*, the chief god, the word meaning two gods, or two in the same person, this being the basis of their dualistic religion. The same number 2 was represented by the *Omeyocan*, the highest of the heavens, where *Ometecuhtli* was placed. *Omeyocan* means similarly two places, or two places in one. The number 4 stands for the four suns, the four seasons, the four initial signs of the days. The 1+4, or 5, signifies the five suns of the Mexica, a later tribe, the five days of the *tianquiztli*, the period of five centuries. The 1+4+4, or 9, means the nine months of the half year, a whole year being composed of eighteen months. The 1+4+4+4, or 13, has reference to the number of years of each one of the four *tlapilli* in which the century of 52 years was divided. Finally, 1+4, or 5, multiplied by 4 produces 20, this latter number representing the 20 days of each month, or the perfect series of 1 to 20 inclusive.

As has been observed, only the first four numbers are spoken of as, or expressed by, simple words, that is, *ce* or *cem* 1, *ome* 2, *yei* or *ei* 3, and *nahui* 4. The first fifth, or 5, is called *macuilli*, and the four numbers succeeding it take in the first four initial digits; that is, *chicuace*, 6; *chicone*, 7; *chicuei*, 8; and *chiconahui*, 9. The second fifth, or 10, has also a distinct appellation, that of *matlactli*, and each one of the succeeding numbers up to 14 inclusive, is composed of the word *matlactli*, incorporating with it, respectively, the same four initial numbers and the particle *on* or *om*, that is, *matlactli-on-ce*, 11; *matlactli-om-ome*, 12; *matlactli-om-ei*, 13; and *matlactli-on-nahui*, 14. For the third fifth, or 15, there is likewise a separate name, that of *caxtolli*, which serves as a basis for the next four numbers up to 19 inclusive, each one of these, again, being composed of the term *caxtolli*, the particle *on* or *om*, and the first four initial numbers, respectively, as follows: *caxtolli-on-ce*, 16; *caxtolli-on-ome*, 17; *caxtolli-om-ei*, 18; and *caxtolli-on-nahui*, 19. Finally, the fourth fifth, or 20, has once more its own name, that of *cempohualli*.

It becomes evident, therefore, that the Nahoas intended always to make a marked distinction of the first four initial numerals, to differentiate them from the fifth, carrying the same distinction up to the 20th, this latter one constituting the initial number of the progressive series. They did not take the 5 for a basis in the way we use 10, as has been supposed. According to Ramirez, from the careful examination of a manuscript, it is clearly made out that the Nahoas formed the number 5 by the act of summing up the four fingers of one hand with its corresponding thumb.

The question arises, then, did the Nahoas use the fingers of both hands and the toes of both feet to construct the first perfect series of 20, as believed by Orozco y Berra? Evidently not; nor does it seem that they even employed the fingers of both hands. The whole procedure seems to have been confined to the use of one hand. Chavero furnishes the evidence of this statement, taking into consideration the etymology of the very words employed to designate the numbers.

In modern times we speak of the appendices of the hand as the little finger, the ring finger, the middle finger, the index finger, and the thumb, referring to their uses, their size, or their position in that extremity. It appears that the Nahoas named the digits on a similar basis.

Chavero's explanation of the formation of the first perfect series of numerical notation is so scientifically plausible, that I, for one, accept it as the true one. It is as follows: The various fruits being among the primitive articles of food employed by the Nahoas, as among other peoples in the first stages of their civilization, it is reasonable to suppose that they designated them by single names, in accordance with the absolute necessity of conveying an idea as to the size, stage of ripeness, and taste of such fruits. For instance, the Nahoas called a fresh and green fruit by the name of *celeltic*; the ripe fruit they designated by the term *omacic;* and when the fruit had a good taste, they spoke of it as being *yectli.* To qualify a person or thing of a regular or an average size, the Nahoas employed the word *nahuatile.* It appears that the words just referred to were the basis upon which the Nahoas built their system of phonetic classification of numerals. Thus, the little finger they called *ce*, from *celeltic*, comparing it to the first stage of a fruit, this being small in size and green in condition. When the fruit is almost ripe, it assumes a larger size, and, therefore, from *omacic* they took the particle *ome*, to mean No. 2, to designate in this case the second finger, which is larger than the first. The fully developed fruit, thoroughly ripe, exhibits at this time its most agreeable taste; hence to the middle finger corresponds the No. 3, or *yei*, from *yectli*, a good thing. The fourth finger is not so large as the third or middle finger; it is of an average size, and, therefore, *nahui*, from *nahuatile* was employed to designate the No. 4 or the fourth finger. It can be said, then, that the names of the first four numerals were practically the same words used to designate the size of the four fingers of the hand, and that these, together with the thumb, formed the first count, or five.

It will be remembered that, according to Gama and Orozco y Berra, *macuilli* signifies the closed hand, or fist, or No. 5, it being a compound word, made up of *maitl* hand, *cui* to take, and *pilli*, or simply *lli*, the appendices, the whole term meaning that the first units were counted by bending the fingers, one by one, upon the palm of the hand, until the fist was produced. But, if this were so, that is, if the word *macuilli* were meant to signify a closed hand or fist, it would, undoubtedly, be so represented in the hieroglyphical writings of the Nahoas. And yet this is not the case. On the contrary, the No. 5 is represented by an open or stretched out hand. By a close observation it is found, that the names of Nos. 5, 10, 15, and 20 terminate with the particle *tli* or *li*, which may be translated by *the which, that, which*, or *who*. Referring especially to the No. 5, *tli* or *li* is the thumb which has made the count of the other fingers. *Maitl*, hand; *cuilia*, to take; *tli* or *li*, the which, that which, or who. Hence, *ma-cuil-li*, would mean *he or it that takes the hand of another*. When we shake hands, notice that it is mainly by the aid of the thumb that we hold the hand that is offered us. The four initial numbers of the Nahoas were, then, called as follows: *ce* or *cem*, No. 1, the smallest finger or digit; *ome*, No. 2, the next finger, which is larger than the first; *yei*, No. 3, the largest or longest finger; *nahui*, No. 4, the regular or average-sized finger; and *macuilli*, No. 5, the finger which takes the hand of another, or which counts the other fingers, and then by itself stands for No. 5, or the thumb. In the open hand, therefore, and not in the fist, we have the fundamental formula of the Nahoan numerical notation.

For Nos. 6, 7, 8, and 9, the thumb again is called upon to act on the other fingers, by bringing them on the palm of the hand. Thus, for the No. 6 the word *chicuace* is employed. This word is derived from *chico*, in an opposing manner; *val*, towards oneself; and *ce*, No. 1; that is, *chicuace*, 6, means *to bring towards oneself the No. 1, to bend upon the hand the little or first finger*. And so with the other words: *chicome*, 7, to bend upon the hand the second finger; *chicuei*, 8, to bend upon the hand the third finger; and *chiconahui*, 9, to bend upon the hand the fourth finger. When the four fingers are bent, and the thumb is placed over them, forming the fist, the hand is reduced to one-half of its original height, and hence, the No. 10 is designated by the word *matlactli*, from *matl*, hand, *tlac-ol*, half, and *tli* or *li*, the which, that which or who; that is, *matlactli*, 10, *he or it that had reduced the hand to half of its original height by bending the fingers*. If now the thumb separates the other four fingers, one by one, by simply raising them, the Nos. 11, 12, 13, and 14 are obtained: *matlactlionce*, *matlactliomome*, *matlactliomei*, and *matlactlionnahui*.

The words are composed of that representing the fist or half-hand, *matlactli*, those of the fingers, respectively, and the particle *on or om*, which in this instance signifies *to separate*, *to take away from the place*. Therefore, *matlactli-on-ce*, 11, means *1 separated from the half-hand or fist; matlactli-om-ome*, 12, 2 separated from the fist; *matlactli-om-ei*, 13, 3 separated from the fist; and *matlactli-on-nahui*, 14, 4 separated from the fist. At the end of this act of unbending the fingers, the thumb becomes itself the number 15, or stands for that number. And that is precisely what the word employed to designate it, *caxtolli*, means. It is formed from *cax-acua*, to loosen, *tol-oa*, to lower or to bend, and the suffix *tli* or *li*, the which; that is, *he or it that has loosened the bent fingers.*

Three positions of the hand are so far brought about. It is entirely open for the first five numbers; for the second five numbers it is made to assume the form of the fist; and for the third five numbers the hand becomes half open, in the prehensile form. If, after this latter position has been assumed, the thumb brings together the other fingers, or joins them, one by one, completing the prehensory act of the digits, not of the hand, then the numbers 16, 17, 18, and 19, are produced. The thumb separates the fingers from their prehensile position and brings them together. Thus, *caxtollionce*, 16, *1 separated from 15; caxtolliomome*, 17, *2 separated from 15*; *caxtolliomei*, 18, *3 separated from 15*; and *caxotllionnahui*, 19, *4 separated from 15*. The fingers being placed together by their tips, the thumb represents now or makes the No. 20, for which the term *cempohualli* is employed. The word originates from the unit *cem* or *ce;* the verb *po-a*, to count; *hual*, towards here; and the suffix *tli* or *li*, the which; that is, *cempohualli*, 20, *he or it that has made a count by bringing the fingers together*. To resume, the numbers 1, 2, 3, 4, and 5 are represented by the entirely open or stretched out hand; Nos. 6, 7, 8, 9, and 10, by bending the fingers until the fist is formed; 11, 12, 13, 14, and 15, by the hand in the prehensile form, half open; and 16, 17, 18, 19, and 20, by the completion of the prehensory act by the tips of the fingers.

A great deal more could be said about the matter, but this article is already long enough. Before closing it, however, I may say that the words used for the intermediate numbers from 20 to 80 are constructed in a very simple manner. In the first place, to the word *pohualli* is added the prefix *cem* for the formation of *cempohualli*, 20; that of *om* for the formation of *ompohualli*, 40; that of *yei* for the formation of *yeipohualli*, 60, and that of *nauh* for the formation of *nauhpohualli*, 80. These are the four progressive series, that is *cemopohualli*, 20; one twenty, or 1 multiplied by twenty; *ompohualli*, 40, two twenties, or 2 multiplied by 20; *yeipohualli*, 60, three twenties, or 3 multiplied by 20; and *nauhpohualli*, 80, four twenties, or 4 multiplied by 20. The intermediate numbers of the latter three series are formed by adding to the word of the respective series the particle *on* or *om*, which now stands for *plus*, and that of each one of the first series up to 19 inclusive. For example, *cempohuallionce* 21, 20+1; *cempohualliomome* 22, 20+2; *cempohualliomei* 23, 20+3; *cempohuallionnahui* 24, 20+4; *cempohuallionmacuilli* 25, 20+5, etc. And so with the intermediate numbers of each one of the other two progressive series.

The number 80 is also known by the name of *xihuitl*, which among its various significations has that of year and grass. Combining the word *xihuitl* with that of each one of the four series respectively, bringing into account addition and multiplication, the Nahoas arrive only as far as 80 multiplied by 80 or 6400, contrary to the opinion of Humboldt and Orozco y Berra. This latter affirms that by combining the primitive words, *ce* (1), *ome* (2), *yei* (3), *nahui* (4), *macuilli* (5), *matlactli* (10), *caxtolli* (15), *cempohualli* (20), *tzontli* (400), and *xiquipilli* (8000), also, through multiplication and addition, any quantity imaginable can be formed.

In the preparation of this imperfect article, I have carefully consulted the works mentioned in the appended list of bibliographical references, and espectally the monumental productions of my distinguished compatriots Manuel Orozco y Berra and Alfredo Chavero.

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NOTES ON THE TEXAS TERTIARIES.

BY E. T. DUMBLE, STATE GEOLOGIST.

Read June 19th. 1894.

In my report on the geology of Southwest Texas, which is now awaiting publication as a part of the Fifth Annual Report of the Geological Survey of Texas, I have proposed a division of the Tertiary and later deposits of the Coastal Plain somewhat different to that which has been used in previous reports. This change was made necessary by the new stratigraphic evidence secured in making the Nueces section and the results of the studies of our collections of fossil shells from various localities in this area by Prof. Gilbert D. Harris.

These divisions, with such correlation as seems to be warranted by the facts now before us, are:

Pleistocene	Coast sands, stream deposits, etc.	
	Coast clays	Port Hudson.
	Equus beds.	
Neocene	Reynosa—Orange Sand.	
	Lagarto.	
	Lapara	Blanco.
	Oakville—Deep Well.	
Eocene	Frio	Lower Claiborne.
	Fayette	Lower Claiborne.
	Yegua	Lower Claiborne.
	Marine	Lower Claiborne.
	Lignitic	Lignitic.
	Basal clays	Midway.

Of these divisions, all below the Fayette have been sufficiently well defined in our various publications. The Fayette, however, is now limited to the basal sandy portion of the beds originally bearing the name, a marked characteristic of which, throughout a large portion of its extent, is the opalized wood it contains. This is succeeded on the Nueces by a series of clays which weather white, which are well exposed at the mouth of the Frio, and are called the Frio clays. With their deposition the Eocene deposits of Texas came to an end, so far as we have any present evidence, and a long period intervened in which the area was dry land.

The succeeding deposits are sands, which in many respects closely resemble those of the Fayette, of which they have hitherto been regarded as a part. They differ, however, in not having the opalized wood, and in that the fossils in the later beds are vertebrate remains of species characteristic of the Loup Fork, while the shells of the Fayette are plainly Lower Claiborne species. These beds form the surface rocks around Oakville, and I have used that name to designate them.

The Lapara beds which follow these are the coastal representative of the Blanco beds of the Llano Estacado, being similar in physical character and fossil contents.

The Lagarto beds include a series of sands and clays of light colors containing considerable quantities of manganese and seamed with lime.

The Reynosa has the widest distribution of any of the beds of the Neocene. It consists of beds of gravel cemented by lime, tufaceous limestone, and interbedded clays, limy sands and limy clays. To the east this is replaced by the Orange Sand phase. It forms the crests of the divides, and south of the great bend of the Nueces spreads out in a plateau closely homologous to that of the Llano Estacado.

The Neocene deposits, as a whole, represent a period of lacustrine, fluviatile, and estuarine deposits, the only marine conditions of the region being those indicated in the Galveston Deep Well section.

Prior to the deposition of the Equus, or basal beds of the Pleistocene, considerable erosion took place in the underlying Reynosa, and those beds were laid down in the channels thus formed. They are the direct correlatives of the Equus beds of the Llano Estacado, and are followed by the Coast Clays or Port Hudson group of Hilgard, which along the coast are in turn replaced by the Coast Sands.

Such, in brief, are the different members of the Post-Cretaceous deposits of the Coastal Slope, the details of which will be found more fully given in the report already referred to and in a short paper entitled "The Cenozoic Deposits of Texas."*

A recent trip along the line of the International and Great Northern Railroad from Houston to Palestine gave some details which are of interest.

Reynosa-Orange Sand.—At Houston we find at the surface a mottled sandy clay such as has, at places further west, been taken as the base of the Coast Clays. It is underlaid by red and greenish clays with calcareous nodules and bands, and containing manganese as well as ferruginous pebbles. Along Buffalo Bayou and in the railroad cuts these beds are well exposed, and are capped in the vicinity of the bayou with sand.

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*Journal of Geology, Sept.-Oct., 1894, pp. 549–567.

From Houston to Spring, no cuts of any depth occur to show anything, but at the tank north of Spring Creek there is an excellent exposure of Orange Sand. From this point to Conroes the Orange Sand, with a covering of brown sand, is to be found in many places. In one or two localities the Orange Sand rests on a coarse white sandrock, the first appearance being near the 121st mile post. Between Conroes and Willis the sandrock becomes more prominent, being capped in most places by Orange Sands, which form the surface at Willis, the wells dug there showing them to have a thickness of 65 feet. It was found that in plaees the Reynosa phase was clearly present in the Orange Sand, adding fresh reason for regarding them as one and the same bed.

Lapara-Lagarto Beds.—Just north of Willis we find gray and brown clays with calcareous concretions passing upward into a sandy shale. This is the sandrock previously noted, and shows cross-bedding. These brown clays, with calcareous concretions and siliceous pebbles, form the surface for some distance, with an occasional capping of Orange Sand. Continuing northward, the clays appear as interbedded sand and clay, in which the dun clays are highly calcareous, with the lime in pockets and some clay pebbles or balls. The sands weather black and closely resemble those at Chappell Hill. The characteristics of these beds further west are reproduced in a measure, but here they do not seem to present that great variability and the sudden changes which are such prominent features in them there. The exposures are not very numerous between Kelly and Phelps, nor, indeed, until within a mile of Huntsville, when the country becomes more broken, and good exposures may be seen of these interbedded light colored clays and sands, resting on a sandstone. In and around Huntsville there are numerous exposures of these beds. The Sam Houston Normal College rests on a bed of Orange Sand, while the gully to the north shows the Lagarto Clays almost as well as at the type locality.

Oakville Beds.—A little more than four miles from Huntsville, on the Riverside road, we find the first exposure of the Oakville beds as a calcareous sandstone, with concretions of calcareous clay and containing an imprint of a palmetto. From this point to the vicinity of Riverside frequent exposures of this character were found, but it was not until we neared that place that a really compact sandstone was observed. The Riverside sandstones have been heretofore regarded by us as belonging to the Fayette sands, and were largely the cause of our early reference of the Fayette sands to the Grand Gulf of Hilgard, Loughridge having so referred these sandstones in his paper, "Report on Cotton Production," in the Reports of the Tenth Census. My examination of them, however, shows conclusively that they belong to the Oakville beds, and not to the Fayette. They comprise two members: A series of interbedded sands and clays underlaid by a bed of massive sandstone. In the upper member the sands predominate, the clays being in thin seams, some of which carry thin sheets of lignitic matter. Some little iron is present, and in places it so closely resembles the Orange Sand that it might easily be mistaken for it. This member is apparently unconformable on the one below it. The sandstone is massive and somewhat cross-bedded, its upper surface being very uneven. The grain is even, color light gray, and it contains a gray clay or kaolin in balls, pockets, and thin sheets. The balls of clay are sometimes coated with ferruginous matter. No fossils were found in these beds, although diligent search was made through them for the greater part of a day.

Frio Clays.—The Oakville beds rest directly upon the Frio clays, which are well shown in the river bank at Riverside as gray clay and sandy clay and red and blue clays weathering yellow or white, and closely resembling those observed on the Nueces River.

Fault.—At Riverside there is a well marked fault running, north 65 degrees east—south 65 degrees west by compass. The downthrow is on the north, and gives a strong dip to some of the beds. The throw is twenty to twenty-five feet, and along the fault the clays have been indurated and the sandstones altered to quartzite.

Fayette Sands.—Along the line of the railroad there are no decided exposures of these beds, but they occur on the Trinity at the old town of Cincinnati.

From Trinity north the geology has already been given by Kennedy in his paper in the Third Annual Report of the Geological Survey of Texas.

CORRELATION WITH GALVESTON DEEP WELL SECTION.

In plotting the results of this trip, I had the log of a deep well at the Huntsville Penitentiary, furnished me by Mr. C. H. Robinson of that institution, numerous shallow wells at various localities, and the deep well at Galveston, as studied by Singley and Harris. From these I find that the various beds thicken toward the coast, being in one case nearly double the thickness in the Galveston deep well section that they are at the southern edge of their outcrop.

The following table gives my present understanding of the relations of beds briefly mentioned above and those of the Galveston deep well:

Bed.	Area of Outcrop.	Galveston Deep Well.
Pleistocene	Galveston to Houston	0 to 468 ft.
Reynosa—Orange Sand	Houston to Willis	468 to 914 ft.
Laparo-Lagarto	Willis to Huntsville	914 to 2,138 ft.
Oakville	Huntsville to Riverside	2,138 to 2,920 ft.

The correlation of the Oakville beds with that portion of the well referred by Harris, from its marine molluscan fauna to the Upper Miocene, is offered because of my knowledge of the fossil contents of the Oakville beds at other localities, and the belief that it represents approximately the period of time embraced by the deep well beds, but with different conditions of deposition. No exposures have yet been found on the Coastal Slope which afford a fauna in anywise comparable with this portion of the deep well, but the Oakville beds appear to be stratigraphically their equivalent.

SOME MORPHOLOGICAL RELATIONSHIPS OF THE CACTACEÆ.

BY C. F. MAXWELL.

Read November 16, 1894.

Some time ago I discovered that seedling Cactaceæ did not at once assume the characters exhibited in the adult form, and the idea was conceived that in this fact might lie concealed some evidence concerning the true relationships of the genera of the group, or of the group itself to other plants; so some experiments were made by germinating seed of some of the genera and observing the changes of form. Living in a region where the cactaceæ are indigenous, many instances of young seedlings were found in the natural condition, and all have agreed with the results set forth in this paper.

The observations do not make a complete series, still there is enough to make some important suggestions; and while these are given, the hope is indulged to carry on the work in future.

It seemed to me from the start very peculiar that such changes should occur in a growing seedling, and the analogy to animal embryology, though it occurs in post-embryonic life, is so strong as not to be overlooked.

The genera studied so far have been Cactus (Mammillaria, Haw.,) Echinocactus, Cereus, and Opuntia. The seedlings have at first practically the same form in all; and its essential features are a somewhat conical body, point downwards, from which originate rootlets, the upper part terminating in two tubercular projections, between which is the growing point. Fig. 1, i. These tubercles remind one of cotyledons,

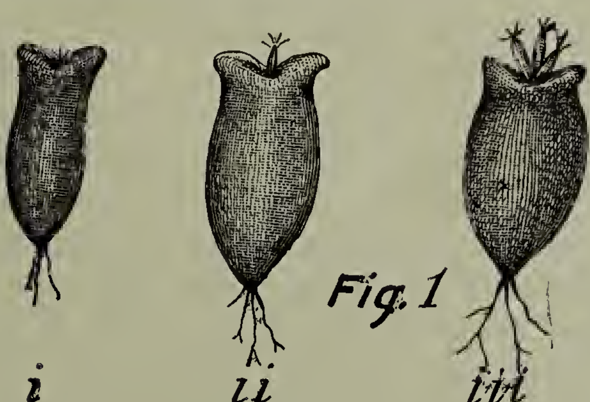


Fig. 1

and though they may bear some relation to them, as subsequent tubercles probably do to true leaves, still there is no reason except superficial appearance for regarding them as other than projections of the stem. They are the embryonic tubercles.

The growing point is indicated at first by only a few soft hairs, but soon a tubercle appears bearing the hairs on its summit. Fig. 1, ii. This is soon followed by another, and then others. Fig. 1, iii. Growth continues for quite a while this way, and if the plant is a Cactus, these tubercles with their spines assume the adult characters, and the process continues throughout life. But not so with the other genera. In Echinocactus, after a while the tuberclea seem to be flattened considerably at the base. This is due to the fact that they increase in size in a nearly perpendicular direction, but not in a vertical. This increase continues until all the space between two adjacent tubercles is filled with substance of the plant body, and ribs are formed. The spines then assume specific characters, and the changes cease. A diagramatic illustration of the idea is shown in Fig. 2, giving an outline appearance of a single rib.

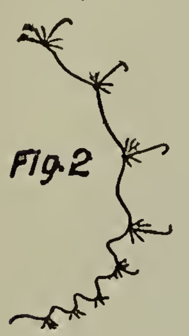


Fig. 2

These ribs may become vertical or spiral in thefollowing way: The arrangement of the tubercles is in the form of a quincunx, and if the growth is such that the tubercles unite as indicated by Fig. 3, vertical ribs are formed; but if the union occurs as in Fig. 4, the ribs are spiral.

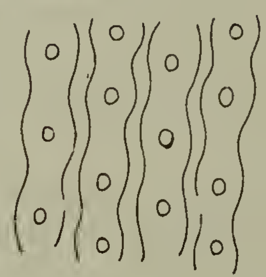


Fig. 3

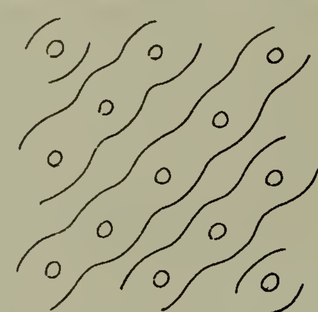
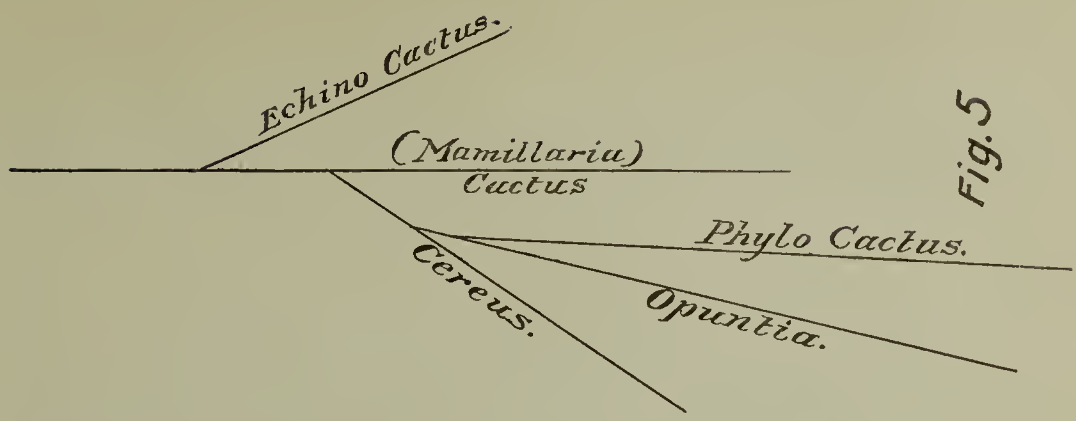


Fig. 4

In the case of Cereus and Opuntia the young tuberculate form begins to elongate, and the appearance is such that both would be taken for some form of cereus. They have cylindrical bodies and soft spines, and are more or less ribbed. Spines of cereus now assume their adult form, and opuntia begins to differentiate into its varied forms.

These observations lead me to the following conclusions: The type of the cactaceæ is a globose or oval plant body bearing tubercles on its surface, and is represented by the various forms of the genus Cactus, which has been lately re-established by Prof. Coulter instead of the Mammillaria of Hawthorn. This type has given rise to two forms, one a ribbed, globose or flattened body, as represented in Echinocactus; the other an elongated ribbed or slightly tuberculate body, which in turn differentiates into the various forms indicated by Cereus and Opuntia. It will be noticed that mature plants of these genera often exhibit a tendency to tuberculate forms, especially if it forms branches. With this fact before us, it will not be altogether unsafe to say that probably Phylocactus, which in the young shoot, or branch, shows a cylindrical, slightly tuberculate form bearing closely oppressed leaves, is nearly related to Opuntia. Observations have not been made on the seedlings of this genus.



The relationship then of these genera may be fairly represented by a diagram as shown in Fig. 5; and when further research is made, doubtless the whole order will show in the seedling, just how it was built up.

THE RELATION OF SCIENCE TO MODERN CIVILIZATION.

BY MAJOR CLARENCE E. DUTTON.

Read before the Texas Academy of Science, March 8, 1895.

My esteemed friend, Mr. Lester F. Ward, one of the profoundest thinkers, and a most luminous writer, in one of his fugitive papers draws a very forcible contrast between the world's moral and its material progress — between its advancement in the principles and practice of justice founded upon benevolence, or, as Herbert Spencer terms it, altruism, on the one hand, and its advancement in the production of those things which minister to our bodily comfort and sensual enjoyment. Ward thinks that moral progress has not been great. Some of it there has been, but much less than there ought to have been. Whatever has been gained along this line has been at a snail's pace, and when the much greater enlightenment of the world is considered it is now a little, and only a little, better morally than it was 2000 years ago. But when we contemplate its material progress, how vast the change! how swift of late, and yet swifter and swifter, the advancement!

Whoever inquires into the state of prevailing morality, with a view of estimating human progress, will probably reach conclusions which are largely dependent upon his own temperament and intellectual training. In all periods of the world there have been many good men, and some great ones, whose feelings have been harrowed by the prevailing depravity of their kind, and who are remembered chiefly for their lamentations over it, and for their exhortations to a better life. The spirit of Jeremiah never has been, and probably never will be, wholly laid. To such men the moral world presents a dark and dismal aspect, and they feel impelled to assume the attitude of the warning prophet. The colors of the rainbow look brighter the darker the pall of storm clouds behind them, and those who are chasing the rainbow of moral perfection and calling upon the world to follow them, seem to strengthen their appeals by painting the moral conditions of the present in the darkest possible shades.

On the other hand, the most optimistic must admit that the amount of vice and misery in the world is vastly greater than it ought to be. If old crimes have gone out of vogue, new ones have been invented. Jails are still big and roomy and well tenanted, and it may be said in all seriousness that if justice were fully done they would be bigger and more crowded still. Institutions of charity and correction continue to make heavy drafts upon public treasuries and upon the pockets of the benevolent, and the poor are still with us. Yet withal, he is blind, or else has converged his vision upon a narrow spot in the whole field of view, who does not plainly see that we are living in a much better world than that of our ancestry. Here it is necessary to make a distinction. If indeed it is meant that human nature, with its instincts for good or evil, which are a part of the animal man, has undergone no marked change, the proposition would have to be admitted at once. I suspect that the proportion of inborn congenital depravity on the one hand, and sense of justice and kindness on the other, is not very different at the present day from what it was in the days of Abraham, Job, or Augustus Cæsar. Possibly, though, there has been going on through the ages a slow process of modification by natural selection by which the hereditary animal instincts of man have been somewhat improved. But if so, the change has been so slight that it would be difficult to demonstrate it. Nor is there any valid ground of hope that in the next two thousand years the human animal will become materially better. Those who, like Henry George and Edward Bellamy, bewail the depravity of the present and picture a future society composed of angels, are only crying for the moon.

But if moral progress means improvement in the conditions under which the passions and instincts of human nature are exercised, the proposition is wholly changed. From this point of view not only has there been progress, but immense progress. The fields, the opportunities, the incentives for the exercise of the nobler and better qualities of human nature have been vastly increased, those for the exercise of the baser qualities have been in many ways and along many lines restricted. Human nature indeed with its mixed propensities for good and evil is either unchanged or changed but little. But its fields of action have changed immensely. The external constraints away from wrong and towards the right have grown stronger through the centuries and are incomparably more potent than they were a thousand or two thousand years ago. And this is the only kind of moral progress we can ever reasonably hope for.

But there is another aspect of the subject under which both moral and material progress are included; and that is the progress of human knowledge.

That the material progress of the world, which has become so swift during the present century, has come from increased knowledge of the laws of force and matter is sufficiently apparent to everyone. Nor is it less true that improvement in moral conditions has come from increased knowledge of the moral consequences of human actions. This statement may not at first be so obvious as the other, but a moment's consideration will make it so. I do not refer here so much to the separate actions of individuals as to the collective actions of societies and communities. Men have always known that certain actions were wrong and their consequences evil. They have always known that murder, theft and robbery, lying, treachery, slander, cruelty, and covetousness were alike wrong and harmful, not only to those immediately injured, but to everybody. But there have been many convictions pervading communities and peoples, and embodied in their laws and customs which were once believed to be right in principle and beneficial in their results, but which are no longer so regarded. In brief, the world has learned better. For instance, the whole theory of civil liberty as founded upon natural right and justice has undergone a complete revolution in modern times. Equally momentous have been the consequences of separating the functions of church and state, which has very much improved the conduct of the state, and also elevated and purified the church, wherever the separation has been accomplished.

Modern advancement then, both moral and material, is the outcome of the world's advancement in knowledge. Yet the statement is not complete. For it still remains to inquire why one civilized nation should advance in knowledge, in the arts, and in morals, while another should remain stationary, or perhaps should even retrograde;—why Europe and portions of America should be moving forward with accelerating speed, while Asia stands still. Surely no one will question the civilization of the oldest of all nations, China, and the next oldest, India. There is learning in China, there are libraries, colleges and scholars, and there are men of learning who are held in high honor. The cumulative wisdom and knowledge of forty centuries are written in their books, and embodied in the manners and customs of the people. India, too, has for many centuries been the home of philosophers and sages replete with the learning of the east. But neither China nor India are endowed with motive forces of progress. In truth, it is the opinion of most orientalists that during the last two or three centuries China has in some respects retrograded, and it is evident that the recent progress of India is only such as has been forced upon her by the terrible power and constraint of her British conqueror. Why is it that the knowledge of the occident has brought such vast progress while that of the orient has brought none?

The answer is that the knowledge of the west is scientific knowledge, while that of the east is unscientific.

But what is science, and how does scientific knowledge differ from knowledge which is unscientific? I would answer that science is knowledge employed for the obtaining of more knowledge and new uses of knowledge. We are reminded here of the definition of capital in political economy, viz., wealth employed for the production of more wealth. Except in one important respect, however, the analogy is only in the sound of words, and is unreal. Capital consists mainly in material things which are worn out and consumed in use, though replaced by new things which it is instrumental in producing, and with an increase. Knowledge is intangible, and is a property of the human mind. It is never worn out, and once secured it is rarely lost or diminished. But in one respect the analogy is real. Wealth may or may not be capital. Whether it be so or not depends upon the use which is made of the wealth; and thus the word capital designates wealth in certain specific relations. So, too, knowledge may or may not be science (or scientific), this depending on the use which is made of it. If it is employed in obtaining more knowledge it is scientific; or if it is employed in finding new uses of knowledge in general it is also scientific. Thus scientific knowledge is growing knowledge. Whatever it gains it keeps, and none is either used up or lost. And as knowledge increases, so, too, increases the possibility of its use.

The knowledge of the Asiatic nations then is unscientific because it is not employed to increase knowledge, nor to find new uses for it. Therefore it is very nearly stationary. It would be wholly so were it not that now and then some new truth or some new utility is stumbled upon by accident, whose importance and suggestiveness are too striking and impressive to be missed. That the Chinese of the present century have more knowledge than the Chinese of 4000 years ago is certain; that they have more than their ancesters of 1000 years ago is probable; but the difference is probably not great, and whatever it may be, it has been achieved by accident and without system, and not by deliberate well-planned systematic research. Charles Lamb's account of the discovery of roast pig is to us a delicious morsel of fun. In Asia it is a serious parable.

Since science is the use of knowledge for increasing knowledge and for finding new uses for it, we may look briefly at the process by which its aims and results have thus far been achieved. There must certainly be some great difference in the methods or processes of the scientific man of today and those of ancient or mediæval philosophers. The questionings and reasonings of antiquity brought but few answers, and the growth of knowledge was dismally slow. More is now added in a year than was added in a century during the flourishing periods of Greece and Rome. What has determined such a vast difference in results? Why are modern inquiries so fruitful when ancient ones were so barren? I believe that the cause of the difference is to be found in the enormous superiority of modern scientific logic. Without attempting to point out the full distinction between modern and ancient reasoning, I will proceed at once to the most striking and important one. In the ancient philosophy the syllogistic form of reasoning, which was almost universal, involved premises which were esteemed to be fixed and ultimate Some were acknowledged to be axioms, others to be founded on authority which was more than human and which could not be disputed without impiety. To question them, even, was held to be mere logical contumacy. Some of these postulates have been held to be true down to the present time, or at least have not yet been overthrown. But a far greater proportion of them have long since been discarded from human beliefs. Since the validity of conclusions can never be greater than that of the premises, the result can readily be imagined. Progress in knowledge was possible only along those lines where the primary postulates were sound, and these were narrow in the extreme. Outside of these narrow lines every argument, every hypothesis, every speculation, was sure to collide sooner or later with some of these fixed beliefs and be flung back to its starting point. It was in the inductive branch of reasoning that this barrier proved to be the most insuperable, and in the advance of knowledge induction is primary and antecedent to deduction. There was however one branch of philosophy in which the ancients made real progress, and that was geometry. But it happens that in this field of thought all the primary postulates were in the main sound; although modern criticism has challenged the proof of some of the Euclidean postulates, the questions thus raised have little relevancy to the geometric problems which troubled the ancient philosopher. Yet the progress of geometry was greatly hampered indirectly by the prevailing disease. For we now know that all branches of science must lend mutual aid and assistance to each, and one branch levies upon the others for pabulum and stimulus. One branch is constantly proposing problems for the others to solve. Ancient geometry was deprived of any such help or incentive.

This exceptional immunity of geometry from the prevailing malady no doubt explains the admiration and delight with which it was regarded by the philosophers of antiquity. In it they found satisfaction of their reasoning powers, resting in sure conclusions and in harmony with the world of phenomena around them. All else was doubt, confusion, mystery—an endless conflict of mind and matter with conclusions in which nothing was concluded. When Plato was asked what was the occupation of the deity he answered, "He geometrizes continually."

But when we turn to modern scientific philosophy how vast the difference! Here no such adamantine barriers, no such crushing interdicts, block the way of logical induction. Science makes but one ultimate postulate and that is the existence of mind and matter conditioned by time and space. What mind is, in the last analysis, it troubles itself little to inquire, but directs its inquiry wholly to matter with its time and space relations. It takes it as it finds it; it collates, measures, studies, and compares; it draws its conclusions, and lastly subjects them to trial and test. Those which stand the test are accepted provisionally, and those which fail are rejected, or are relegated back for further inquiry and revision. Those which are accepted become, for the time being, principles of science, and are used as the premises of further induction. And yet all of them are held provisionally only, and subject to whatever changes or modifications the growth of induction may seem to demand. There is no higher validity for any of them than that of the proof on which they rest, and every step of that proof is open to criticism. In science it is always in order to challenge first principles. But the challenger must come armed with new proof as strong and trenchant as that which he proposes to attack, before his gage can be lifted or the lists thrown open to him.

Modern civilization then is characterized by its rapid progressive improvement in the condition of the nations or races in which it prevails. It is most conspicuous in its material aspects; but the progress has also been great, though less conspicuous, in respect to morals. This progress has resulted from the rapid increase of knowledge, which in turn is the result of the pursuit of knowledge by scientific methods. In brief, that which distinguishes the present civilization of western Europe and of the United States from that of antiquity and of Asia is modern science and the results which have emanated from it. This is a very sweeping and magnificent claim; but let us inquire into it a little more in detail.

I have characterized science as the use of knowledge for increasing knowledge and for finding new uses of knowledge. Thus a double function of science is suggested. As the progress of science and of its applications becomes more rapid the distinction between these two functions becomes more and more marked. The first function, the finding of new knowledge, is most conspicuously inductive, though far from being exclusively so, and is frequently called "discovery." The second function, the finding of new uses for knowledge, is chiefly deductive, though often inductive, and is usually called "invention." One of the most striking features of the more recent developments of science has been that discoveries are usually made by one set of men and inventions by another. A scientific discoverer is seldom a scientific inventor, and an inventor is still more seldom a discoverer. The two fields of mental activity have become almost separated. They require, respectively, different casts of mind and different temperaments, and the mental qualifications required in one field are apt to prove disqualifications in the other, though happily it is not always so. The combination of qualities which makes a man at once a discoverer and an inventor is rare in the extreme; but it is sometimes found. Yet if the material progress of the world were measured by the contributions of these men it would be small; — not because their results would be of slight value, but because they would be comparatively few and infrequent. As it is, the greatest possible progress is secured by the division of labor, one class devoting their energies to the discovery of new knowledge, the other to the invention of means for making it useful.

To the world at large the inventor is best known and understood. He it is who first puts the fruits of science into the hands of the community which consumes them. With him, or with his agent or assignee, the capitalist and promoter, the community reckons, paying in money the commercial value of his invention. Nor is his reward merely a pecuniary one. He is honored in his lifetime and often commemorated with tokens of public gratitude after his death. For his encouragement and reward laws are passed patenting to him the exclusive use or sale of the material benefits of his invention, and protecting him against infringement. Nor are these rewards too great, nor is the appreciation too high. The material benefits of truly useful inventions are almost always far greater, as measured by any standard of commercial or utilitarian value, than any reward of this kind that can possibly accrue to the inventor. It is equally right and fitting that he should be honored and commemorated.

The scientific discoverer on the other hand is further removed from the great mass of the community than the inventor. His results are seldom such as can be turned to immediate commercial profit. They are contributions to knowledge in general, without reference, so far as he is concerned, to their material utility or to their money value. How far his work may minister to human bodily wants, to human pleasures or passions, is to him a matter of no concern. The sole object and the final end of his pursuit is the increase of knowledge regardless of the use which may be made of it; the discovery of new truths and laws of nature, of new facts and principles, caring nothing for the value which others may place upon them. To him all truths are of equal value. For in his mind truth is at once manifold like the waves and also one, like the sea. In the system of the knowable universe every fact has its place like every stone in the wall; every truth is but a corollary or a lemma of some broader and more comprehensive truth.

But it may be asked: Would it not be better if the energy of scientific discoverers were directed more to the investigation and discovery of new knowledge which would be available quickly for utilitarian purposes than to inquiry about facts and relations which offer no immediate prospect of being so utilized? The answer is decidly, no. It is far better as it is. The question tacitly assumes that human foresight is as good as hindsight. The investigator has no more conception, in advance, of the utility of the results that he may reach than has anybody else;—he does not even know what the results will be. And it is well that he does not care, for the prepossession would inevitably become a mental bias which sooner or later would be sure to lead him astray. The question contains another mistaken implication; for it assumes that some knowledge is useless. If we were to understand that nothing is useful which does not immediately contribute to the board, clothing and lodging of mankind, the implication might be justified. To the mere dollar-hunter, or to the man with the pick and shovel, it may be a matter of the profoundest indifference what is the sun's distance from the earth, what are the affinities between two families of plants, or what are the relative ages of two beds of limestone or shale. Perceiving no relation between them and dollars or cents, they are useless questions. But the term utility has a far wider significance to the more enlightened, for it means to them the capacity for ministering to human desire. And it is comforting to know that the number of men is not small who desire knowledge for its own sake, with a love for it as strong as any appetite for dainty food or fine raiment, or as the laboring man's love for his grimy tobacco pipe or his pot of beer. If there is utility in the knowledge which facilitates the production or improves the quality of food and clothing, or of tobacco and refreshing beverages, why is there no utility in the knowledge which is suited only to the hunger, the craving, the thirst for knowledge for its own sake? In the broader sense of the term, therefore, all knowledge is useful.

The division of labor then, between the discoverer of new knowledge and the inventor who seeks new utilities for the material and commercial benefit of mankind, is for the best. In the final outcome the results of both are the greatest possible and the progress is the most rapid. In this division however, the discovery of new truths is antecedent and the invention of utilities is consequent. And here we come upon a consideration which the unlearned or unscientific perceive only very dimly or not at all.

It is well enough known to nearly all people of education that inventions in electric appliances such as are now rapidly multiplying, would have been impossible without the pre-existence of such discoveries as those of Volta, Arago, Peltier, Ampere, Ohm, Faraday, Weber, Thomson, and Henry and a host of others whose names have become immortal. Nor could such an invention as the steam engine have been possible without a previous knowledge of the properties of elastic vapors; nor could the compound engine in its present form have been invented without a still more advanced knowledge of the laws of thermodynamics and of the conservation of energy. But of all fields of applied science that which presents the greatest number of inventions is that of industrial chemistry. The chemist will best understand how absolutely indispensible have been discoveries in the laws and facts of chemistry to the development of the modern metallurgy of iron and steel, gold and silver, copper and lead, zinc, nickel, and mercury; to inventions in photography, in acids and alkalis, in paints and oils, in the derivatives of petroleum and coal tar, in materials for scouring, cleansing, bleaching and dyeing, in pottery and glassware, in drugs and medicines, in starch, soap, sugar, gelatine, in the products of the brewery and distillery, in tanning, preserving, and decorating. By many people this dependence of invention upon scientific discovery is but little thought of. These manifold products of human ingenuity and industry are looked upon solely with reference to their utility, and the man who first confers one of them upon the community in available form and condition is regarded as the true originator of them. In reality he is but one of a series of scientific workers all of whom are equally essential. Thus the inventor figures prominently before the public gaze while the scientific discoverer is either unperceived or but faintly seen in the distant background.

On the other hand, while discovery precedes invention as a general rule, it is very often indebted to invention for suggestions which lead to discovery. Before a discovery can be regarded as complete and established upon a secure basis it is necessary to test it experimentally. Every invention furnishes such a test, and it will generally bring to light some facts not at first suspected, and which suggest amplifications of the original and central idea involved in the discovery. These hints at further knowledge are quickly followed up, and new truths are revealed. Thus the two divisions of science constantly stimulate and strengthen each other, and progress continually accelerates progress.

I must not be understood, however, as urging that every invention must be preceded by a new discovery. Far from it. A single principle may be followed by numberless applications of it, and may be fruitful of new inventions for generations of men after its discovery, even though no fresh discoveries are made. A very large proportion of modern inventions are applications of discoveries made perhaps a century or two ago. But this in no degree alters the nature or reality of the dependence. Discoveries being made without reference to their future utilities may remain indefinitely without useful application. Perhaps a more striking illustration of this could not be found than the discovery by Volta, which was known for nearly a century before its first application for utilitarian purposes.

Thus far I have dwelt chiefly upon the material results of science, and its agency in promoting progress in the useful arts and in the material comfort and enjoyment of mankind. The effects of science upon human ethics, though they have not been so conspicuous, have still been profound and even radical. For it has caused a different mode of reasoning to take the place of that which formerly prevailed in all classes, and which still prevails among the least intelligent classes of the present time. I have already explained one great difference in the logic of the ancient civilized peoples as contrasted with modern scientific logic, and which consisted in the assumption of fixed and arbitrary premises. The logical forms and processes were syllogistic, and they were highly elaborated by the Greek philosophers and sophists, who often used them with great ingenuity. But with premises which were usually either wholly false or incomplete, the conclusions were either invalid or imperfect. The scanty results thus obtained were just what might have been expected. With the decay of Greek philosophy the art of reasoning became degraded to lawless, incoherent disputation, which reached its lowest state of depravity in the scholasticism of the middle ages. In the dark ages nothing was so dark as the reasoning of those who claimed it to be their province to enlighten the world. But this was only the proverbial darkest hour before the dawn. With the beginnings of modern science came the beginnings of new modes of reasoning. Scientific knowledge can be reached only by sound methods of research and sound logic, and its results must be sustained by their own practical workings in harmony with the system of nature. It must begin with the closest possible scrutiny of facts; its observations must be accurate, and the observing mind must be trained to candor and freedom from bias. The modern art of observation calls to its assistance a highly developed system of measurements in all things which are susceptible of measure, to the end that the highest attainable accuracy of observation may be secured. Then follows comparison. Its object is to ascertain what are the natural relations existing among observed facts. Here the chief quality of mind demanded is candor, or the freedom from any prejudice in favor of one relation rather than another, or in favor of any relation except such as the observed facts themselves appear to indicate. Next in order comes the generalization, or the statement of the natural law. By natural law is meant the statement of the relations which natural phenomena bear towards one another, as disclosed by observation. The last step is the test of the natural law, so formulated, by experiment, whether in the laboratory, or in the workshop, or in the daily incidents of human life and human action. Those which are sustained by all the tests to which they are subjected are ultimately received as true, and those which fail are either rejected or amended.

In dealing with material phenomena, *i. e.* with the relations of matter to time and space and force, most of the relations are quantitative. In dealing with such quantities as mass, time, force and space, modern science has developed a logical machinery unknown to the ancients, though some partial clements of it were contained in their geometry. This logical machinery may be called by the name *Algebra* in the broader sense of that word, though it is common to use the more wordy designation of analytical mathematics. Algebra in the broader sense is the logic of quantity. As a reasoning machine, within the limits of its capacity it is logically perfect. But as it is a machine, it is in nowise responsible for the data which may be supplied to it to operate upon. As Huxley has remarked, the mathematical machine always grinds true, but the grist it turns out will depend upon what is fed into the hopper. If the results yielded by algebraic analysis are false, we may still know that the error is to be sought, not in the algebraic reasoning, but in the data submitted to its operation—in other words, in the premises. This is an enormous gain. In the old syllogistic and scholastic methods the reasoning might be erroneous, indeed, generally was erroneous, at any step in the syllogism. In the modern analytical methods the errors may be chased into one corner, where they can be hunted for and ferreted out within a narrow space.

This surer and sounder mode of modern reasoning was at first, and within two or three centuries, understood and appreciated only by a few men of science. But during the present century especially it has diffused itself among wider and more numerous classes of men, and is already reaching in some measure, though in a very imperfect one, to all classes except the most ignorant and uneducated. Would that it were universal! But we have to consider the enormous load of prejudice it has been obliged to encounter and the fixity of old notions and traditions, old habits of thought, which seem to have become hereditary and ingrained in all races. Moreover the scientific logic is intrinsically difficult to master and is beyond the grasp of minds which are either deficient in natural acuteness or else have lacked the training and opportunities to master it. Although these modes of thought have thus far diffused themselves imperfectly and in diminishing degree as we descend in the scale of intelligence, it is absolutely clear that the effects have been great and highly beneficial. We have but to look back a few generations to recognize the fact that old superstitions, many of them harmful and even cruel and all of them ridiculous, have either vanished or become limited to the lowest order of intelligence. Among these old and almost extinct beliefs are those concerning witchcraft and magic, evil spirits casting baneful influences upon mankind, the visitations of ghosts, and attributing unaccustomed events or striking coincidences to miraculous interventions, the casting of horoscopes, the telling of fortunes, and the use of charms against accident or disease. These superstitions are greatly diminished though by no means wholly extinct. Nor are they easy to conquer even in minds whose intelligence should lead us to expect from them more intelligent things. For one of the most deeply implanted and strongest instincts of the human mind is the love of the marvelous. We naturally like to hear and tell some new or strange thing, and most people love to believe that such things are true, and there is an instinctive natural bias in almost all minds in favor of the startling, the strange and the preter-natural. To find the astonishing, the mysterious, the extraordinary, degraded to the commonplaces is being compelled to submit to the destruction and robbery of our most pleasing and thrilling illusions.

Not only has science made deep inroads upon superstitious beliefs and trampled many of them remorselessly into the dust, but it is constantly waging a relentless war with mental forces which are still more stubborn and difficult to conquer. These may be characterized as the polemic tendencies of human nature. Most men are more or less prone to controversy, and in the heat of it are determined to secure a triumph over other disputants, whether it be a real or only a seeming one—whether the opponent be convinced or merely silenced. In such contests a large proportion of men are quite reckless of the kind of arguments they use—if, indeed, they can be called arguments—and look only to the ends to be gained. Anything that may tend in their judgment to secure a victory is to them a good and proper argument, no matter whether it be true or false, sound or unsound. Take for example a partisan newspaper or a stump orator in the heat of a political campaign. Here it is needless to go into particulars; I think you all understand me. Possibly a more extreme illustration may be seen in the so-called arguments of lawyers before a jury, in which every principle and every canon of sound reasoning is ruthlessly violated, if by doing so it is thought that a verdict may be won. This is not so much the deliberate ex parte pleading in which all favoring considerations are grossly exaggerated and all opposing ones ignored or belittled; nor even the argumenta ad hominem in which passion, prejudice, clannishness, and all the weaknesses of men are appealed to that are the most reprehensible, for it is a very weak and ignorant jury nowadays that does not receive these appeals in the Pickwickian sense. It is rather that countless brood of sly, slick, sneaking fallacies which fall in the category of the "undistributed middle," that are really dangerous and misleading. I surely mean no disrespect to my esteemed friends of the legal profession. For behold! a miracle! if you take one of these cold blooded butchers of logic and put him upon the bench it is not unlikely that he will soon give utterance to judicial decisions so sound, so just, so truly logical, that we are compelled to forgive him all his former logical atrocities.

No greater contrast could be offered than that between the scientific method of seeking conclusions and the ex parte disputations which are the legacy of antiquity and scholasticism. Slowly and almost imperceptibly the scientific logic is establishing its foothold. Up to the present time it must be confessed the progress made bears but a small ratio to what must yet be achieved before its candor, its accuracy, its judicial temper shall completely dominate the thoughts of mankind. Absolutely, however, much has already been accomplished. There is no doubt that men of all classes, except the lowest, reason more logically than they did a century ago. Still more conspicuous is the improvement in the reasonings of the educated classes, who are relatively more numerous and much better informed than in any former period. The improvement, moreover, is wholly along the lines of scientific thought and methods.

Modern civilization has now reached a stage of development in which right methods of thinking and reasoning have become imperatively necessary to its safety. All social and economic functions have become highly complex. Not only in relation to material wealth, but also in social relations our lives have become very artificial and are rapidly growing more and more so. The social organization has become like an extremely complicated series of machines, with a vast number of coordinated parts, each performing its limited function, and as with all very complex machinery the liability to derangement is increasing. But unlike any inanimate machine, each individual, as a part of that organization, is endowed with a limited spontaneity of action. Society is no longer governed and regulated by despots, but by the predominant opinion of its members and by the agency of its chosen representatives. But if public opinion is to be the ruling power in this complex machinery of society, is it not of transcendent importance that public opinion should be born, nurtured and disciplined under conditions which constrain it towards sound methods of thought and reasoning? And here is for the present generation at least, the highest mission of science, to inculcate logical methods of thought and reasoning upon the social and economic questions of the day. I am far from implying, however, that such methods are rare or uncommon in any class of society. On the contrary I repeat that much progress in this direction has already been made. But more is demanded, and the necessity for it presses harder and harder as population and wealth increase, and as social and economic functions grow in complexity. Take the burning question of the hour, the silver question. The problem is a purely scientific one. It is complex and difficult; much more so than most of the public debaters seem to be aware of. But its complexity is not beyond the reach of scientific analysis. Unhappily the question has become a political one, and from time immemorial it has been the inveterate habit to argue political questions *ex parte*. It is a survival of the ancient and scholastic methods of dealing with questions, and though tempered in some degree at the present day by the more judicial spirit of modern reasoning, it is still not the method in which such a momentous question should be treated.

The mission of modern science then is not alone to discover more knowledge and to invent new uses for it, but also to teach men how to investigate, how to compare, how to think, how to reason, and finally how to establish the verity of their inferences and conclusions by testing their conformity with the processes of nature.

A CONTRIBUTION TO THE STUDY OF THE PHYSIOLOGICAL ACTIONS OF SPARTEINE.

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Read December 16, 1893.

Sparteine is an alkaloidal substance obtained from the common broom plant, the *cytisus scoparius*, or the *sarothamnus* (*?*) *scoparius*. Sparteine is represented by this chemical formula: $C_{15}H_{26}N_2$. The alkaloid appears as an oily, volatile, unstable liquid, with a penetrating odor resembling that of pyridin, and has a decided bitter taste. It melts at 550.4°F (288°C). The salts of sparteine are readily soluble in water, alcohol, ether, and chloroform. The *sulphate* is a crystalline salt of a pale greenish color.

Though somewhat largely used in practical medicine, sparteine has not been investigated physiologically to any very considerable extent. The drug has been studied by Mitchell who, according to Husemann†, quoted by H. C. Wood‡, states that four grains of it produced in a rabbit a brief period of excitement, followed by sleep, and death in the course of three hours. Similar results were obtained by Schroff according to Wood§. De Rymon|| Grief ¶, and Gluzinski** noticed also two periods of poisoning under the influence of sparteine; one of excitability, followed by one of depression. All of these three authors likewise hold that the alkaloid diminishes the irritability of the muscular fiber, but without destroying the functional activity of the muscles. Fick††, in corroboration of Mitchell's experience, affirms that sparteine acts as a narcotic, and that the drug, further, paralyzes both the motor nerves and the spinal cord. On the other hand, Wood‡‡ quotes Legris as saying that twenty-five cen-

† "Planzenstoffe."

‡ "Therapeutics; Its Principles and Practice;" Edition of 1891.

§ *Ibid.*

|| *These*, 1880.

¶ *These*, Lyon, 1887.

** *Deutch. Archiv. Kli. Medicin.*, XLIV, 1884.

†† *Archiv. f. Experiment Path. u. Pharmacol*, 1887.

‡‡ *Loc. Citat.*

tigrammes of the medicament produce no perceptible influence on the human brain or spinal cord, although larger amounts cause headache, vertigo, palpitations, and tingling in the extremities. Cardiac pain, redness of the face, and loss of motor power in the lower extremities, are symptoms which have been observed by Garand.*

FIG. I.

TRACING I.—Showing irritability of muscle.—(*a*) Normal muscle-reaction in a frog weighing 32 grammes. (*b*) Reaction of the same muscle, 15 minutes after the administration of 0.001 gramme of sparteine.

The preceding evidence, and the results of my own general experiments on frogs and mammals, principally dogs, lead me to state that two distinct stages of general poisoning may be produced by sparteine: one characterized by excitement, especially under small doses; and the other by depression of both the higher and the lower nervous system, and, in fact, of all the other functions, particularly when large amounts of the drug have been ingested. In the first instance, that is, when minute quantities of the drug are administered to both the batrachian and the warm-blooded animal, the period of excitability is generally followed by incoordination of movements, a period of quietude and finally of stupor. During the excitement, the animal becomes restless, breathes more rapidly than in normal conditions, exhibits muscular tremors, increased reflexes, and acceleration of the pulse-rate, and sooner or later is attacked by either clonic or tetanic convulsions. In the second stage, particularly when the dose has been sufficiently toxic, symptoms of depression are manifested, in which an embarrassed respiration, a slow, but strong pulse, general muscular relaxation, and true paralysis, are observed. The animal passes into a kind of stupor, not precisely that of sleep, however, and finally dies, generally from failure of the respiration. Death is often preceded by convulsions. The heart usually stops in systole, although a diastolic arrest is not an infrequent occurrence. After death, both nerves

* *These* 218, Lyon, 1886.

and muscles retain their excitability for a considerable time. No post-mortem lesions of any consequence are observed. I may say, in passing, that in my experiments I have employed the *sulphate of sparteine*-Merck, free from all impurities.

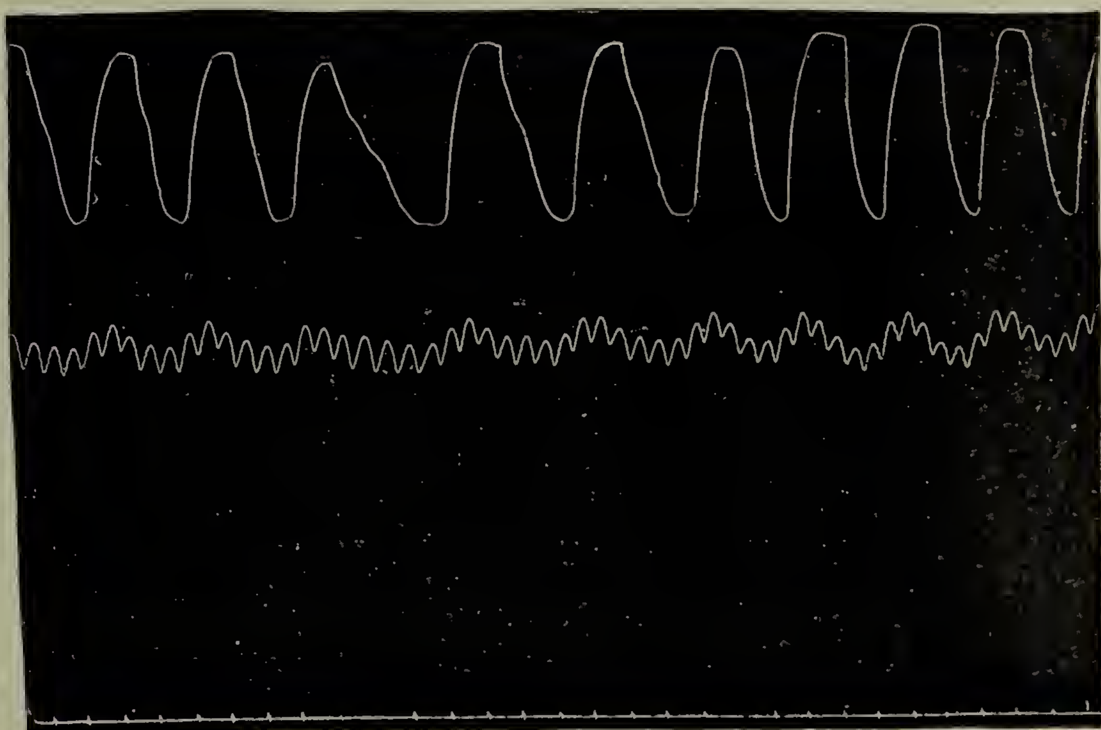

FIG. A.

TRACING II.—(Normal).—Dog weighing 7.5 kilos. Injected intravenously 0.01 gramme of sparteine sulphate. Upper line represents respiratory movements; middle line the blood-pressure and pulse; lower line abscissa and time in seconds.

The following general experiments are given as illustrations:

Experiment I: Medium sized frog. Gave subcutaneously at 2 p. m., 0.001 gramme of sparteine. 2:20, animal is restless, and breathes rapidly; muscular twitchings are observed, and reflexes appear increased. 2:45, decided increase in reflex action, but movements are somewhat slow. 3:10, clonic and tetanic convulsions, alternately, are developed; respirations irregular and labored; placed on its back, frog lies motionless, with occasional twitchings and convulsive movements. 3:30, same condition of quietude; the reflexes are now slowly elicited on mechanical irritation. 3:50, respiration stops; animal apparently dead. Opened chest, and found heart still beating slowly but vigorously. 4:30, the organ ceased to act, being arrested in diastole. Muscles and nerves intact.

Experiment II: Frog, weight 32 grammes. Injected, hypodermatically, 0.0015 gramme at 12:30 p. m. 12:45, batrachian jumps about lively; respirations rapid, much restlessness, with decided increase of reflexes. 1:05, frog quiet; voluntary movements are sluggish, but the reflex activity continues above normal, as shown by mechanical irritation. 1:10, a slap on the table produces convulsions in the frog; the breathing is now very slow, and, let alone, the animal has a tendency to assume a condition of stupor. 1:40, tetanic convulsions occur, and afterward the respiration ceases. The heart continues to beat, however; this organ ceasing to act fifteen minutes later. After death, both nerves and muscles responded to electrical stimulation.

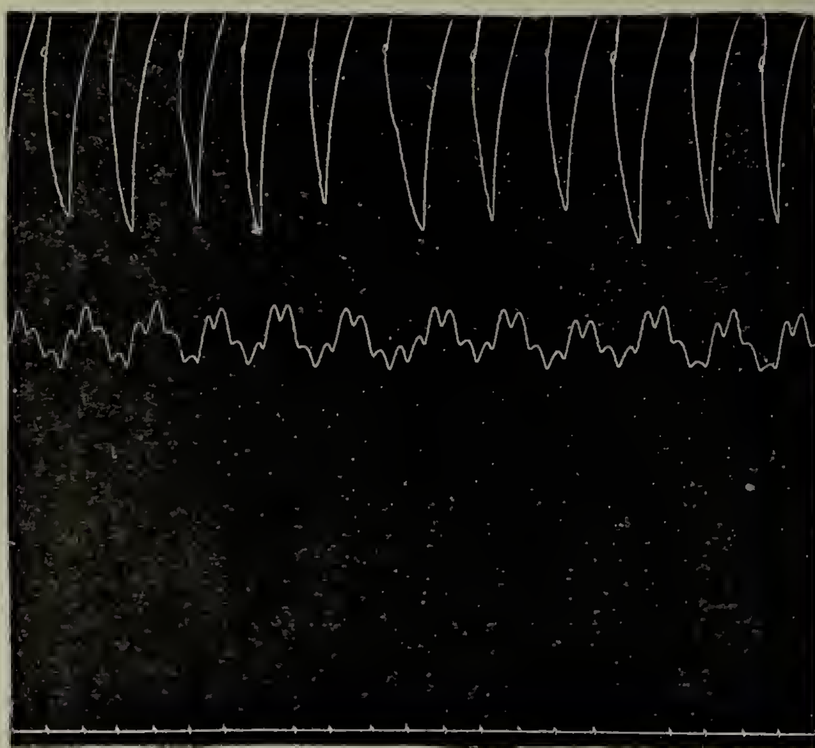

FIG. 3B.

TRACING II.—The same, 5 minutes afterwards.

Experiment III: Dog, weight five kilos. Exposed the external jugular vein and injected into it, well diluted and slowly, 0.01 gramme of sulphate of sparteine, at 10:32 a. m. 10:40, animal exceedingly restless; runs about and pants as if tired. The heart beats rapidly; tremors are observed. 11:15, lies down in a corner of the room and remains quiet, with occasional startings. 11:25, excitement has returned. 11:30, animal quiet again. Dog finally recovered and was used for another experiment.

In similar experiments, large amounts of the drug produced from the beginning a stage of general depression, this being gradual but marked till the occurrence of death. For a more clear and better understanding of the subject, I will take up the study of the actions of the drug on the different systems, *seriatim.*

ON THE MUSCULAR SYSTEM.

There appears to be produced, under the influence of sparteine, especially when administered in minute doses, a brief period of increased muscular irritability, which, however, soon disappears; but I have never been able to note any marked depression of normal irritability of the muscles even under massive quantities of the drug. Yet, according to

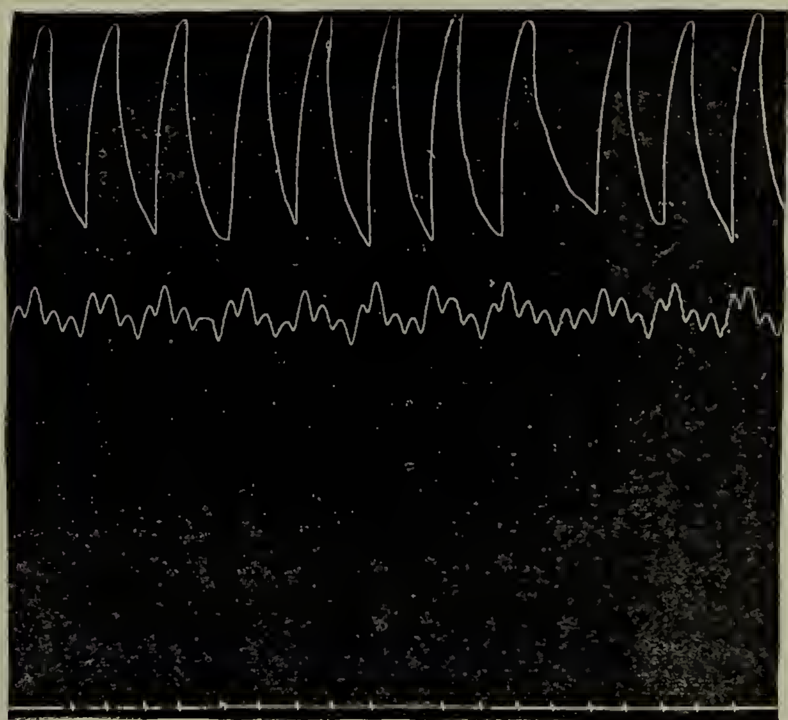

FIG. C.

TRACING II.—The same, 25 minutes afterwards. At this point a second injection of 0.03 gramme was given.

the observations of Griffe, Gluzinski, and De Rymon, it appears that, locally applied, sparteine diminishes to a certain extent, the excitability of the muscular fiber, whereby the duration of the latent period of contraction is prolonged. The results obtained in my studies with the use of the myograph are sufficiently clear, and do not seem to fully sustain the statement of the investigators just mentioned. I will detail one experiment out of many similar ones performed.

Experiment IV:

Time. h. min.	Height of contract'ns in mm.	Remarks.
		Gastrocnemius of frog prepared. Connection made with myograph. Stimulation by means of a Dubois-Reymond electrical apparatus, with the corresponding key. Current obtained at 15 c.c. between coils.
2:30	26	
2:35	26	
2:40	—	Injected, hypodermatically, 0.0015 gramme of sparteine sulphate.
2:48	29	
2:50	30	
2:53	32	
2:58	—	Convulsive movements.
3:05	—	Tetanic convulsions.
3:12	28	
3:15	28	
3:20	28	
3:28	26	Gave, hypodermatically, 0.0015 gramme more of drug.
3:40	24	
3:50	24	Tetanic convulsions.
3:53	22	Convulsions continue.
4:05	24	

ON THE NERVOUS SYSTEM.

Although so asserted by some observers, I, myself, do not believe that sparteine exercises any important action on the brain. In fact, there is no direct proof, experimentally or clinically, to the effect that the agent acts as a narcotic. Its influence is exerted particularly on the lower nervous system, and it is to this that I shall chiefly direct my studies on this part of the subject.

Reflex action. Moderate, and especially small doses of sparteine cause an increase of the reflexes. I studied this action in a large number of experiments. The following experiment is given as an illustration:

Experiment V: Frog, weight 28 grammes. Destroyed brain and waited for disappearance of shock; then tested the reflexes in the usual manner, that is, with acidulated water. Time was carefully measured by a registering apparatus. 11:15 a. m., reflex action in 10 seconds. 11:20, same result. Injected at 11:22, hypodermatically, 0.001 gramme of sparteine sulphate. 11:30, reflex action in 3 seconds; 11:45, reflex action in 4 seconds; convulsions; 11:55, reflex action in 8 seconds; 12:25, reflex action in 10 seconds; 12:45, reflex action in 20 seconds.

Generally, in sparteine poisoning, motion is abolished before sensation. Again, this stimulation of the reflexes occurs after previous ligation of the peripheral blood-vessels, by which any influence of the drug on the terminal portions of both sensory and motor nerves is thus destroyed. The action must, therefore, be a centric one.

Experiment VI: A frog, weighing 32 grammes. After the animal was pithed, the sciatic nerve of the right side was dissected out carefully, and isolated. All the tissues with the exception of the nerve, were ligated, and the shock from the operation was allowed to pass off. At 3:10 p. m., reflex action was manifested in eight seconds. 3:15, subcutaneous injection of sulphate of sparteine, 0.0015 gramme. 3:25, reflex action in 4 seconds in non-protected leg; the same in protected leg. 3:30, reflex action in both legs in 3 seconds; convulsions. 3:35, reflex action in 3 seconds, in both legs. 4:30, reflex action in both legs in 15 seconds.

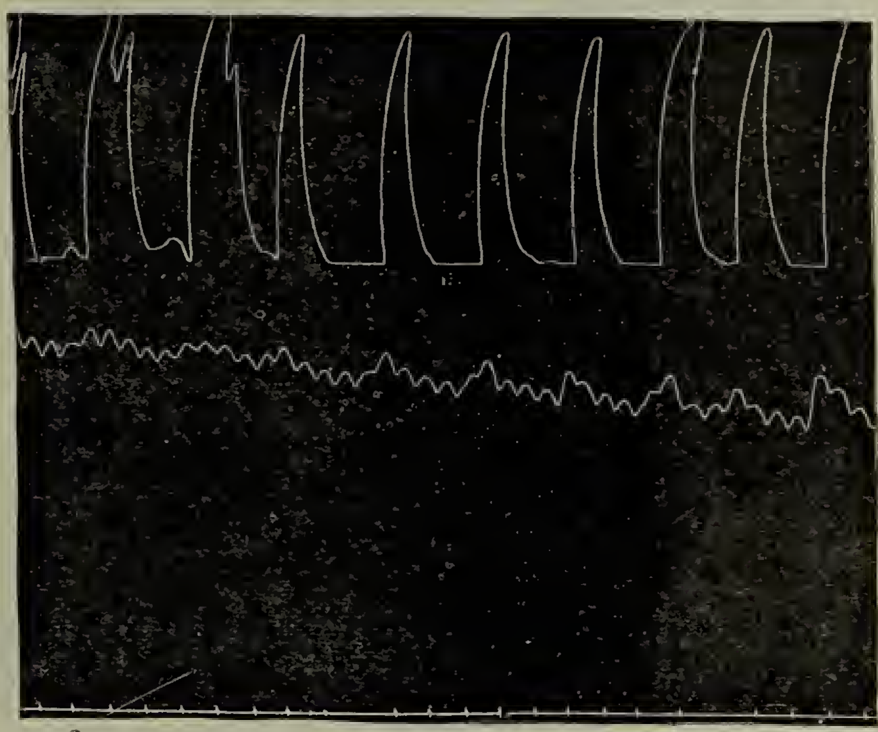

FIG. D.

TRACING II.—The same, 10 minutes after the second injection.

Shutting off the circulation to the lower extremities, not only by ligating the peripheral vessels, but also by tying the abdominal aorta, does not prevent the production of increased reflexes through the action of sparteine. The results observed in the following experiment, an example of many others performed, are sufficiently self-explanatory.

Experiment VII: Frog. Ablated cerebrum and then carefully tied the peripheral blood vessels and abdominal aorta. Waited for the disappearance of shock. The usual test showed the production of reflexes in 6 seconds. Five minutes after, an injection of 0.0015 gramme of sparteine sulphate was administered subcutaneously, at 4:20 p. m. 4:28, reflex action in 4 seconds. 4:35, reflex action in 2 seconds, followed by tetanic convulsions. 4:40, reflex action in 3 seconds. 4:50, reflex action in 8 seconds. 5:55, reflex action in 22 seconds.

In a frog in which one sciatic nerve was divided previously, the alkaloid produced convulsions all over the body except in the leg operated on.

The stimulation of reflex activity by sparteine is generally followed by a distinct depression. This diminution and the final abolition of the reflexes, under sufficiently large doses of the drug, can not be due to an influence on the nerves themselves or their peripheral extremities, since the phenomenon occurs after protection of these parts from the action of the agent, as clearly shown in the preceding experiments. It would seem, therefore, that the depression of reflex action, like its destruction, is of centric origin. Again, when the reflexes are below normal in an animal poisoned with sparteine, section of the spinal cord high up results in an apparent return to the physiological standard. The reflexes, however, are secondarily depressed and ultimately abolished. These results lead me to the belief that, under sparteine, there is a primary stimulation of the chief reflex inhibitory center (Setschenow's), this explaining the first stage of depression. The second period of diminished reflexes and the final abolition of the same, are, undoubtedly, the outcome of a direct action of the poison on the spinal centers. In this respect, the behavior of sparteine resembles that of quinine, digitalis, and probably of hydrastine.

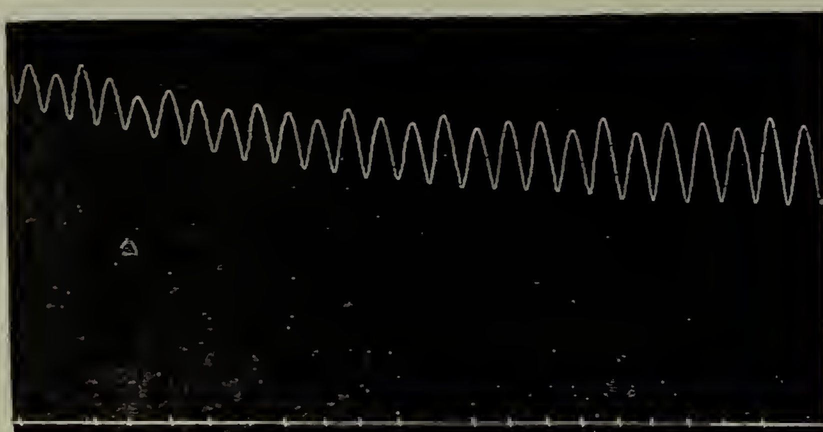

FIG. E.

TRACING II.—The same, 15 minutes after the second injection. Respiratory tambour got out of order, and the movements could no longer be registered.

Convulsions.—As has been observed, sparteine so stimulates the system as to cause convulsions, these being usually of a tetanic nature. From a close examination of the preceding experiments, it becomes evident that this phenomenon is not the result of a peripheral action of the drug. Experiments VI and VII clearly show this. The convulsions must be either cerebral or spinal. Previous division of the cord does not prevent the coming on of convulsions. If the medulla spinalis, again, is destroyed beforehand, the administration of sparteine is not followed by convulsive phenomena. The results of the following experiments are self-evident:

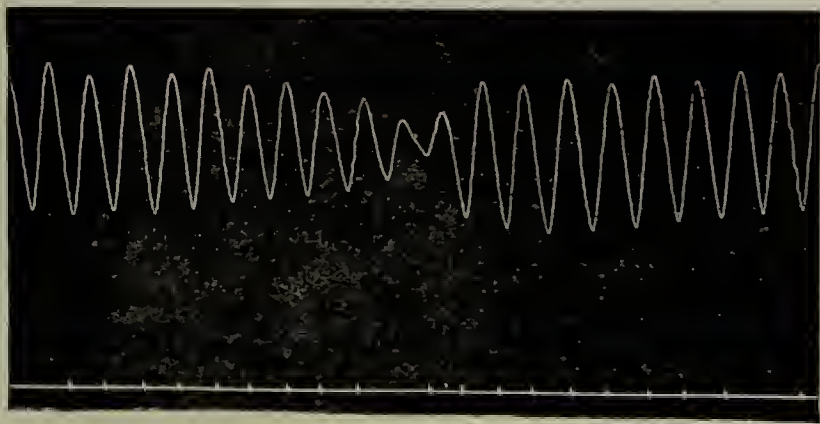

FIG. F.

TRACING II.—The same, 32 minutes after the second injection.

Experiment VIII: Frog. Divided cord high up. Gave then a lethal dose of sparteine subcutaneously. The usual general toxic symptoms occurred, with decided tetanic convulsions below the point of section.

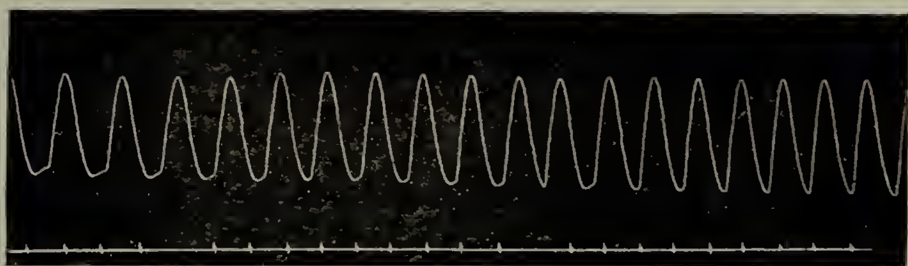

FIG. G.

TRACING II.—The same, 42 minutes after the second injection; at this point the respiration ceased entirely.

Experiment IX: Rabbit, weight 1.5 kilos. Cut cord in cervical region, and administered subcutaneously 0.5 gramme of the drug at 12:15 p. m. 12:45, animal breathes rapidly, this symptom being accompanied

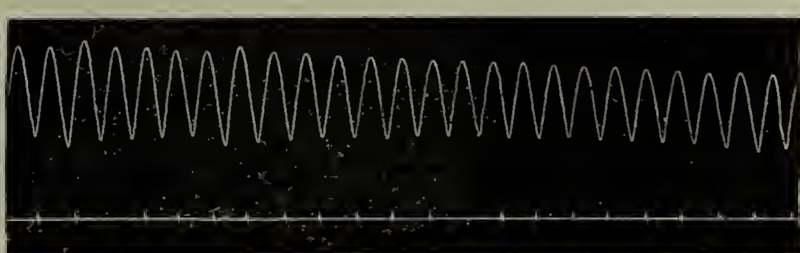

FIG. H.

TRACING II.—The same, 3 minutes later.

with increased cardiac action and muscular twitchings. 1:20, tetanic convulsions ensue, and the rodent soon after died from respiratory failure. Opened chest and found the heart beating slowly but vigorously, and was finally arrested in diastole.

Experiment X: Frog. After the brain was ablated, the spinal cord was dissected out and carefully destroyed. Administered then 0.002 gramme of sparteine. No convulsions were produced.

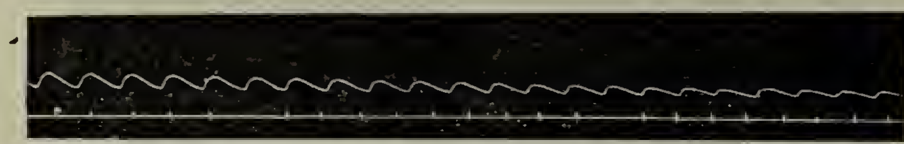

FIG. I.

TRACING II.—The same, 2 minutes later.

This evidence justifies me in assuming that the convulsions produced by sparteine are spinal in origin.

Paralysis.—After the death of the animal from the effects of sparteine, both muscles and nerves, as has been shown, respond more or less readily to electrical stimulation. On the other hand, no marked depressing effect on these tissues is observed when they are placed in even comparatively strong solutions of the drug. Apparently the medicament exercises little or no local influence. It is safe to infer, therefore, that the paralysis in sparteine poisoning is the result mainly of an action upon the cord itself.

ON THE CIRCULATION.

Notwithstanding the fact that sparteine exercises a decided influence on the circulatory system, comparatively little work has been done regarding the actions of the drug upon this important part of the animal economy. The literature of the subject is not very extensive, and yet there appear some discrepancies in the conclusions of the various observers who have devoted some attention to the matter.

The first investigator to study the actions of sparteine on the circulation was Laborde.* He called attention to the influence which sparteine exerts on the heart of mammals, and on that of the frog, asserting that the remedy enormously increases the size of the pulse-waves. After Laborde, other observers carried out similar studies. Thus Griffe,† who investigated the action of sparteine on the isolated heart of the batrachian, found that the alkaloid causes an increased cardiac beat through paralysis of the inhibitory centers, this phenomenon being followed by a

* *Compt-Rend. Soc. Biol.*, November 21, 1885.
† *These* 224, Nancy, 1886.

slowing of the heart. Under large amounts he noticed a slow pulse from the beginning. The same author likewise observed a decided persistence of cardiac contractions. In mammals, Griffe noticed a primary stimulation of the pulse, under small doses of sparteine, without alteration of the arterial pressure. With larger quantities the acceleration of

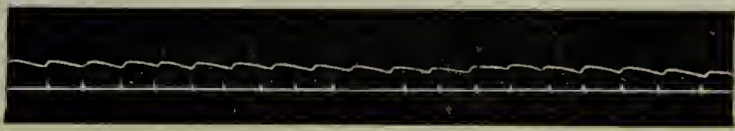

Fig. J.

Tracing II.—The same, with 10 seconds' pause.

the cardiac-rate was followed by a diminution. Toxic amounts, he found, produced at first a slow pulse accompanied with lowering of the arterial pressure, the size of the pulse-waves, however, continuing to be large and full. The author states that the peripheral vagi become finally paralyzed.

Somewhat similar results were obtained by Massius*, Garand†, and Fick‡. The latter author also states that muscarine has little or no effect upon the sparteine-heart, concluding that the drug under consideration

Fig. K.

Tracing II.—The same without interruption.

paralyzes the inhibitory centers in the cardiac organ. On the other hand, Gluzinski§ points out three stages as resulting from the influence of sparteine upon the mammalian heart. He noticed, in the first place, a slowing of the heart's action, and this he ascribes to pneumogastric stimulation. Again, he observed a short period of slowness in the cardiac pulsations, and sometimes a primary increased pulse-rate, a phenomenon which, according to him, is dependent upon paralysis of the inhibitory ganglia in the heart and of the pneumo-gastric centers. In a third series of instances, the results were those of slowing the heart's action due principally to the direct influence of sparteine on the cardiac muscle. Though apparently so, these results of Gluzinski are not discordant with those of the other investigators just quoted, and in this regard I concur in the well-founded opinion of Wood‖ to the effect that "it is evident that if

* *Bull. Acad. Royal Med. Belgique*, p. 218, Vol. I.
† *Loc. Citat.*
‡ *Loc. Citat.*
§ *Vratch*, No. 3, 1887; also *Med. and Surgical Reporter*, July, 1887.
‖ *Loc. Citat.*

the drug acts in the manner made out by Gluzinski, the apparent effects must vary according as one or more of the cardiac actions of the drug appear to triumph; so that the phenomena noted by Gluzinski are not absolutely contradictory to those of the other observers.''

In my own experiments with sparteine regarding the actions of this agent on the circulation particularly, the frog and the dog were the animals chiefly employed.

When sparteine, in doses of about 0.005 gramme per kilo of the animal's weight, is administered intravenously to mammals, especially the

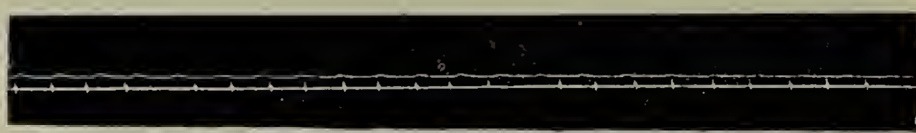

FIG. L.

TRACING II.—The same, without interruption, the heart ceasing at this point, or 6 minutes and 20 seconds after the stoppage of respiration.

dog, there occurs at first a slight rise of the arterial pressure accompanied with an increased action of the heart. In a short time both the rate of the pulse and the height of the blood-pressure fall below the normal standard, to return, if the dose is not pushed beyond the limits mentioned, to the original point. If the ingestion of the drug, however, be continued, the depression, with slight variations is gradual till the occurrence of death of the animal. A noticeable phenomenon is the enormous increase in size of the individual pulse-waves accompanying the reduction in the frequency of the cardiac beat and the fall of the arterial pressure (See tracing II, Figs. E, F, G, and H; and tracing III, Figs. O and P). Regarding the heart itself, phenomena similar to those seen in the dog are observed in the batrachian.

I shall first study the action of sparteine on the heart of the frog. These experiments consisted of two series: one in which the organ was simply exposed; in the other series, the heart was isolated. In both instances a control experiment was at the same time performed, using for the latter a normal solution of chloride of sodium. I detail the following experiments:

Experiment XI: Took two frogs, A and B, and after both had been pithed their hearts were exposed.

HEART A.

Time. h. min.	Pulse. p. min.	Remarks.
3:40	62	
3:45	60	
3:47	60	0.001 gramme of sparteine.
3:50	64	
3:53	68	
3:56	72	Convulsive twitchings.
3:59	74	
4:05	70	Ventricular contractions marked.
4:10	68	0.001 gramme of sparteine.
4:15	64	Convulsions.
4:22	56	Ventricular contractions vigorous.
4:28	48	
4:42	32	Prolonged diastole marked, followed by ventricular contractions so vigorous as to send out apparently every drop of blood, the ventricular walls becoming white at each systole.
4:52	30	
4:58	24	
5:02	24	
5:10	20	
5:20	16	Diastole and systole quite marked yet.
5:30	8	
6:00	—	Heart still beating about once or twice in the minute.

HEART B (Control experiment).

Time. h. min.	Pulse. p. min.	Remarks.
3:42	68	
3:46	66	
3:48	66	
3:52	62	
3:55	62	
3:58	60	
4:02	56	
4:08	50	
4:12	46	
4:18	38	
4:25	26	
4:40	12	
4:50	—	Stopped in diastole.

Experiment XII: Isolated two frogs' hearts; one of these (C) was placed in a one per cent solution of sparteine; the other (D) in the salt solution, and their actions carefully watched.

HEART C.

Time. h. min.	Pulse. p. min.	Remarks.
2:02	64	
2:05	68	
2:09	72	
2:12	78	
2:18	72	
2:22	66	
2:28	52	Ventricular contractions vigorous.
2:35	46	
2:40	30	Ventricular contractions vigorous.
2:48	12	
2:52	12	
3:02	6	
3:10	2	
3:25	—	Arrested in systole.

HEART D (Control experiment).

Time. h. min.	Pulse. p. min.	Remarks.
2:04	76	
2:07	74	
2:11	72	
2:14	68	
2:20	52	
2:25	40	
2:32	26	
2:36	8	
2:45	—	Stopped in diastole.

It is thus seen that sparteine, when given hypodermatically or applied directly, causes in the batrachian a brief period of acceleration of the pulse, followed by a distinct diminution. Although the organ is slowed in its action, its force is increased, evidenced by the vigorous contraction produced. During the retardation of the pulse a marked irregularity of this is of frequent occurrence. The same is also noticed in dogs.

The fact, again, that the heart continues to beat for a longer time in the sparteine solution than in the salt solution, would seem to show that the drug, as is the case with digitalis, for instance, powerfully stimulates the heart muscle and probably also the intracardiac ganglia. Finally these become completely paralyzed, and the organ is arrested either in systole or diastole.

My experiments in the mammal were divided into four series, as follows: *first*, on normal animals; *secondly*, on animals under the influence of *curare; thirdly*, on dogs whose vagi had been previously divided; *fourthly*, on those in which all nervous connection with the heart was destroyed by previous section of both pneumogastrics and the spinal cord high up. In these latter instances, as in currarized dogs, artificial respiration was employed. After the various operations, which were made under an anesthetic, the animal was connected with the recording kymograph by the carotid artery, and with Marey's tambour, by a rubber tube and metal canula, this latter being introduced into the trachea.

Before injecting the drug, the dog was allowed to recover fully from the effects of the anesthetic, and thus more or less vitiated results were avoided. Ten experiments were made on normal animals, of which I only detail the following in tabular form. The accompanying tracings also aid materially in illustrating the results obtained.

In *Experiment XIII*, for which a dog weighing 6.5 kilos was used, a dose of 0.01 gramme was followed in a few moments by a rise of the arterial pressure and an increase of the pulse-rate. Two minutes and a half later, both the rate of the cardiac beat and the blood-pressure were still above the normal. Three minutes and a half afterward, while the pressure continued high, the pulse-rate began to decline, and convulsive movements occurred. The respirations were increased in rate but apparently not in depth. A second dose of 0.02 gramme produced a lowering of the arterial pressure to even below the original point, and then both the pulse and the pressure descended together till the occurrence of death, this taking place from respiratory failure.

EXPERIMENT XIII (Normal).

Time.	Dose.	Pressure	Pulse.	Respiration.	Remarks. (Dog weight 6.5 kilos.)
m. s.	grammes.	m.m.	p. m.	p. m.	
0.	....	140	112	18	Normal.
5.00	0.01	140	112	18	Injection begun.
5.30	....	150	129	30	Injection ended.
7.30	....	150	130	....	Convulsive movements; labored respiration.
11.00	....	154	114	30	
11.30	0.02	154	108	30	Injection begun.
12.00	....	154	93	18	Injection ended.
13.00	....	110	90	18	From this on the pulse rate, the blood pressure, and the respiration declined gradually till the occurrence of death, this taking place from respiratory failure.

A dog weighing 5.14 kilos was employed for *Experiment XIV*, in which a single dose of 0.05 gramme of sparteine was administered. Similar results were obtained in regard to the pulse, but there was no rise of the arterial pressure. A little over two minutes, when the pressure marked 80 mm. (normal 150 mm.), the cardiac beats had increased from the normal rate, 69, to 90. The pulse became then very irregular, but soon assumed a steadier character. Three minutes later, or a little over six minutes after the injection, both the pulse and pressure had regained their normal standard in rate and height respectively. The respiration, though it was not recorded on the cylinder, gave practically the same results as had been obtained in the last experiment.

The animal used for *Experiment XV* weighed 6.804 kilos, the changes observed in this instance resembling those noticed in experiment XIII in regard to the blood pressure. Soon after the first injection of 0.01

Experiment XIV (Normal).

Time.	Dose.	Pressure	Pulse.	Remarks. (Dog-weight 5.14 kilos.)
m. s.	grammes.	m.m.	p. m.	
0.00	....	150	69	
1.00	0.05	150	69	Injection begun.
1.30	....	148	66	Injection ended.
2.10	....	100	78	
2.50	....	80	90	
3.50	....	40	....	Pulse very irregular.
4.50	....	140	66	
7.50	....	150	68	Animal was afterwards killed with ether.

Experiment XV (Normal).

Time.	Dose.	Pressure	Pulse.	Respiration.	Remarks. (Dog-weight 6.804 kilos.
m. s.	grammes.	m.m.	p. m.	p. m.	
0.00	....	140	165	32	
1.30	0.01	140	165	32	Injection begun.
2.00	....	166	165	30	Injection ended.
3.00	0.02	166	153	33	Injection begun.
3.30	....	160	138	21	Injection ended.
4.30	0.02	166	138	18	Injection begun.
5.00	....	166	138	18	Injection ended; convulsions.
16.30	0.03	136	153	33	Injection begun.
17.00	....	136	129	45	Injection ended; pulse waves large (22 m.m.)
18.00	....	130	116	45	
19.30	....	128	112	45	

gramme, from 140 mm. the column of mercury rose to 166 mm. It soon fell to 160, still above the normal, and was again seen at 166 about one and a half minutes after a second dose of 0.02 gramme of the agent. Convulsions appeared half a minute later, these lasting but for a few moments. The pressure continued high but was soon brought down by a third injection of 0.02 gramme, and especially after a fourth dose of

0.03 gramme. The pulse behaved differently from the last two experiments. There was no increase in rate—in fact, no change whatever, although the rise of the pressure was marked. After the second dose, however, the cardiac rate was notably diminished notwithstanding the increased pressure. Immediately on the ingestion of the fourth dose, although the pressure had now descended to even below the normal height, there was a sudden increase of the cardiac rate, but only to 153, still less than the original number of beats. The pulse soon again decreased in rapidity, accompanied with a considerable increase in the size of the individual waves. The respiration exhibited a marked irregularity. They were at first diminished in number, and toward the end of the experiment increased in rate but not in depth.

For *Experiment XVI* I used a dog weighing 5.668 kilos. In this instance both the pulse and the arterial pressure declined after each one of the two injections administered. Following the first dose of 0.05 gramme,

EXPERIMENT XVI (Normal).

Time.	Dose.	Pressure.	Pulse.	Remarks. (Dog-weight 5.668 kilos.)
m. s.	grammes	m. m.	p. m.	
				One vagus and one crural nerve prepared. Small electric current used to produce inhibition of heart in ten seconds when applied to central end of nerve (vagus), and in about six seconds when applied to peripheral end.
0.00	....	130	123	
1.45	0.05	130	123	Injection begun.
2.15	....	110	114	Injection ended.
3.45	....	90	93	Pulse waves large (18 mm.).
6.45	....	110	102	Pulse waves not so large.
14.15	....	120	96	
16.30	0.05	120	102	Injection begun.
17.00	....	100	93	Injection ended.
18.00	....	60	66	Pulse waves very large (28 mm.).
21.00	....	48	45	Pulse waves very large, current to vagus, either end, caused immediate arrest of heart.
22.30	....	30	60	Strong current to crural nerve; no effect on pressure; respiration ceases.
24.00	....	10	54	Pulse waves still large, giving evidence of prolonged cardiac systole.
25.00	....	....	....	Heart ceased; postmortem showed organ in diastole, full of dark blood.

the pressure, which had fallen from 130 to 90 mm., showed a tendency to regain its normal standard, but even after fourteen minutes it only marked 120. The second injection of the same amount was followed again by a lowering of the pressure, the fall being gradual. When it was marking 30 mm., a strong current of electricity applied to ischiatic nerve produced *no* effect whatever on the column of mercury. The pulse-rate was depressed also after the first dose, and when it was marking only 93 (normal 123), the individual pulse-waves became enormously large. Three minutes later, the rate of the heart was 102; in about eight minutes it again fell to 96, and once more, in the course of nearly two minutes afterward, a rate of 102 was produced. After the second dose, the pulse-rate fell again *pari passu* with the descent of the arterial pressure, the secondary fall being again accompanied with an enormous size of the individual pulse-waves. The beats were reduced to 45, and when a minute later the action had become a little faster, 60 per minute, both ends of the cut vagus were stimulated by the small current of electricity used before the ingestion of the drug, and an almost immediate arrest of the heart followed. Death of the animal finally occurred from failure of the respiration.

Thus it is seen that the actions of sparteine upon both the arterial pressure and the rate of the pulse, in normal animals, is not by any means constant, the effects of the drug being undoubtedly dependent not only on the size of the dose administered, but also upon which one of the actions predominates.

As an example of the more constant results obtained in curarized animals, the following experiment is submitted:

EXPERIMENT NO. XVII. DOG-WEIGHT 6.916 KILOS.

Time.	Dose.	Pressure.	Pulse.	Remarks. Curarized.
m. s.	grammes	m. m.	p. m.	
0.00	....	140	84	
10.00	0.5	140	84	Injection begun.
10.30	....	150	93	Injection ended.
11.30	....	110	75	
13.30	....	70	57	
16 00	....	70	57	
24.00	....	100	57	
27.00	....	140	81	
30.00	....	148	87	
35.00	....	150	102	
41.00	0.1	150	102	Injection begun.
41.40	....	100	69	Injection ended.
42.00	....	100	60	
45.00	....	96	51	Pulse waves very large (30 mm.).
48.00	....	90	54	
54.00	....	90	54	
59.00	....	90	54	
64.00	....	80	51	Pulse waves still very large. Two more doses of 0.01 gramme each were administered half hour apart. The same effects were noticed as regards blood-pressure and pulse. The animal was kept alive by artificial respiration, and was finally killed with curare.

The following experiments are self-explanatory:

EXPERIMENT NO. XVIII. DOG-WEIGHT 6.5 KILOS.

Time.	Dose.	Pressure.	Pulse.	Respiration.	Vagi cut.
m. s.	grammes	m. m.	p. m.	p. m.	
0.00	....	158	183	12	
10.00	0.05	150	188	8	Injection begun.
10.30	....	160	190	10	Injection ended.
12.30	....	162	90	15	
13.30	....	90	84	20	
15.30	0.05	110	84	12	Injection begun.
16.00	....	110	84	8	Injection ended.
17.30	....	80	....	6	Pulse very irregular.
20.30	....	40	87	4	
24.30	....	16	45	2	
25.45	....	....	....	....	Animal dead.

EXPERIMENT NO. XIX. DOG-WEIGHT 10.2 KILOS.

Time.	Dose.	Pressure.	Pulse.	Resp.	Vagi cut.
m. s.	grammes	m. m.	p. m.	p. m.	
0.00	....	180	210	14	
15.00	....	184	210	10	
16.00	0.5	184	210	10	Injection begun.
16.30	....	190	165	16	Injection ended.
17.00	....	210	168	18	
21.30	....	200	162	18	
26.30	....	190	162	12	
38.30	0.5	180	180	10	Injection begun.
39.30	....	180	180	8	Injection ended.
40.00	....	190	168	6	
43.00	....	214	180	6	
44.00	....	230	165	6	
45.30	0.5	180	168	6	Injection begun.
46.00	....	190	176	4	Injection ended.
47.00	....	160	138	4	
52.00	....	....	....	....	Killed with chloroform.

EXPERIMENT NO. XX. DOG-WEIGHT 7.2 KILOS.

Time.	Dose.	Pressure.	Pulse.	Remarks. Cord and vagi cut.*
m. s.	grammes.	m. m.	p. m.	Cord severed in cervical region.
0.	....	52	158	
20.00	0.01	50	158	Injection begun.
20.40	....	52	162	Injection ended.
21.30	....	54	162	
22.30	....	56	158	
24.30	....	56	158	
28.00	0.02	54	160	Injection begun.
28.50	....	54	158	Injection ended.
29.50	....	52	140	
32.30	....	48	132	Pulse-curves large.
34.30	....	30	126	Pulse-curves very large.
38.00	....	20	110	
42.00	....	20	98	Was afterwards killed by a third dose of 0.02 grammes.

*That the cord was completely severed was verified on post-mortem examination in both this and the following experiment.

EXPERIMENT NO. XXI. DOG-WEIGHT 5.8 KILOS.

Time.	Dose.	Pressure.	Pulse.	Remarks. Cord and vagi cut.
m. s.	grammes.	m. m.	p. m.	Cord severed between 4th and 5th cervical vertebræ.
0.	....	48	112	
15.00	0.01	48	112	Injection begun.
.40	....	50	118	Injection ended.
16.30	....	56	120	
17.30	....	56	120	
20.00	... .	54	118	
26.00	....	52	112	
28.30	....	48	....	Pulse irregular.
32.00	0.02	38	102	Injection begun.
32.30	....	26	92	Injection ended.
33.30	....	20	80	
35.00	....	12	42	Pulse-waves large.
38.00	. ...	10	30	Pulse-waves very large.
42.00	....	....	....	Heart ceased suddenly.

Having given the details of the preceding experiments, the results of which have been considered in general remarks, it remains for me to discuss the manner in which the various phenomena are brought about in regard to the circulation.

The Pulse.—Sparteine, in small or moderate doses, causes in normal animals an increase in the frequency of the heart beats, followed soon afterward by a distinct decrease of the same.

Though not accurately determined as yet, there are various ways in which a drug may increase the rapidity of the pulse: (*a*) an action on the heart itself, whether through stimulation of the automatic motor ganglia, or paralysis of the intracardiac inhibitory ganglia; (*b*) paralysis of the medullary cardio-inhibitory centers, the few accelerator fibers contained in the vagi remaining intact, and in this way being still able to convey impulses from the respective unaffected centers toward the periphery; (*c*) direct stimulation of the accelerator centers in the medulla oblongata through the fibers of the cervical sympathetic.

Though by no means a constant phenomenon even in normal animals (both in the dog and in the batrachian), the brief period of increased pulse-rate under sparteine is observed in curarized animals (avoiding in this manner, as far as possible, any extraneous influences, especially alterations dependent on respiratory changes), in those in which section of both vagi had been previously performed, as well as in those dogs in which the heart was isolated from all nervous connection by previous division of the pneumogastrics and the spinal cord. These results and those obtained in the frog, appear to be concordant, and show, I think, that the rapidity of the pulse, when it does occur, is due to a direct cardiac action.

But the more frequent phenomenon observed regarding the pulse-rate, is the slowness produced by sparteine when given particularly in therapeutic or large amounts. This decrease is quite distinct, and is, as already stated, generally accompanied later in the poisoning with a remarkable increase in the size of the pulse-curves.

From a physiological standpoint, there are also several ways in which a reduction of cardiac rate may be brought about by drugs: (*a*) a paralyzing influence exercised on the heart muscle; (*b*) stimulation of the intracardiac inhibitory ganglia, or of the medullary cardio-inhibitory centers through the vagi nerves; (*c*) paralysis alone of part or of all the accelerator-nerve apparatus.

Under the action of sparteine, the fall of cardiac rate occurs not only in the normal dog, but also in animals in which division of the vagi has been practiced beforehand, as well as in those instances in which the heart has been separated from all nervous connection by section of both pneumogastrics and of the cord in the cervical region. From these results alone it could be inferred that the action of the drug was mainly of cardiac origin, but the inference would be illogical indeed. For while it can not be denied that direct cardiac influence is a prominent factor in the production of a slow pulse by sparteine, there can be no doubt, on the other hand, that the agent likewise acts on the nervous mechanism of the heart, to cause the same effect.

As is observed in Experiment XVI, a current of electricity sufficiently powerful to produce total arrest of the heart, in 10 and 6 seconds, when

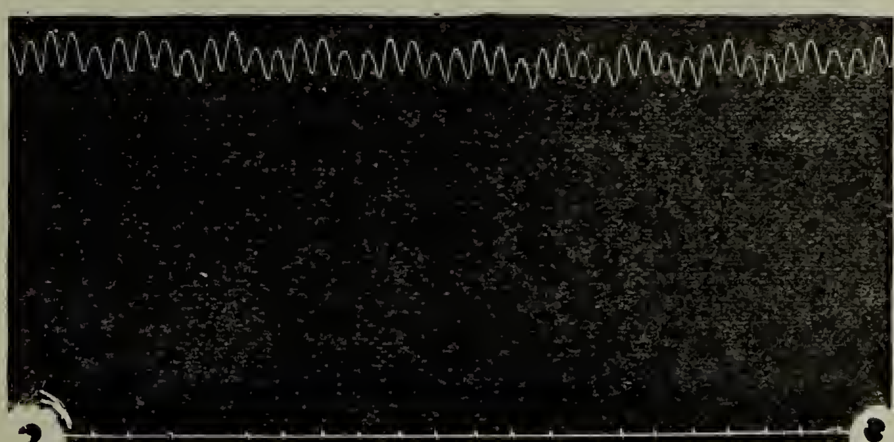

Fig. M.

Tracing III.—Dog weighing 7 kilos, under the influence of curare. Gave 0.1 gramme of sparteine sulphate intravenously.

applied to the central and peripheral ends of a cut vagus, respectively, caused in the sparteinized animal an almost immediate stoppage of the cardiac viscus. In other words, in the one instance 10 and 6 units, respectively, of a certain faradic current, applied to the central and peripheral ends of a severed vagus, were required to arrest the heart; in the other instance, that is, under the action of the drug, 1 unit or a fraction of a unit of an electrical current of the same strength, was sufficient to bring about a similar result in the same animal. It is obvious, therefore, that sparteine induces a hyper-excitability of the cardio-inhibitory centers, centrally and peripherally, which results in the slowing of the pulse rate. To the same stimulation, or better, perhaps, to a direct influence exerted on the cardiac muscle, may be attributed the increase in the size of the individual pulse-curves, this being an evidence of prolonged diastole, a greater filling of the heart with blood. These high pulse-waves appeared frequently proportionate to the decrease in cardiac rate.

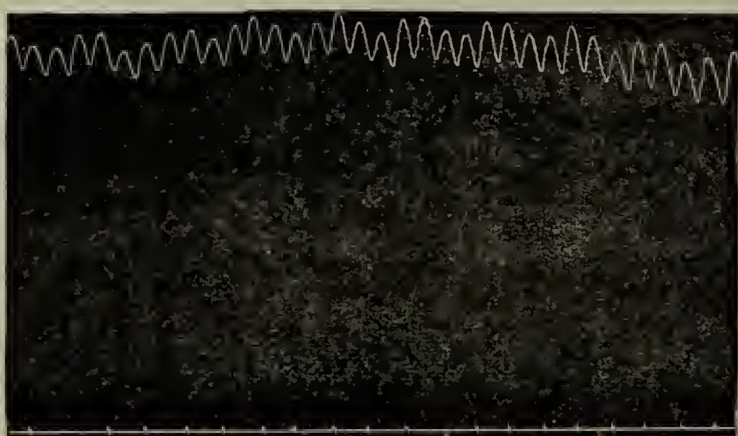

FIG. N.

TRACING II.—The same, 1 minute after the injection.

As regards the action upon the pulse sparteine resembles digitalis, though at no time was there observed the distinct dicrotic curves peculiar to the action of the latter drug. In one or two instances, it is true, was there noticed what might be called a kind of abortive systole (See Tracing II, Fig. F), but this was more probably due to some interference in the proper working of the registering needle in the manometer, and not to the action of the medicament.

To the foregoing results may be added the observations of Fick,* to the effect that muscarine (a cardiac depressant) exercises little or no influence on the sparteinized frog's heart. The results, again, of my own experiments on the cut-out cardiac viscus of the batrachian are obvious, and point to one evident conclusion. It is apparent, then, that sparteine slows the pulse-rate through a double action: by stimulating the heart itself, whether its muscle or its contained ganglia, or both, and by exciting the extrinsic cardio-inhibitory centers as well.

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* *Loc. citat.*

The blood-pressure.—The arterial pressure is generally increased by small doses of sparteine, this phenomenon being more or less marked according to the quantity of the agent administered. The drug sometimes, however, instead of an increase, causes from the outset a decrease of the blood pressure. When an increase is produced, the normal standard is obtained after a certain length of time. Even large and poisonous amounts of sparteine produce often a brief rise in the column of mercury, which is soon followed by a decided fall, this continuing till the occurrence of death. The fall, however, if the dose has not been fatal, is also recovered from in the course of time. The changes observed, as in the case of the pulse, are not constant, and, again, may be said to depend on which part of the mechanism influencing the arterial pressure is being acted upon at the time.

Let me examine into the primary elevation of the pressure caused by sparteine. Various causative factors must be taken into consideration in explaining this rise. Physiologically, the phenomenon may occur: (*a*) from a direct action on the heart itself or its controlling nerve-mechansm; (*b*) from a stimulating influence exercised on the vaso-motor system,

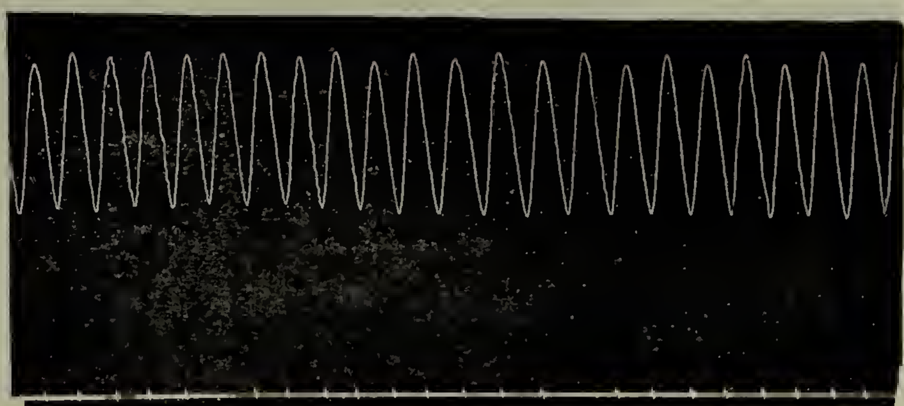

Fig. O.

Tracing III.—The same 8 minutes after the injection, showing the fall of the pressure, the diminution of the pulse-rate, and the large size of the individual waves, as in Tracing II, Figs. E, F, G, and H. (Normal experiment.)

whether centrally or peripherally; (*c*) from a direct action on the muscular coats of the arterioles. The first action, by augmenting the *vis a tergo force*, will naturally increase the resistance in the capillary blood vessels; and as a result of the second and third actions there will be produced a contraction of the arterioles, causing also an increase of resistance. In any one of the three instances the arterial pressure will rise, as shown in the distinct elevation of the column of mercury in the manometer.

It is quite difficult to ascertain with accuracy whether the muscle-coats of the arterioles are ever influenced exclusively of other changes occurring at the same time, even though the microscope be used (and by the aid of a micrometer) to watch alterations in the size of said arterioles under the influence of drugs. The results alleged to be obtained in these cases may be attributed largely to the imagination of the observer, and the method, therefore, is unreliable. Two, then, are the principal factors to be considered in explaining changes of blood-pressure; one relating to an action on the heart itself or its nerve mechanism, and the other relating to an influence exercised on the vaso-motor system which directly or indirectly may alter the caliber of the blood-vessels. But not only must the changes of the pressure be noticed, the rate of the pulse should similarly be observed at the same time for various reasons.

When in the intact animal the pneumogastric nerves are stimulated by an electrical current, the heart-beats are diminished in number and the blood-pressure falls. The contrary takes place when the vagi are simply divided; under these circumstances the pulse-rate is increased and the arterial pressure rises. It is assumed that here it is the heart or its controlling nerve-mechanism that is being directly influenced. A graphic

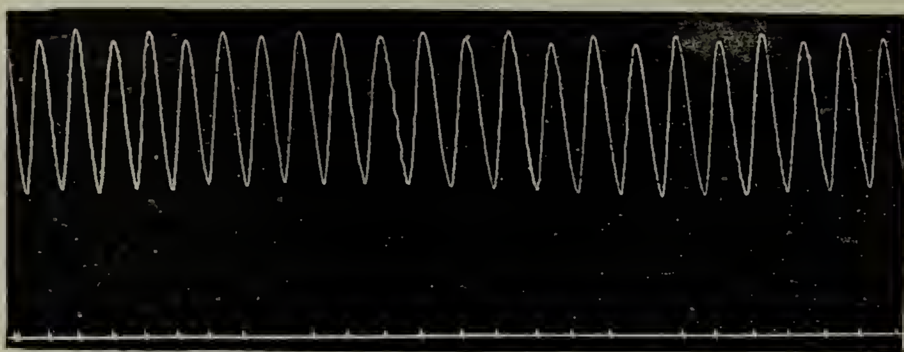

FIG. P.

TRACING III.—The same, 7 minutes later, or 15 minutes after the injection.

record taken in either of these instances would show a more or less *parallel* course of two curves, one representing the height of the pressure and the other the rapidity of the heart's action.

On the other hand, if a sensitive nerve be stimulated, by which the medullary vasometer centers are roused into activity, and hence contraction of the arterioles is obtained, by and by an elevation of the pressure is noticed, but *pari passu* with this rise there occurs a diminution in the pulse-rate; that is, the increased blood pressure *per se* is sufficient to excite the medullary cardio-inhibitory centers, and hence slowing of the cardiac beats is obtained. *Vice versa*, if the arterioles be dilated, as a consequence of a vaso-motor paralysis, the blood pressure falls, and under these circumstances the vagi centers, then deprived of a proper amount of blood, the natural stimulant, are freed from inhibition, and thus the cardiac viscus beats a great deal faster than in normal conditions. In either of these instances a graphic record of the pulse and pressure would show an *opposite* course of the curves.

Returning to the study of the action of sparteine, it is found (and a careful examination of the tabular records here given shows it) that the drug does not act in a constant manner even in the normal animal. In other words, the agent produces a rise of the pressure sometimes, and sometimes a fall of the same from the beginning, these variations being dependent probably on the amount of the agent ingested, or upon which one of the actions predominates.

The rise of pressure is sometimes accompanied with increased, and sometimes with diminished, pulse-rate. By curarizing dogs, changes of pressure, which may be caused by nervous excitability or respiratory influences, are avoided. The rise of pressure under sparteine is also obtained in curarized animals.

Previous section of the vagi does not prevent the same results as regards the pressure, and a similar irregularity in the relation of the pressure to the pulse, as in the normal animal, is sometimes observed. In dogs in which all nervous connection with the heart is destroyed, as shown in Experiments XX and XXI, a rise of the pressure is still produced by sparteine.

These results would lead one to suspect an action mainly of cardiac origin. But in the instances of previous vaso-motor paralysis by section of the spinal cord, the elevation of the arterial pressure, though it does occur, is not, comparatively speaking, so striking as in normal animals, I believe, therefore, that the action is a double one.

The fall of the arterial pressure under the action of sparteine occurs not only in normal animals but also in curarized dogs as well as in those subjected to the various operations already sufficiently described. The influence would be obvious. When in the normal animal, however, the pressure is far below the original point after a sufficiently large dose of sparteine, asphyxia on the one hand, and irritation of a sensitive nerve upon the other, are no longer able to effect a rise, evidently showing that the vaso-motor system is paralyzed. To produce a reduction of the pressure, other things being equal, the drug acts undoubtedly also on both the heart and the vaso-motor system.

The Respiration.—Sparteine at first stimulates the respiratory function. The movements are increased in rate but not in depth. The same results are observed after previous section of the pneumogastric nerves. The action is therefore a centric one. Later, and especially under large amounts of the drug, the respiratory movements become notably decreased in number, this depressant action being exercised in the normal dog as well as in those animals whose vagi have previously been functionally destroyed by section. The respiratory centers in the medulla oblongata are the ones affected by the drug, and it is precisely by paralysis of those centers that sparteine generally kills. (See Tracing II, Figs. G, H, I, J, K, and L.)

From the results obtained in this imperfect study, I am led to draw the following conclusions:

1. Sparteine causes a brief period of increased muscular irritability.

2. The drug increases reflex action by directly influencing the spinal cord.

3. Reflex action is afterward depressed by sparteine; first through a primary stimulation of Setschenow's reflex inhibitory center, and secondly by influencing the cord directly.

4. The convulsions produced by the drug, generally of a tetanic nature, are of a spinal origin.

5. The paralysis caused by the medicament is similarly the result of an action on the medulla spinalis.

6. Sparteine increases both the rate of the pulse and the force of the heart. The acceleration of the heart's action is soon followed by a distinct decrease of the same.

7. The primary increase in rate is due to an action on the heart itself.

8. The subsequent decrease in the rapidity of the pulse is of double origin; a direct cardiac action and stimulation of the cardio-inhibitory centers, centrally and peripherally.

9. The enormous increase in size of the pulse curves is probably the outcome of a direct influence on the cardiac muscle.

10. Sparteine increases the blood-pressure by an action on the heart and also by stimulating the centric vaso-motor system.

11. The subsequent fall of the arterial pressure under the drug, is likewise the result of a double action; paralysis of the vaso-motor apparatus and a depressant cardiac influence. Cardio-inhibitory stimulation, through the vagi, is possibly a third factor in the causation of reduced pressure.

12. Both the increased number of the respiratory movements and the secondary depression of the same, are due to a direct action on the respiratory centers in the medulla oblongata.

13. Sparteine kills generally by respiratory failure.

14. Sparteine may be classed as a decided cardiac stimulant, its range of action being similar to that of digitalis.

GALVESTON, TEXAS; 1320 AVE. E.

THE STORM-WATER STORAGE SYSTEM OF IRRIGATION.

ROBERT A. THOMPSON, M. A.

(*Read April 5, 1895.*)

As the humid areas of any country become more densely settled, the necessity for the reclamation of the arid and semi-arid portions becomes more pressing. To meet the requirements of the ever increasing population and demand for room, some methods of artificial watering must be provided when possible, whereby the arid and semi-arid regions can be made suitable for cultivation and be brought into a state of fertility sufficient to support these people, by the production of grain, fruit, etc.

In Texas to-day this demand is being felt stronger than ever before, as is shown by the deep and growing interest taken by the people in all questions pertaining to irrigation. Heretofore there has been little absolute need for those lands that require irrigating to insure regular crops, as up to this period in the State's history immigrants have found cheap and abundant fertile lands in the eastern and central humid portions, and settled there. These have, however, been largely taken up, and now new settlers are being pushed farther and farther westward, and large sections of the sub-humid areas are already occupied by those who attempt agriculture. To support the rapidly increasing population throughout these semi-arid portions, some decisive steps must be taken towards ascertaining the best methods for reclaiming the tillable lands and bringing them into a suitable state for cultivation.

Conservative estimates place the amount of arid and semi-arid lands of Texas at two-fifths of its total area; in fact, under this head may be classed all that portion of the State lying west of the 98th meridian. In this region lie some of her most fertile lands, supplemented by a climate salubrious, and in most cases superior to that of the humid district, making it more desirable for occupancy. In this area from the most northern to the extreme southern portions of the State are soils adapted to the greatest diversity of crops.

Thousands of acres in this region can be watered artificially by utilizing the flow of such perennial streams as the Rio Grande, Pecos, Devil, Nueces, Guadalupe, and Colorado rivers and their major tributaries. These acres lie in the immediate valleys of the different streams or adjacent thereto; but considering the amount of available land along any one of these streams, only a small part can be watered by the ordinary flow. By building immense dams across their channels, and storing the "storm water" at various points along the streams, nearly the whole of these lands can be irrigated.

But for the lower plateaus and the valleys of the non-perennial streams, this water can not be made available, and for them another system must be devised. Under this head are included by far the greater percentage of fertile and tillable lands; hence a system that will water these will be of very great importance. In many cases small areas can be irrigated from surface and artesian wells, but irrigation by this system has proven costly and impracticable on a large scale. It is with "storm water" stored in impounding reservoirs that these lands must be watered; it is the best and only system practicable, and it is to this system that the greater part of the semi-arid lands must look for reclamation.

The water that collects and flows on the surface of the earth during and after storms is commonly termed "storm water.". It flows down the natural water courses, filling the dry channels of the periodical streams, and increasing the ordinary flow of the perennial ones. With reference to these latter streams, this extraordinary flow is called its "storm water," and must not be confused or classed with the ordinary flow, which is usually derived from other sources than surface.

Major C. E. Dutton, in a recent address on irrigation, delivered before the San Antonio Scientific Society, considers the advancement of the science of irrigation divisible into four successive stages. The first two affect the use of the perennial waters of streams; the third utilizes the storm water of streams; and the fourth impounds the storm water from catchment areas in storage reservoirs. There can be no doubt but that the third and fourth stages will eventually become the most important to the people of Texas.

Prof. E. T. Dumble, who is an authority on questions of this nature in Texas, in a paper read before the Irrigation Convention at San Antonio, gives the systems of irrigation, in the order of their importance to the State of Texas, as follows: First, "*use of storm waters;*" second, "*use of the flow of the perennial streams;*" third, "*artesian wells.*"

Irrigation by use of "storm water" is properly divided into three systems. The first considers the storage and use of the "storm water" of the perennial streams; the second, the storage of the "storm water" that flows down the non-perennial water courses; and the third, the collecting and storing of the "storm water" from local limited catchment basins in tanks or excavated reservoirs.

The first two are very important, but on account of the few perennial streams in the arid districts, the latter are of broader scope, and deserve at least equal consideration. Across the beds of the greater perennial streams, down whose channels flow such enormous volumes of storm water, immense dams can be built, whose size is determined only after having obtained a full knowledge of the "ordinary flow" and distribution of the "storm flow," and the area of the land it is desired to irrigate. The building of these dams, whose height must not only be sufficient to raise the water to the "country level," but also to store a supply above this level, entails great expense and shrewd, careful engineering. In India, where several large storage dams have been successfully built, the engineers have followed closely the cross section pointed out by theory.

Under the influence of the second division of the storage system can be brought the greater percentage of the semi-arid lands, and it will be seen that the great aim of this method of irrigating is to augment the natural supply in semi-arid and sub-humid regions, where the rainfall, though ordinarily sufficient to produce crops, is irregular. In this case only a comparatively small supply need be stored for a large area, as seldom will more than two waterings be required in succession. A small supply will tide over a short season of drouth where otherwise the entire crop would be lost. Dams for these reservoirs can be built in most cases from materials near its location; either of rock or of clay mixed with sand or gravel, as may be most economical. It is cheaper and safer in all cases that the surplus water be discharged over a waste-weir built at one or both ends of the dam, rather than over the whole length of the crest; and it may be well to put particular stress on recommending that special attention be always given to the construction of the waste-weir.

Where storm water is to be stored, economy always suggests the building of waste-weirs for the escape of surplus waters, rather than a submerged dam. They should be made large enough to discharge the greatest flood of which there is any record. In Arizona and California a number of very expensive dams have been destroyed, either because of erroneous calculations on part of the engineer, or because of incorrect or insufficient data in regard to the maximum flood discharges of the streams.

The third division, or the collecting and storing of storm water in excavated reservoirs, is of greatest importance to orchards, gardens, and small farms, where methods of watering other than by gravity distribution can be made profitable. This method of storing water is now practiced extensively on a small scale in the semi-arid districts, as a source of water supply for man and beast. Especially is this done in those localities where surface water is not abundant in the streams, or is obtained in wells only at great depths, or where obtained is unfit for use. A "tank," as it is commonly called, built in a bed of clay, will retain from 75 per cent to 90 per cent of the collected water.

For any system of irrigation the question of rainfall is of first importance, and especially so with the "storm water" storage system. It is particularly necessary that the minimum annual precipitation, ascertained from observations extending over a number of years, be known. This will indicate the maximum amount of water that will be required to be stored to irrigate any given area. In the sub-humid regions exceptional seasons will come, when the precipitation is sufficient and distribution even, which will make unnecessary the using of any stored water. A rainfall of 28 inches per annum is considered sufficient for the successful growth of any crop, if evenly distributed throughout the cropping season; even a less amount is considered ample by a great many authorities—some as low as 20 inches; but stress is laid on the fact that it must be evenly distributed. Such a season as the latter must be preceded by a wet period, that the ground be already in prime condition.

Lands over which the annual rainfall is from 20 to 28 inches are classed as sub-humid or semi-arid; though more properly *semi-arid* lands are those over which the rainfall is from 18 to 24 inches per annum. In Texas the rainfall decreases almost gradually along an east and west line, from very humid climate in the east to a very arid one in the west. The line of 28-inch rainfall may be considered as the dividing line between the humid and the arid areas. This line follows approximately the 98th meridian from the north as far south as San Antonio, where it swings slightly to the east, and follows the 97th meridian to the coast. More properly speaking, the arid region is separated from the humid, not by any well defined, closely cut *line*, but by an *area* or *belt*, over which this line of 28-inch rainfall fluctuates each year, passing eastward or westward, according as the rainfall is greater or less than the average. For any point within this belt it will be seen that the rainfall throughout a number of years will suffer some extreme variations; for instance, at Abilene, in 1888, the rainfall was 29 inches, while in 1891, it was only 17; at San Angelo, in 1884, the precipitation was 35 inches, and in 1886 it was 11. In these regions, where the annual rainfall suffers such extreme variation, and when sufficient, such uneven distribution, it will be seen immediately that some means of irrigation must be provided, if it is intended to make them a successful agricultural country. Some steps should be taken, properly by the State government, towards the establishment of observing stations, particularly in Western Texas, so that a complete and accurate knowledge of the rainfall may be obtained. The data at present is very inaccurate and insufficient; and where there have been stations, they have been so far apart that no definite information has been obtained regarding particular localities. No system of irrigation should be projected unless a correct knowledge is had of the amount and distribution of the annual rainfall.

The sub-humid region at present requires particular attention, and a short review of the history of farming in this belt may not be found inappropriate, and will be found full of instructive lessons. Experience shows that the wet and dry seasons alternate in groups: two or more wet seasons will be followed by several successive dry ones. When the period of several seasons in succession of sufficient rainfall comes, the settlers, tempted by the fertility of the land and salubrity of the climate, flock to these regions, and their first years are marked by prosperity; but when the succession of dry years comes, and one crop after another fails, their stores melt away, and poverty and famine result. Lands are mortgaged to speculators, houses and cattle are sold, and disaster to the country is a consequence. Perhaps in the history of the United States there has never been so large a body of people who have been a prey to land speculators as those who have from time to time settled in this sub-humid region. As a rule, they return to the humid regions and endeavor there to retrieve their shattered fortunes. Soon another succession of good seasons comes, and these lands are again sold at a fair price—the new settlers to suffer the same sad experience.

This condition of affairs should not exist; there is a remedy for it. It is a well known fact that throughout the world similarly situated and less fertile lands support a large and prosperous people, who with irrigation cultivate orchards, gardens and small farms. The arid West can support a like people if only they provide themselves with a means for artificially watering crops. Often a store sufficient to give a crop two or three floodings will be ample; sometimes more will be required, and again the precipitation will be sufficient to require none.

When considering the available systems of irrigation for a region, it will be seen that for those lands that can be brought under the influence of perennial waters the systems utilizing these will be most economic; but for the upland valleys and valleys of the minor streams the "storm-water" storage system is the only one practicable. For each small valley a storage reservoir can be built near its head, and lands below irrigated with the water collected. Nearly every farm possesses a reservoir site where water can be stored for at least a portion of its land.

Even in very humid regions the value of a supply of water reserved for the occasional drouths that occur, is realized, and by so doing many crops are saved or their yield increased. This practice is followed with advantageous results in France and Spain, where the annual rainfall is from 40 to 50 inches. In India irrigation is extensively practiced, where the total rainfall (annual) is greater than it would seem would make irrigation necessary to produce crops successfully; but though the fall is sufficient, the distribution is so irregular that the natural supply can not be relied on, and artificial watering must be resorted to. The Upper

Ganges Canal irrigates 1,600,000 acres in an area having an average annual rainfall of 33 inches. The Lower Ganges Canal irrigates 1,187,000 acres, with a rainfall of 31.1 inches over the area which it controls. On the lands watered by the Agra Canal, the precipitation averages 27 inches per annum. Movements have been made to bring the very humid lands of Louisiana and Mississippi under some system of irrigation. As irrigation is more appreciated it will be more practiced all over the world in what are now considered very humid lands, to increase the yield and offset the disastrous consequences of drouth.

Where the precipitation is small and evaporation great, particular attention must be given to the size of the catchment area, and selection of the reservoir site. After determining the percentage of evaporation and percolation from a given catchment basin, the amount that can be collected in the reservoir can then be estimated. This is ordinarily estimated at 40 per cent of the total rainfall. The reservoir should be in some narrow place between hills, so that the cost of the dam will be minimized and the sides of the reservoir steep, in order that a small surface will be exposed to evaporating influences.

The "storm-water" storage system of irrigation can not be considered impracticable or impossible, and when it is seen that for such a large part of the fertile lands of Texas it is the *only* system practicable, some credence will be given to its importance. The necessity of *making* land available for agriculture is not yet felt or appreciated by the people to the extent it will be.

To encourage this system of irrigation, and to demonstrate its practicability, Major Powell, of the United States Geological Survey, at the the urgent request of the Texas Survey, caused several catchment basins to be surveyed in West Texas, and the favorable sites for reservoirs located. All data pertaining to rainfall, etc., have been collected, on which the following estimates are based.

One nine miles south of Marfa, in Presidio county:

Approximate area of catchment basin...........	440 square miles.
Surface area of reservoir......................	1.43 square miles.
Height of dam..................................	100 feet.

It is estimated that a rainfall of one and one-third inches from the entire basin would fill the reservoir and be sufficient to irrigate 20,000 acres.

One seven miles south of Alpine:

Approximate area of catchment basin...........	203 square miles.
Surface of reservoir..........................	1.43 square miles.
Height of dam..................................	50 feet.

A rainfall of one and one-fourth inches, collected from the entire catchment basin, will fill the reservoir and irrigate 7000 acres. More attention has also been given this question by the State Geological Survey, and a number of reservoir sites located in Trans-Pecos Texas and in the Colorado coal field of Central Texas. One of the latter has been recently selected by the Brown County Irrigation Company as a locus for their reservoir and dam. Also, another site located by them on the San Saba river, above San Saba, has been selected by an irrigation company, who have made complete surveys and are expected to begin operations soon.

The prime costs of irrigation works are so great that capitalists hesitate investing money in them until it is assured that they will prove a financial success, and also that their interests will be properly protected by law. Some of the largest enterprises of this kind in India paid but a very small dividend on the capital invested till a number of years after their construction.

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THE LAW OF HYPNOTISM.

BY R. S. HYER.

The numerous allusions in current literature to the phenomena of hypnotism, "mind reading," "telepathy," "telekinetics," etc., are generally of such nature as to show a very prevalent belief that certain favored minds possess unique powers, by virtue of which they may so rise above the old limitations as to act directly upon matter, to endow other minds with new capacities, to suppress them into slavery, or to rob them of their most secret thoughts. Such views have been explicitly stated by the editors of widely circulated magazines. They are clearly implied in such popular novels as *Trilby*, *The Fair God*, and *Mr. Isaacs.*

The foundation upon which this belief chiefly rests is the fact that the singular, yet unquestionably genuine, phenomena first made generally known by Mesmer, have not been explained by any investigator to the complete satisfaction of all who are recognized as having a right to an opinion on this subject. Of hypnotism Mr. Edward Gurney has truly remarked, "for so short a span of existence few sciences have been so prolific of theories, presented so often simultaneously and with but little attempt at mutual refutation."

The commission appointed by the French Academy to investigate the claims of Mesmer reported that his results, instead of being due to a "hitherto undiscovered force," "specific influence," or "occult power," were but the products of the excited imaginations of his subjects.

To Dr. Braid of Manchester is usually ascribed the honor of being the first to attempt a scientific explanation of the phenomena,—the report of the aforesaid commission being considered descriptive rather than explanatory. From the fact observed by him that paralysis and even coma might be induced by protracted gazing at a brilliant object, and also by such other means as produce fatigue in a sensory organ, he concluded that Mesmeric phenomena have a physiological origin; and he applied to them the term Neurohypnotism.

This view that it was a "nerve sleep" was further extended by Prof. Heidenhain. The pressure of his thumb against that of his subjects would be followed by the paralysis of any muscle or set of muscles that he had designated. These results he ascribed to nervous disturbances originated by external stimuli, and transmitted to the outer cells of the brain; where, if the original disturbance had been intense, the effect would be the paralysis of those parts of the brain employed in the higher intellectual operations, thus leaving the body a mere automaton to move only in response to outward agencies. Such, in brief, is his theory of the "inhibition of the activity of the ganglion cells of the cerebral cortex." So brilliant were the experiments of this professor of physiology, and so satisfactory was it to thus find a scientific basis for the phenomena, that his views were at one time generally accepted by scientific men.

Against this theory, however, certain objections have been brought that appear unanswerable. Among many of this nature we notice the following. The supposition being that "inhibition" extends to the higher psychic operations and that all acts are merely of an imitative order, why does the subject obey, as a rule, only the operator; and how can he, if such be his mental condition, carry out commands involving the performance of many separate and orderly acts? In many instances it is so apparent that the subject retains consciousness, memory and all other mental powers save the single one of determining his activities, that Heidenhain's theory of "cortical inhibition" is declared by many competent observers to be utterly at variance with facts.

Abandoning all attempts to account for the phenomena on purely physiological grounds, the investigators have constructed theories out of psychic factors. Dr. Carpenter relied chiefly on "reverie and suggestion;" others have stressed the importance of the "dominant idea," "expectant attention," "imagination," "belief," "tonic cramp of the attention," etc.

Against all of these, Mr. Gurney, writing in *Mind*, vol. IX, has with much ability urged the objection that not one of them furnishes an answer to such questions as the following: Why is the operator alone obeyed? Why can he alone terminate this state? What is the connection between the manipulation employed and its effects? Why can not all hypnotize? Above all, what is the law for the production of this state? By such questions Mr. Gurney has clearly set forth the real difficulties presented by the phenomena of hypnotism. Declaring that these questions, "lying on the very threshold of the subject, * * * have scarcely been recognized, much less answered," he clearly intimates the belief that our only recourse is to return to the old hypothesis of "occult powers" and "specific influences."

Many have done this in substance if not in form. Designating their theories by various names and formulating their views in terms of modern science, they advocate the old theory of the possession of unique powers by a favored few. They declare that he who does not possess these is no more justified by this lack in denying their possession by others than would the individual afflicted with *Daltonism* be justified, from his own inability, in declaring that no one can tell by its color whether a berry is ripe or green. Among the advocates of such views are to be found some eminent in the scientific world. Their *a priori* position seems to be that man has reached that stage in his psychical evolution where new powers are beginning to be developed. That which has been done they regard as but the grapes brought back by spies from a land of promise, a land that posterity is some day to possess in full. Nor is this faith without its prophet. Flammarion has turned his telescope upon our own earth as it shall be some thousand years hence, and has seen its inhabitants "emerge from the limits of animalism, with senses so refined that mind can act upon mind at any distance, recalling departed spirits by virtue of a transcendental magnetism of which children may avail themselves."

If it can be clearly shown that among the many reported instances of "mind reading," "thought transference," etc., there is a single genuine phenomenon of this nature, we must necessarily resort to the hypothesis of a "hitherto undiscovered force in nature," and declare that a new and most promising field has been opened up for scientific investigation.

Have we any certain proof that there have been phenomena of this nature? The experiments of Dr. Luys at the hospital of Nancy seemed to prove the certainty of their existence till Ernest Hart made the whole affair quite ludicrous by proving that Luys himself had been duped by clever subjects who had been making themselves "interesting."

Lombroso reported that he had made a subject write music and speak German though he knew neither. Yet, according to Donato, this very subject has stated that he was quite familiar with both. Many like instances could be given of the errors into which men of high scientific attainments have been led. The Society for Psychical Research reports that instances of thought transference have been witnessed by its members in which all were agreed that there was no possibility of fraud. The value of this opinion must be determined in the light of the fact that for two years this society was chiefly occupied in studying thought transference as practiced by a set of girls, and for two years they were successfully imposed upon. When at last the fraud was detected "certain members were disposed to regard this deceit as an afterthought that had engrafted itself upon a genuine phenomenon." When two years are required to detect one fraud, and its detection shows the lengths to which some are willing to go to sustain a preconceived opinion, we can but suspect that, after all, there may be some mistake in the announcement that other cases were genuine.

It is well known that the feats of the professional "mind reader" are usually only clever tricks of "muscle reading" that almost any one may impose upon a marvel-loving public. The celebrated feats of Bishop and

Cumberland I have often repeated with friends, who could not detect how they were done.

Not till there is at least one instance of "thought transference" or "mind reading" that is above all suspicion of fraud on the part of the operators, and of errors and self-deception on the part of the observers, is there to be found in these practices any confirmation of the view that the phenomena of hypnotism are to be ascribed to the possession of unique powers by the hypnotist.

The purpose of the present paper is to describe certain phenomena of hypnotism that arose under somewhat peculiar circumstances, and to further relate how they were reproduced under conditions, such that, judging by some of the theories already noticed, we would deem them impossible. This account is given in hopes that it may throw some light upon the problem as presented in Mr. Gurney's criticism.

In the September (1892) number of the *Review of Reviews* Mr. Stead described a performance given by Phyllis Bently before a number of European monarchs. This performance, we are told by the editor, "touches one phase of that vaguely apprehended psychic force which begins to manifest itself in so many suggestive ways to the aroused spirit of inquiry." It is quite evident that Mr. Stead and Mr. Shaw had no idea that they were extolling the cleverness of an impostor. Such was really the case. Yet, I am disposed to think that their estimate of the value of this performance was correct. When rightly understood it does throw light upon some obscure mental processes.

My attention was first directed to this subject by witnessing a performance almost identical with that described by Mr. Stead. For some years one calling herself "Annie Abbott, the Georgia Magnet," has attracted considerable notice in America, and has also gained some notoriety in Europe, as is shown by the following letter from Andrew D. White, Minister to Russia. In reply to certain inquiries, Dr. White writes from St. Petersburg: "Miss Abbott certainly did attract much attention in various capitals of Europe. I was present at one of her performances given here last winter, and can testify that the audience was large and brilliant, and was, I think, as much surprised as myself at the things she did. That you are right in your general manner of accounting for her feats I am very much disposed to believe, and you would render a great service by giving to the world a careful study of the subject."

The opinion that I had expressed to him was that her feats were accomplished by a clever combination of imposture and hypnotism. In my investigations I did not rest satisfied till I had reproduced every important feature of the original. Time would fail me to describe the whole in detail. My object being, not the exposure of an impostor, but a contribution to our knowledge of the conditions under which hypnotism may arise, I shall confine myself to those points which throw most light upon this interesting question.

Consisting largely of feats that were only mechanical performances of such simplicity that the only mystery about them is that they passed for evidences of a "hidden power," they were, nevertheless, genuine hypnotic phenomena. We must clearly understand the conditions under which these arose. This woman places her hands upon a chair, and no one can hold it still when she springs away, some being forced to follow her so long as she moves. One after another various persons are requested to lift a chair; she places her hands against it, and then no one can put it to the floor. She stands upon one foot, and no one can push her over. Two, even four, strong men fail to support her when the chair upon which she has been standing is removed. She lifts a chair in which four men are seated. She can not be lifted by anyone. She borrows a thermometer from a physician, holds it in her mouth five minutes, and it records a temperature of 93°. The physician counts her pulse and says it is 150. That there is no collusion on the part of others is certain. They are all well known to the audience. Now I have discovered that each of the above apparently marvellous feats can be repeated by using only the simplest mechanical principles. As already remarked, the real mystery about them is that they are so successfully palmed off as evidence of a "mysterious power which the woman herself does not understand." This is largely due to her ingenuity in arousing the expectation of her audience. She recites her "marvellous career," relating that both Lord Kelvin and Mr. Edison have investigated her power and have concluded that it must be a form of electricity. (It is perhaps scarcely necessary to state that I am authorized by both Lord Kelvin and Mr. Edison to say that they have never made any such investigation nor expressed any opinion concerning her, though Lord Kelvin adds that a friend did once request that he should do so.)

But, aside from these impostures which for a time escaped all detection, there were certain genuine phenomena clearly of hypnotic nature. It has already been mentioned that some were at times compelled to follow her for a considerable distance when they attempted to hold a chair upon which she had for a moment placed her hands. That it moved slightly with all for a moment is easily explained, but no mechanical theory will explain the duration of this motion at her will. Nearly all who came in contact with her felt peculiar sensations which they described as "electric shocks." The so-called "transfer of her power" to children in some cases caused them to lose consciousness; and strong men tried in vain to lift children upon whom she had operated from a distance of several yards. On one occasion she apparently fainted, and while in this state her arms could not be lifted by several whom she had selected to make the attempt. A long account might be given of the experiences of different individuals, all tending to show that, at several exhibitions, all who were experimented upon were, at some time or other, more or less under what is commonly called the hypnotic influence.

So far as I am aware the voluminous literature relating to this subject contains no record of the experiences of one who was able to trace the mental process by which he was made to enter the realm called hypnosis. As it was chiefly by my own experience that I was led to the conclusions to be hereafter stated, I shall now attempt to describe how I was hypnotized. During Annie Abbott's performance I was at all times fully persuaded that she was largely an impostor. Her statements concerning Lord Kelvin and Mr. Edison were quite sufficient to convince me of this. But from accounts given me of previous performances I believed her to be a hypnotist of unusual power. I had no definite idea of what hypnotism is, save that it is generally believed to be largely a matter of will power. In the first experiment I was not greatly surprised to find that I could not hold the chair perfectly still at the moment when she sprang away from it. But, when a young friend could not prevent it from following her across the stage, I was utterly at a loss to know how to account for it. When asked to try to put to the floor a chair that she held at arms' length, I was astonished at the audacity of the proposition. This was changed to utter amazement and confusion when I found that I could not lower it, though I had pulled so hard as to break one of the legs. That unsuccessful attempt was the most complete surprise of my life. Up to that moment I had not believed it possible for any one to hypnotize me. I then began to fear that this woman had done so. I could give no other explanation to my failure. I determined to watch myself to see if I could detect any indications of this mysterious influence. When I tried to push her over, and found that I could not, I asked myself, "Are my muscles all in normal working order?" I discovered that I could not maintain the posture necessary to give a strong forward push. This was really due to the ingenious mechanical advantage taken by the woman; but at that moment I was fully convinced that there must be something the matter with my legs. Quickly turning my attention to them I found that it was as I had expected: the muscles were all contracted to such an extent that I could scarcely bend my knees. Believing that I had detected the real nature of her power, and realizing my helplessness, I made no further attempt to push her over. I was next asked to try to lift her. I had said that I would, and determined to do so, though I knew that a number of stronger men had failed. Grasping her as directed, I would not make the attempt till I had examined myself to see that my legs were all right. Just as I had predicted to myself, I found them again paralyzed. "This," said I to myself, "is certainly hypnotism; but it shall not hold me: I will throw it off and lift this woman." With one mighty effort I wrenched myself from the grasp of my invisible foe; my strength returned, and instantly I lifted with all my might. The effort proved a failure, for the reason, as I at once detected, that the position in which I had been forced to stand made it a physical impossibility. Upon telling her this, she allowed me to change. When she had again placed her hand upon my neck I once more examined myself to see if my invisible foe had not again seized me. Again I found it necessary to shake it off. Then suddenly I pulled the woman towards me and raised her to a height of a foot or more, despite her struggles and painful pressure with her thumb against my neck. This, her only failure, she explained, to the complete satisfaction of her audience, as being due to the fact that her hand had slipped from my neck; thus breaking the "flesh contact" necessary for the full exercise of her power.

Fully satisfied that hypnotism was the agent employed, I was now only concerned in the manner of its production. She used none of the manipulations usually employed, and denied that she was a hypnotist. I soon saw that contact with her subjects was not necessary, several whom she did not touch at all being unable to lift children. I could at that time see nothing common to her various feats save the single fact that she succeeded only when her demands were fully met. The real significance of this could be made apparent had we time to consider the feats due solely to mechanical agencies. It is mentioned now that we may trace the effects produced by the significance I at that time attached to it. Some surrender of will I knew to be the one thing usually declared by hypnotists to be indispensable to their success. Believing that by implicit obedience we were in some way surrendering ourselves to her influence, I determined to make certain mental reservations when next I was asked to do a thing in a definite way. Being directed to stand behind a child and grasp it by its arms, I departed from her instructions, but so slightly that she did not notice it. I then felt confident that I would be able to lift the child, and did so with ease. Turning quickly she directed that I should try it again. For a moment I hesitated whether to disobey again or to follow in full her directions. I was anxious to defeat her, but there was a fascination in the thought that, should I obey her, there would again be an opportunity to experience that strange sensation. I submitted, and when I then attempted to lift the child it proved a task as impossible as it would have been had I attempted to lift a statue made of iron and bolted to the floor. Knowing where to look for the cause of my failure, I examined my legs, and found them again paralyzed. With a vigorous shake I regained control over my muscles, and then lifted the child.

Turning to a friend who had been watching others in an unsuccessful attempt at a like feat, I remarked: "Doctor, you can't lift this child." He tried, but could not. Another, who only wanted to "see how the child felt," likewise failed.

When, after many experiments, it had been definitely determined how the greater part of this performance could be reproduced by the very simplest means, the personal experiences of many individuals were carefully compared. This comparison most clearly revealed the fact that each had been affected in accord with his preconceived ideas; that each one's experience had been just what he had believed it would be. For example, I was one of the few who felt no "electric shocks." Being the only one who thought of any form of muscular paralysis, I alone discovered it.

But so real had these experiences been that the simple theory that they were from no influence save our own beliefs meets with but little favor. It was generally declared that such simple methods of performing the various feats would not have escaped detection, and that mere beliefs would never give rise to such phenomena. I determined to make an experiment that would be conclusive. This was nothing more nor less than to determine whether or not I could repeat the feats without being detected; and most of all, to determine whether or not I could obtain essentially the same hypnotic effects. The first favorable opportunity presented was an invitation to deliver a lecture at Lampasas. In accepting this invitation, I stated that my subject would be "Occult Science," and requested that it be made known that I would repeat the celebrated performances of Phyllis Bently and Annie Abbott, and would at the close fasten a boy to the floor by a hidden power that would defy every attempt to lift him.

Some to whom my purpose was known feared that the attempt would end in failure and utter discomfiture. For it was well known to them that I had never attempted an experiment in hypnotism. Furthermore it was believed that the agencies upon which I relied were so simple as to make it highly improbable that any one would be deceived thereby, and that the proposed results had never been ascribed to such agencies by any investigator of hypnotism. To pose as an exhibitor of curious arts was but little to my taste; but I believed it to be indispensable to the solution of the problem in which I was deeply interested. According to my theory, the one thing needed on my part was audacity, it being believed that others could be found who would contribute the remaining essentials.

It was deemed necessary that first of all the audience should be aroused to a high state of expectancy. With this end in view, I began by referring to the prevalence of the belief that certain favored individuals possessed unique psychic powers by virtue of which they are enabled to accomplish things wonderful and mysterious to others, and which they themselves can not satisfactorily explain. As advocates of this belief I cited a list of names eminent in literature and science. I then referred to the estimate that Mr. Stead had placed upon the value of the performances given by Phyllis Bentley, and also mentioned the notice that Annie Abbott had attracted in Europe. I then stated that after many experiments I had discovered that it was possible for me to reproduce these performances. As soon as a committee had been appointed to "investigate my power," I presented a chair to one with the announcement that by simply holding my hand against its back I would prevent him from putting it to the floor. I knew that he could not do so under the conditions, and was quite uneasy lest he should detect that it was a mechanical impossibility. For in reality it was nothing more than asking him to grasp a lever at its fulcrum and thereby prevent me from turning it when he attempted to carry it to the floor. The experiment had often been tried in private, and in no instance had its real nature been misunderstood. Not from any lack of sagacity or common sense, but solely by reason of the excitement incident to the surroundings, not one detected the real nature of the feat. They were expecting to contend against some subtle, hidden force, and thereby all attention was diverted from things so commonplace as simple mechanics. The fourth one to attempt this feat made no effort that was appreciable. His declaration that the chair seemed to be resting on a "solid block" encouraged the hope that very decided hypnotic effects would arise. This hope was in part fulfilled in the case of one who was by several observed to flinch and start when I placed my hand on his forehead. In reply to my inquiry he publicly stated that he had "felt a shock." After having performed the various feats of Phyllis Bentley, to the very evident astonishment of all present, I announced that I would conclude by showing that this "mysterious power" could be transferred to a child in such a way that a man could not lift him from the floor. Up to this point the various feats had been as sure of success as is the application of well known mechanical powers. But now it was dependent upon the will of another. By what agent could I deprive him of all power to do this simple thing? I left this to his imagination; to the belief that he had in my power over him; to the conviction imposed upon him that whatever I attempted must succeed. Pointing to a boy in the audience, I told him to stand in the aisle. Telling him that I was about to fasten him to the floor, I looked intently at him for a moment, asking him if he knew what I was doing. He nodded his reply with a stare. Suddenly the corners of his mouth twitched, his eyes for a moment opened wide; a shudder passed over him; his eyelids dropped; and he lost consciousness. All eyes were fixed upon the now rigid cataleptic form. Turning to the audience, I watched to see what impression this very evident change in the boy had made. It was quite clear that I was master of the situation; that all acknowledged my power over the boy. To no one, perhaps, was this result as unexpected as to myself. It had not occurred to me that my effort to impress him sufficiently to keep him quiet while the experiment was being tried would result in his complete hypnosis. I had trusted that the impressions already made would be quite sufficient for my purpose. This result, altogether unintentional on my part, greatly heightened the effects already produced. Seeing from the expression of one well known to all present that he was thoroughly convinced of the presence and operation of mysterious agencies, I asked him to go quietly behind the boy and see if he could lift him. Grasping him by the arms he made what appeared to be a most vigorous effort; yet he did not even elevate the boy's shoulders. Turning to the audience, he remarked that he had never felt a weight like that, and that though a strong man, he could not lift the boy. By a word from me the boy was brought back to his normal state.

Having obtained these very satisfactory results, I next endeavored to explain as fully as possible the real nature of the whole performance. The mechanical feats were repeated and explained. Concerning the hypnotic phenomena, the theory was presented that they had not been due to the real possession of any unusual power on my part, but had been produced solely by the belief that such power had been at my command.

With the foregoing illustration of how such a belief may arise, and with these statements of the results obtained when this belief was the only agent relied upon, I shall now, with much diffidence, attempt a formal statement of the real nature of hypnotism and of the law for its production.

These phenomena of mind and body classified under the term hypnosis originate in one's belief that he is under the absolute control of an irresistible agent; such belief compelling him to obey the one supposed to direct this agent; and in many cases by the reflex action of mind on body, producing physiological disturbances that correspond to mental images.

A hypnotist is one who, by some form of manipulation calculated to excite the imagination, produces an unexpected result or sensation, for which the subject can find no explanation save the presence of a suspected, mysterious agent, and by which he is convinced that already he has fallen under its dominion.

If the above statement be substantially correct, it furnishes at least a partial answer to the questions which Gurney has raised.

But the question that most would raise is, Can mere belief accomplish so much? From the time of Franklin many investigators of hypnotism have pointed out the necessity for recognizing the subject's imaginations or beliefs as being its most important factor. The same is apparent in the kindred arts of "faith cures," "magnetic healing," and "spiritualism." No view of these is complete that does not recognize their existence in all ages and among all people. According to Taylor, the "highly developed trance medium" is found among the Figians, the hill tribes of Burmah, in New Zealand, China and Siberia. Mr. Lang declares, "the power which produces hypnotism has always been known, even among people in a low state of civilization." Let us see to what agent we must ascribe these closely allied phenomena in that period when they were most extensive, varied and intense. This period was the Middle Ages. All historians declare that during this age the brightest intellects were dominated by imagination, and every department of life subject to the wildest fancies. The philosopher whose experiment failed at the critical moment when he expected the base metal to change to gold, was as prone to ascribe his ill luck to the presence of an evil spirit as was the "breathless housewife" when her churn was "bootless" and "the drink bore no barm." At this period an all-powerful Church, under the reaction of older beliefs, had filled the earth with contending spirits, and had constructed formulæ for their exorcism. Under this powerful stimulus there were nightly encounters with fiends and monsters, witches and spirits. Compacts were made with the devil in human form. Accusations and confessions of witchcraft were common. For all of these encounters, apparitions, visions and epidemics of imaginary diseases, we can assign no reason, save that they were "shadows cast by human hopes and fears," which ecstacy and despair made subjective realities. The same continues to be done in our own day. If encounters with devils and witches have ceased, it has only been to give place to visitations in bodily form of dead relatives and friends. Why the mind should thus make real its beliefs will doubtless ever remain in the "substratum of unexplained facts" upon which all knowledge rests.

This creative dynamic power of belief is seen in other phenomena not usually classified with those of hypnotism. As Mr. Bain has stated it, "an idea always tends to act out itself." Though usually finding its highest manifestation in hypnotism and spiritualism, it is by no means limited to these. A lady well known to me was treated for rheumatism with a patented apparatus supposed to be electrical. Its application resulted in "shocks" of such intensity that she was soon prostrated. Its use was discontinued because it was apparent that the treatment was too severe. To one at all familiar with the conditions necessary for the production of appreciable amounts of electricity, it was quite apparent that these shocks had been caused by no agent save the belief that they would ensue when the apparatus was applied. He who can thus obtain powerful physiological effects by the application of an appliance utterly devoid of energy is a hypnotist who masquerades as a great discoverer. Charcot, doubtless very innocently, did the same when by the use of magnets, he transferred paralysis from one part to another of certain hysterical patients. Such therapeutics is by no means equal to that of the "illustrious Boerhave" who once stayed an epidemic of spasms in a boarding school by the threat that he would apply a red hot iron to the one next seized. It is not even equal to the practice in Calabar of divining diseases into wooden puppets, nor to that of the Indians of the Antilles, who in the days of Columbus drew diseases from the body and blew them away. Such jugglery now-a-days is given the more dignified titles, "Faith Cure," "Magnetic Healing," and "Christian Science."

Fully recognizing the power of belief to produce such phenomena as found in hypnotism and these kindred arts, there are those who still declare that the fundamental problem is to show how the operator produces, or gains control over, his subject's beliefs.

The case of the boy upon whom I operated as already described can not be explained by any purely physiological theory such as that of Braid or Heidenhain. There was no contact to produce a "stimulus." The brief moment during which I demanded his attention could scarcely have been sufficient to produce "weariness in a sensory organ," "nerve strain," nor what Stanley Hall calls "chronic cramp of the attention." Still less would this have been possible in the case of the gentleman sitting in the audience, of whom nothing was demanded save that he should go behind the boy and attempt to lift him.

It is hoped that the account already given of my own experience is sufficient to illustrate how under peculiar circumstances one may, by the normal process of thought, arrive at the conclusion that he is under the control of the operator. Before any hypnotic phenomena arose I had been convinced that I had been already hypnotised. Such is doubtless the case with every subject. Reversing the phraseology of certain members of the Society for Psychical Research, we may say of hypnotism—it is an aftergrowth of genuine phenomena that ingrafts itself upon a fraud. This is not an accusation that the hypnotist is an impostor, but a declaration that the phenomena are the results of self-deception on the part of his subjects.

It is difficult to formulate a law for the production of this belief that shall accord with well recognized mental processes, and be applicable to the many different methods of manipulation that have been employed. The following is offered as a suggestion of what are the successive steps under the most usual methods. The subject must be in an excited state of mind. The idea that the attempt is about to be made to hypnotize him is frequently sufficient for this. The importance of this idea is shown by the fact that no hypnotist has ever made a subject of one who was unaware of his purpose. To face unmoved the confident look of one believed to be able to hypnotize would be impossible with many. For what is hypnotism as it is usually understood? A strange and mysterious region, where the visitor is led on by illusive visions or left to grope amid grotesque forms; a bourne from which no returned traveller has ever been able to tell how he went there, save that he was carried by an irresistible agent. Many will be excited by the possibility of being forced to make a similar journey. The fascination of an untried danger leads to compliance with the hypnotist's demands. Excited over the idea of a novel experience, half dreading its possibility, the subject is now waiting to see "how it is going to feel," and his whole attention is directed towards his sensations. This state of mind will greatly heighten the usual effects of exertion, a sudden sensory expression, protracted attention, the uncomfortable feeling arising from constrained positions. Some such result may arise from the manipulations of the operator. Their real cause being misunderstood and greatly exaggerated by the heightened susceptibilities, they are presented to the mind as evidence of the presence and operation of the anticipated agent. The alert operator detects from the expression of his subject that some such suspicion has arisen in his mind, and his confident look, sudden command, quick, imperative glance are taken as further evidence of his complete overthrow and necessary surrender. Being told, it may be, that he can not now do some simple act, his confusion is heightened by the audacity of the proposition. He hesitates, turns again his attention to himself to see what is his condition; for he can not put forth a volition if there be the least suspicion that it can not be executed. This state of mind further heightens his feelings, and they in turn further decrease the possibility of his forming a correct judgment. But judge he must; for, as Bain has said, "it is a standing weakness of the human mind to pronounce general opinions under the pressure of the passing moment." Under such pressure and from such data the opinion formed is quite likely to be that the suspected power has already seized upon him and that further resistance is useless.

If such be in substance the way in which this belief arises, it shows why the operator alone is obeyed, why he alone can restore to the normal state, why so many methods having apparently nothing in common are about equally successful. It further shows that success depends not so much upon the method as upon the skill of the operator, the preconceived ideas and mental habits of the subject. It also explains why small children, idiots, and lunatics can not be hynotized.

In the practice of "faith cure," "magnetic healing," and "christian science" there must be conformity to the same general principles. If the admission must be made, that like hypnotism, they are based upon natural laws and are capable of producing certain physiological effects, the same admission embraces the practices of the African "conjurer" and Indian "medicine man." And if we accept the conclusions of such competent observers as J. M. Buckley, and others, that these arts sometimes cure certain classes of disease, we must condemn them on the ground that, like all therapeutic agents, they become dangerous when in the hands of one too ignorant to diagnose the disease, and unable to determine whether in a particular case his agent will be productive of good or evil. It is very generally agreed that all of these are often followed by evil consequences, and that they should be prohibited, save when under the direction of competent physicians. By no amount of legislation could they be entirely suppressed; but by proper education they could be made impossible. If their real nature were understood by those upon whom they are attempted, they would never fall under their dominion. The truth would make them free!

Read before the Texas Academy of Science, June 18, 1895.

COUNTY ROADS.

By Charles Corner, Assoc. M. Inst. C. E.; A. Mem. Am. Soc. C. E., Engineer to the Railroad Commission of Texas.

Mr. President, Gentlemen of the Texas Academy of Science: At a recent meeting of this Academy, a distinguished member, whom we all heard with much profit, ventured the assertion that all human progress, material, and even moral, would be found in the last analysis to be due to science. Now, although I can not agree with the whole of that statement, it furnishes me an excellent excuse for introducing the subject of County Roads to a scientific gathering. For, I believe, sir, little as questions of pure science enter into this subject, that good roads are not only a large part of progress in themselves, but are the prolific parents of a great deal more.

Now-a-days the drift of population is towards the cities, and the energies of our people seem devoted to their enlargement and wrapped up in their adornment. It is still true, however, that God made the country and man made the town, and it is to the country that we must always look for the simpler and stronger forces and the sturdier virtues that must forever underlie all true progress. If we flatter ourselves that the cities foster our highest achievements, we can not forget that they are also the breeding ground of our greatest plagues. It is by making the country districts more prosperous, and therefore more desirable to live in, that county roads may become an enormous factor in the well-being of the State.

Addressing the Texas Academy of Science, no apology is needed for treating the matter locally. It is also my earnest desire to contribute somewhat to the actual establishment of these highways amongst ourselves, and from some technical and practical acquaintance with the matter in hand, I hope to add my mite to the general fund of knowledge that must flow from all honest discussion.

Merely for the sake of illustration, let us glance at some previous phases of the subject.

The Romans, who were an exceedingly practical people, built roads in Gaul and Britain whose tracks remain to this day. They were constructed in straight lines, and convey an impression of a desire to get there very characteristic of ourselves. We shall not adopt their specifications, for we have not the unlimited labor supply of a subject people, nor are our first considerations merely military. As the Roman Empire fell to pieces in the fifth and sixth centuries, the appliances of civilization became dilapidated, and during the long night of the middle ages, wheeled carriages were replaced all over Europe by the primitive pack-saddle. This state of things remained practically unchanged, so far as it affected the common people, until the end of the last century. In discussing a bill for the betterment of English roads about 1750, a country member humorously remarked that judging from their general condition they might be more readily turned into canals than improved into highways.

Napoleon the First, amongst his other endless activities, inaugurated an admirable system of roads in France. In that country the highways were divided into Imperial, Departmental, and Communal. They are very thoroughly constructed, and are frequently adorned with avenues of noble trees. They are now, of course, National instead of Imperial, and are admirably directed by the splendid engineering department of the "Ponts et Chaussées" or "Bridges and Roads." In Great Britain the work was done by turnpike companies and highway boards, and it is only in recent years that the "Turnpike Trusts" have become extinguished. This brings us to Kentucky, and there is always a temptation to copy Kentucky in the matter of roads. The result of its system was good, and the argument that the people who used the roads paid for them has a show of reason, but as a matter of fact their maintenance is exceedingly costly to the community. Mr. N. S. Shaler, writing in Scribners in 1889, points out that there are not less than one thousand families, or not far from 2 per cent of the population of the State, who are supported by toll-gate keeping, and that the tax on the commonwealth is in consequence at least one million dollars per annum in excess of the cost of maintaining the roads. Again, one of the most important utilities of country roads is partially defeated by a hesitation to travel as freely as one would without the toll, thus preventing much of that social intercourse which it is desired to foster.

By force of circumstances we, in Texas, have stumbled in the matter of transportation and communication upon a certain inverted order of progress. We are able to travel to the ends of the earth in conditions of luxury that the Cæsars might envy, whilst denying ourselves the privilege of visiting our neighbors in the same precinct, if the rain has destroyed the usefulness of the road to their house. We eat the excellent fruits and vegetables of California, Colorado and the tropics largely because the truck patches of our farmers are not in touch with our towns. Notwithstanding this, we have on account of our cheap and fertile lands, low taxation and the freedom of our institutions, held a commanding position in the markets of the world with certain of our staple raw materials, and the wealth that has come to the whole country in a similar way has gridironed the continent with railroads, and in one section, at least, established manufacturing industries of the first importance and magnitude. I think we have cause to be proud of our progress, and that is one reason why it behooves us to meet new conditions with the right front. I do not think it can be candidly said that the rural districts have advanced *pari passu* with the great cities in the ease and comfort of living; on the other hand, it is true that we have not developed like conditions of poverty. We use improved machinery in our fields, but it has been purchased in other States, and we are not very thrifty in taking care of it. We have built court houses of imposing dimensions, and established excellent schools which are annually turning out school children somewhat dissatisfied with their surroundings.

We have also secured a reasonably efficient system of railroads which the people have largely subsidized; but roads to market, roads to school, roads to church, roads to our neighbors do not exist.

It has been estimated in the State of Massachusetts that the absence of good roads in any neighborhood is a greater money loss to the community than the sum of all taxation, local, State and Federal. Another authority puts it at $10 per head of population, man, woman and child. In any farming district of Texas it may be easily demonstrated that the lack of roads is a much more costly burden than the construction of a first class system of highways.

In short, we not only have no roads, but we pay handsomely for the evil of doing without them.

Captain Daugherty in addressing the convention held at Houston last February, elaborated figures which went to show that the saving in the marketing of our cotton crop alone would pay five per cent interest on an expenditure of $54,000,000. I can not quite agree with him as to the cost at which really efficient and economical highways can be built, but his general conclusions on the matter are of great value. I have gathered many startling statistics on these lines, but it is well to avoid long arrays of figures, as they are apt to convey no more definite impression to the mind than that of magnitude. A simple inspection of the following traction table shows in a moment at what a terrible disadvantage we are placing ourselves in the struggle for economical production and development:

(1) On paved roads the traction needed to move a loaded wagon is 33 pounds per ton.

(2) On macadam roads the traction needed to move a loaded wagon is 42 pounds per ton.

(3) On dirt roads in good order, the traction needed to move a loaded wagon is 70 pounds per ton.

(4) On soft land the traction needed to move a loaded wagon is 210 pounds per ton.

Now, the pull of a horse working all day has been estimated to be about 125 pounds. Then a good animal ean move on a level, including the vehiele—

On a paved road, about 4 tons.

On macadam, 3 tons.

On good dirt road, $1\frac{3}{4}$ tons.

On soft land, a little over $\frac{1}{2}$ ton.

The last is a case of bogging down in an empty ambulance.

Let us get these figures into our heads for what they actually mean. They show that any horse or mule hauling a load on the roads of any country that has a system of highways is doing from two to six times as much work as a similar animal is doing for us day by day. This is a most unreasonable handieap to put up with.

The experiments of Morin in France corroborate the above figures very exactly, and nothing further than an additional testimony is to be gained by quoting them at length.

Having said this mueh with a view to insist on the necessity of this contemplated reform, let us discuss the question as to how it may be brought about in the least time and with the best economy; and by economy I mean the best results at the least eost. We have to solve each of the following divisions of the problem:

(1) Legislation.

(2) Construetion.

(3) Maintenance.

It may, I think, be granted that the railways have superseded the necessity of the National roads which were such a burning question in the politics of the first quarter of the century. There remain then the State and county to consider. The present law has by common consent quite outlived its usefulness.

Perhaps the keystone of the sueeess of any new general law is the prineiple that heneeforth no road tax shall be paid by labor. I believe that this is the mature opinion of some of the ablest men in Texas, both in public and private life.

Many years ago I remember being called to "work the roads" in Gonzales eounty. I went prepared in a humble way with a hatchet, thinking perhaps that others might bring picks and shovels. There were about thirty of us at the rendezvous, and at least a half were provided with axes or hatchets. During the day we moved about a half a dozen yards of sand into a washout and cut a little brush to protect the place.

We swapped yarns and traded horses, ran two or three races, and had altogether a very good time, and one which I often think of with pleasure from the point of view of a picnic. It must be confessed that the day was innocent of serious road making, although in truth there was plenty to be done. Our inefficient work was not at all exceptional, for although I have never worked the roads since, I have often run across a crowd doing just as I have described above.

A general road law has been repeatedly recommended by our Governors in their messages to the Legislature, and if I remember rightly one was very nearly passed by the Twenty-first.

Some independent work has recently been done by the counties, and local laws were passed by the Twenty-fourth Legislature affecting Fannin, Dallas, Lamar, Medina, and I think others. These acts were long steps in the right direction and show the growth of an intelligent public opinion in the interest of this reform. When general legislation is had, there will probably be some differences of opinion as to what share the State shall take in the work. It may be urged that State roads are no more needed than National, and that the road building of the future should remain entirely in the hands of county officers, as being a matter of purely local concern.

Still it would seem the part of wisdom to have our highways laid out as part of some general system. We are, after all, citizens of the same State, and even the most loyal advocate of home rule must deprecate the possible lack of roads in a county where an intelligent minority needs them every day. We have in many things recognized the rights of minorities, and a majority wielding the authority of the State might perhaps not improperly insist on the construction of roads of a certain standard between county seats of a given population. This is a delicate phase of the question, and its solution depends upon how completely it is recognized as being a matter of general necessity and concern to the whole people.

Whether the State takes direct action or not, it has been suggested that it should in any case reserve certain rights of approval and supervision as to design, construction and maintenance, and particularly in the matter of cost and bonds.

If this be done, the provision of the law should be undoubtedly extended to county bridges. Under the present system the best intentioned board of commissioners is greatly at the mercy of designing men, when in the public interest they should be in a position to be consulting designers. Our bridges have often been sold to us with less knowledge on our part of what we are getting than a private citizen ordinarily brings to the question of buying a horse.

The foregoing suggestions necessarily imply the creation of a State

Board of Highways and Bridges, and although everybody is naturally opposed to the multiplication of functions and functionaries, I believe that this is a branch of administrative activity which would very quickly repay its cost.

If it be found after mature discussion that the State is not to take up the matter directly, then sound public sentiment must be worked up in the counties; our commissioners must be pledged to push the question to the front, and by electing the right men, our county government will make a very good highway board, having the advantage of a thorough knowledge of the peculiarities of their locality, its topography, resources, and the nature and extent of its available road material.

The tools they need are not many:

A roller,
A sprinkler,
A crusher,
Some screens,
A plow or two,
Some scrapers, picks and shovels,
And in the open country, a grader.

The road engineer should be the county surveyor. In these days this office should be magnified. The incumbent should be a civil engineer, something of a geologist, a man versed in the value of things, and all this in addition to his knowledge of lands and land lines, a thing of itself not to be decried, important as it is in the settling of neighbors' disputes and the quieting of titles.

Unfortunately, hitherto private land lines have had more than their fair weight in controlling the alignment of county roads, to the neglect of physical suitability and the convenience of the traveling public.

A road should, as far as possible, be scientifically located with due regard to direction, drainage and grade.

Having the contour of the country thoroughly in view, a line involving the minimum work consistent with economical service and maintenance should be established. This should be done as a whole between governing points, with no patching or makeshifts. These are always expensive, and a road may be ever so good in places that is just as bad as its boggiest part. Grades in Texas present very few difficulties, especially in the more settled districts, and for that reason it is well to make the most of the situation, which can be generally done at a comparatively trifling expense. That it is worth doing, is clear enough from the following table deduced from Mr. Herschell's able paper on this subject. It presents a very different problem from the same question on railroads, for reasons too long to go into here, but some of which are indicated by the simple fact that it is easier to walk up a gravel roof at, say, an angle of 40 degrees, than a tin one of the same inclination.

If we say that on a given road on a level a horse can move a total load of 3 tons,

Then on a rise of one per cent he can pull only 2.70 tons.

On a rise of two per cent he can pull only 2.40 tons.

On a rise of three per cent he can pull only 1.80 tons.

On a rise of four per cent he can pull only 1.50 tons.

On a rise of ten per cent he can pull only .75 of a ton.

These figures are worth considering in laying out a road, and particularly so at river crossings.

The eminent authority, Gen. Roy Stone, writes as follows on this subject, speaking of New Jersey:

"Your roads were laid out as is the custom in this country, without any attention to the general topography, and generally by following the settlers' paths from cabin to cabin or by running along their farm lines, regardless of grades or direction, and most of them still remain where they were laid and where untold labor has been wasted in trying to improve them. It would have been worth millions to you to have had them systematically and skillfully laid out in the beginning."

And Mr. Shaler says:

"The difference between well aligned ways and those which are placed haphazard in the country is, as far as the commercial interests of the people are concerned, of very great importance. In several counties well known to me in this country, I am satisfied that the difference which could have been effected by the exercise of a little skill would have amounted in the tax upon the community to a saving of many thousand dollars per annum."

The natural condition of our present roads in the various soils is simply this:

In dry weather the clay and black land roads are tolerable.

In wet weather they are impassable.

In dry weather our sandy roads are abominable.

In wet weather they become serviceable enough.

In parts of the State, notably in the west, are limestone and other rock surfaced roads which make good traveling in level places all the year round. In other districts, and I remember many such in the "post oaks," is a mixture of sand and gravel that forms excellent natural roads. Upon the black lands and the sandy loams, on the red loams and the sandy lands we have to graft a new surface and maintain it in condition. Let us definitely throw aside plank roads, straw roads, "excelsior" roads, and similar contrivances as among the things that perish. Some form of macadam is what we want, and as this is costly, we must make up our minds to improve only a portion of the width of recorded road for a long time to come. For main roads intersecting at the county seat or other important points, I would suggest 18 feet as a desirable width for the track, and in byways 10 or 12 feet.

A road that has given excellent results is built as follows: Width 30 feet, centre 6 inches higher than the sides; an 8-inch bottom layer of rock broken to pass through a $2\frac{1}{2}$-inch ring, and 12 inches of "metal" to clear a $1\frac{1}{2}$-inch ring. The whole rolled in two layers with a slight binder, which last should *preferably not be clayey*, but acts better if it is as hard as the road material itself. Soft binders are apt to become lubricators in wet weather and tend to make the stones move upon each other. If the rock be broken by hand, it is in better shape than if broken by a crusher, but the process does not form a sufficient proportion of chips and screenings to compact the metal readily under the roller. It has been suggested that convicts might break the stone at suitable points along the line of work, and it certainly seems practical justice that those who have worked the State an injury in one way, should be made to repair it in another.

In North Carolina the State lets convicts to the counties, and our own recent local laws contemplate the employment of county convicts in this work, and indeed many counties have done so in the past.

The specification given above is too expensive for any district where rock is not immediately available, and gravel will generally have to take its place, and the width must be reduced. In the coast counties shell makes an excellent road surface, and mixed with sand forms a sort of concrete, as may be seen to advantage in Corpus Christi, where the streets made of this material are very good. There are rumors of the possibility of burning black land to a sort of adobe clinker, and this is being experimented upon by the Texas Midland Railroad for ballast. That such a material will make a wearing surface or stand rolling is very much to be doubted.

Telford roads are out of the question for the country generally. They are expensive, and unless the foundation stones are thorougly laid and well spawled, they become energetic puddlers of the mud, shifting on one another, and forming lumps and holes, and further destroying the wearing surface of the road by the upward suppuration of the mud. San Antonio furnishes many examples of this action. Herschell agrees with Telford, and says that Macadam's idea of small broken stones as a foundation has been proved to be all wrong. I think he must have formed this opinion by observing exceptionally bad examples.

The earth or sub-grade having been established, it is ready for the "metal." In very bad black land bottoms I would change the practice somewhat, and suggest a track 18 feet wide having a bottom layer of 6 inches of coarse sand and a surface of 10 inches of broken rock or gravel.

Sand is a very effective foundation when confined, and is only improved by being wet. And if it work into the metal it will only increase the cohesion, and any settling or sinking will take place evenly by reason of the uniform spread of the sand bed within its limit of motion. I had thought this solution of the bad bottom roads original, but there is nothing new under the sun, and I find that the specification has been used on a boggy New York road with excellent results.

In most soils, however, if the question of drainage and culverts be skillfully managed, it will be found sufficient to roll from 9 to 12 inches of good macadam in two or three layers, the larger stones of about $2\frac{1}{2}$ inches in the bottom, and 2 inches, $1\frac{1}{2}$ inch, and screenings on top, in the order given.

Rolling is an important matter. Steam rollers are better than horse rollers, and, weight for weight of actual rolling, are very much cheaper. Judicious sprinkling should also be kept up during the work. No rule can be given for this, but the behavior of the metal will act as a guide.

Macadam himself, who has become, as it were, the tutelary divinity of country roads, relied entirely on the traffic to compact his road surfaces. This, however, is very rough on the horses, and besides wears out a large per centage of the material.

There is a horse roller made with a water tight drum, which upon being filled increases the weight of the machine very greatly and gives more satisfactory results than the ordinary one.

For compacting roads in the first instance rollers with revolving discs of differing diamenters have been recommended as giving good results.

Curbing becomes a question in particular cases. Where timber is at hand it can be used in the rough for this purpose. Too much can not be said as to the desirability of keeping the track clear of the mud of adjacent sideways, which, by the way, should generally be used by the people in good weather.

As to maintenance, it should be continuous, and no road should be allowed to develop weaknesses that are not immediately attended to.

Widening the tire of our heavy wagons, and to some extent of our carriages, has an important bearing on this subject. In the heaviest vehicles the front and hind wheels should not track, but move in parallel lines, thus serving in their very progress as a sort of a modified road roller.

Frequently the chief expense indicated by this bare outline will be the placing of the material along the line of the road, and in this connection I have the following suggestion to make: Most farmers have a spare team and a little idle time. The county commissioners might arrange, where possible, for the receipt of loads of road material at stated points on the work. These loads (they should also be yards) to be receipted for by tickets signed by the surveyer. The price should be fixed on the basis of $3 per day for a man and a team. The idiosyncrasies of men, mules and horses vary very greatly. Let the data be arrived at from the work of an industrious man with an average team. By this method some of the profits of construction will be secured to labor, and the money will remain in the community.

In conclusion, and bearing in mind the great variations which must necessarily characterize undertakings in different localities, such as the relative nearness of material, character of foundation, topography, and possible land damages, it may be said that good roads in Texas can be built at from $1500 to $2500 per mile for by-roads and from $3000 to $5000 per mile for the best highways.

Let us say that a county can not do with less than four good arterial roads from the county seat to the county line, say 80 miles of road; then it seems clear that the sum of $300,000 can be profitably expended in good roads by any county of the first class.

By the undertaking of public works on a large scale our court houses will become more than ever the seat of government, all the offices will be of more importance to the public. Everybody will acquire a new interest in "politics," or, to use a better word, in "county affairs," and an important help to the thrift of the people will be inaugurated.

A strong social bond, now only felt in cities, will be created—a pride in one's county as such. Life in the country will be robbed of that intolerable *ennui* that is ever driving the boy from the farm to the city, ambitious to sell goods and to earn wages which for the most part are a toll upon his kind. And as the country life expands, and attracts youths from the city to the farm, to its healthier labors, and its more wholesome pleasures, surely the strength of the State is better nourished than by the growth of those vast aggregations of bricks and mortar which are overshadowing the Republic with an ever-increasing spectacle of the terrible inequalities of life.

THE SOILS OF TEXAS—A PRELIMINARY STATEMENT AND CLASSIFICATION.

BY E. T. DUMBLE, STATE GEOLOGIST.

Read June 18th, 1895.

CONTENTS.

INTRODUCTION.

Of all the materials, minerals or ores which lie within the domain of economic geology, there is none of greater value or that should receive more careful consideration and investigation than the soils.

The soil is the connecting link between the sciences of Geology and Agriculture, and in all advanced effort for its utilization the work of the geologist and the farmer must go hand in hand.

The geologist studies the soil in its relations to the past history of the earth, its present condition, and its future possibilities. The farmer, in a new country especially, is too often content to know that it will yield him fair returns for his labor for a year or two, because his immediate wants are few, and new land may be had for almost the trouble of breaking it. As population increases, and it is not so easy to take up new land as the fertility of the old decreases, the farmer must seek a more rational method of tillage, and it is then, if it be properly presented, that he comes to appreciate the assistance which may be given him by the geologist and the agricultural chemist.

For the purpose of ascertaining the value of any soil, the crops to which it is best adapted, the best means of maintaining or increasing its fertility, or its amelioration if necessary, the farmer considers its appearance, the plant growth he finds on it, and the results obtained by actual cropping and experience. The geologist takes it up differently. He seeks to ascertain the origin of the soil, the manner of its formation, the character of the materials composing it, both as to their chemical composition and physical condition, the local supplies of suitable fertilizers, the conditions of water supply, of irrigation and of drainage. He also notes the character of the existing plant growth, and from the results of these studies decides upon the true character and utility of the soil.

These facts, whether they be gathered by the trained geologist or dug out by the more laborious and often uncertain methods of the farmer, are those on which rational agriculture must depend. The farmer learns them for his own farm only, and each must learn them for himself, or, at most, only over a limited area; while the geologist, studying them over wider areas, embracing hundreds or even thousands of farms, is enabled thereby to solve the questions of the individual more satisfactorily than he can do for himself, and to furnish him just that information which he needs in order that he may be able " to make bigger potatoes and more in a hill.''

Soils and Their Derivation.

The unconsolidated and comparatively thin materials of the earth's surface, which we know as *Soil*, and the subsoil which extends to various depths below it, have their origin in and depend for their character on the natural processes which have formed the earth and which are still in operation around us. Upon the seashore or the quiet lake, by the tiny rivulet or rolling river, in valley and plain, on mountain side or flaming volcano, in the action of the atmospheric forces, of the air itself, and of the snow and rain and frost and wind, we see the action of the natural powers which have fashioned the world as we find it, and which are ever busy corroding, decaying, and breaking down the solid materials, transporting the debris elsewhere and building it up anew, perhaps only to be remodelled in its turn.

Over the greater portion of the surface of the earth these processes have taken hold of the existing rock materials, whether of sand or clay, of limestone or granite, or even of peat, and by the chemical reactions induced, and the assistance of the growth and decay of plants and animals, have transformed them to greater or less depths into true soils at their original place of location, and differing from the subsoils principally in their greater alteration and the presence of remains of organic origin. Such soils are known as Residual, Primitive, or Sedentary soils, or soils of disintegration.

Where water or wind has taken up these materials in suspension or solution, transported them to other localities and deposited them, they form what are known as transported or derived soils.

While both classes have a common origin in the rock materials of the surface, the former or Residual Soils, being local and dependent on the character of the rock immediately underlying them, must differ among themselves with every change in its character, while the transported soils, being derived from many different localities, but usually thoroughly commingled by the water, are often more homogenous.

The different soils, then, are due to the different rocks from which they are derived. A belt of sandstones will yield a sandy soil, a bed of clay a clay soil, while a bed of disintegrating limestone may yield either sandy or clayey soil in accordance with the impurities contained in the original rock.

If, by a careful study of the geology of a region, we determine the locality and extent of the surface exposures of the several beds of clays and limestones, sandstones, granites, etc., and carefully plot these upon a map, we have a sure index as to what character of soil we may expect in any portion of the area so mapped. If to this be added the chemical and physical examination of these soils and their interpretation, and proper statements regarding the plant growth, drainage, and water supply, all the data are at hand for forming the most intelligent idea possible concerning them. A thorough geological survey, which naturally includes this, has therefore as great, if indeed it has not a far greater, interest for the farmer than for the miner, the quarryman, or the manufacturer. In proof of this it may be stated that it has been fully demonstrated in France, Belgium, Germany, and Austria, where the improvement of agriculture has received the closest attention, that the *only* sound basis for soil maps are those showing the details of the geological formations.

Since the character and distribution of by far the greater portion of the soils is governed by the rock structure of a region, in any system of local soil classification the geology must first be understood, and all possible information obtained regarding the distribution, character, and composition of the rock materials. It also follows that the classification of the soils can not be more detailed than knowledge of the geology of the region will permit. Therefore, in our case, since the work of the Geological Survey has only progressed to the determination and mapping of the broader features of our geologic structure, we must content ourselves with equally broad classification of the soils which they produce, and leave the more detailed work for the future.

It must therefore be understood that the following statements and classification are very general, and preliminary to a more detailed study of each bed and soils resulting therefrom, and subject to rearrangement and correction as the work progresses. The geological work on which it is based was done principally by the Geological Survey of Texas. The analyses and descriptions of the soils made use of are those of Dr. Loughridge in "Cotton Production" in the Tenth Census Reports, Prof. H. H. Harrington, of the Agricultural and Mechanical College of Texas, and others, appearing in the Survey Reports or existing in its records.

In presenting this paper, it is simply proposed to place the classification on its true basis and as far as may be to lay the foundation on which other workers may hereafter rear a complete structure. To do this a glance at the geology of the State is necessary.

Geology.

The geological development of the broad area we call Texas had its beginnings, according to present evidence, in what are now the granite highlands of Llano and Burnet counties and in El Paso county. Of the early history of the more western portion we can say very little at present, but from the exposures of the central area a fairly well connected history can be made out, although it is very incomplete in detail.

In very early times the rocks of this granitic core formed an island or, more probably, a headland extending southward from a similar area in Indian Territory, and possibly connected in some way with the older granites of El Paso county. These rocks were subjected to strong earth-movements, which crumpled them into great folds and made fissures in them, into which were forced the molten rocks from below. The surface was acted on by atmospheric forces and by the waves of the surrounding ocean, and the materials derived in this way from the land were deposited in its waters as a series of broadening fringes, interrupted or assisted at various times by the operation of volcanic forces. This gradual growth continued until the beginning of the Coal Period, at which time the central core had an area at least approximating that of our Central Mineral Region, comprising Llano county and parts of Burnet, San Saba, McCulloch, Mason, Gillespie, and Blanco. During the same time rocks of similar character were being formed in our Trans-Pecos area, where they now appear as detached mountain masses or long lines of beetling cliffs in El Paso and Presidio counties. Up to this time the rocks are composed, principally, of granitic materials, sandstones or limestone, and the few clays which were deposited were metamorphosed into slates.

With the beginning of the Carboniferous, however, the clays appear as the equals at least of the sand and lime, even if they be not in excess of either of them.

Very early in this period a great fold was formed, the ridge of which extended northward from the Central region to Indian Territory, and in the basin thereby created to the west of the ridge were deposited the greater portion of the beds of the Coal Measures. These beds in the eastern portion, or Central Coal Field as we know it, are of clay, lime and sand, and were largely derived from the rocks of the Llano region and from Indian Territory. The southern shore line of this Carboniferous sea, with its numerous bays and headlands, is plainly traceable through Lampasas and San Saba counties to-day. In the west, beyond the Pecos, the sea was deeper and conditions different, so that by far the greater part of the deposits are limestones.

As the Coal period gave way to the Permian, the sea which covered what is now the northwestern part of the State became gradually shallower, with corresponding changes of conditions of deposition, and we have the clays and clayey limestones of the early Permian, followed by sandy clays and sands, with the great beds of salt and gypsum which mark the closing of that period and with it the close of the Paleozoic era.

The sandy beds of the Triassic, which ushered in the Mesozoic, are now exposed only as a fringe around the eastern and northern border of the Llano Estacado. Their original extent is unknown, but it is probable that they covered a large area east of their present boundaries, and that it was largely from this source that the basal sands of the succeeding deposits were derived.

Following the Triassic, so far as our present evidence shows, there was a long period in which dry land prevailed over the entire State, and in consequence no deposits were formed.

This was followed by the incursion of the Lower Cretaceous sea from the south and west. The waters gradually crept inland until they covered almost if not the entire State east of the Pecos, except the Central Mineral Region, which appears to have been uncovered up to the close of the Fredericksburg period at least. If later deposits covered it, there now remains no direct evidence of the fact. In Trans-Pecos Texas, the waters of this sea seem not to have covered the mountain blocks of El Paso county, but to have met in them barriers to their progress, and in consequence the deposits of this period are mostly found in the valleys or flats. In this region the deposits of the latter part of the Lower Cretaceous are much thicker than are those of the eastern part of the State.

The rocks of the Lower Cretaceous are sands and limestones with some clay, and their present surface exposure occupies a very large area known as the Grand Prairies, stretching from Red River to the Rio Grande.

The Upper Cretaceous beds are, for the most part, composed of lime and clay (although some beds more or less sandy are found both in the Red River and Rio Grande sections), and may be generally classed as marls, passing into a pure chalk limestone on the one hand, and into a clay with comparatively little lime on the other. They were deposited in quiet waters of moderate depth, containing vast numbers of minute organisms, the remains of which have contributed largely to the formation of the chalk and glauconitic beds. These beds occupy a belt of variable width, lying between the Grand Prairies and the coast, the present line of which it roughly parallels.

So far as present surface exposures indicate, the Cretaceous sea seems to have finally receded to the south and west, for the upper deposits of the Rio Grande region appear to be later in time than any of those of the Red River section.

The earliest deposits of the succeeding Tertiary were derived immediately from the upper beds of the Cretaceous, and so closely do they resemble them that it is often difficult to say where the one ends and the other begins. A great coal-making period followed, during which were formed the earlier of our great deposits of brown coal and lignite. Then a period of marine or brackish water deposits, accompanied by or alternating with lagoons and peat bogs, in which were formed other beds of brown coal and the iron ores of East Texas. The action of Foraminifera in the production of glauconite is repeated in this period, as is evidenced by the beds of green sand marl, and the resulting red hills of East Texas.

Succeeding these are belts of clays with still other large deposits of brown coal, and followed by sands. These are followed by still other clays and sands, forming altogether a series many hundred feet in thickness and of broad areal extent.

The upper portion of the Gulf Tertiary beds contains a considerable amount of lime, although no compact limestones like those of the Cretaceous are found, except in the southwestern portion of the State.

These Tertiary deposits occupy a belt of country larger even than that of the Cretaceous, and lying between it and the Gulf, in whose waters, at that time so much more extended than at the present, they were deposited.

During the middle portion of Tertiary time, there occurred another interval of dry land in the Texas region, and this was succeeded in the northwest by great lakes, the site of one of which is now indicated by the deposits of the Llano Estacado. These lakes probably extended into the mountain region of the west also.

The belt of country lying between the Tertiaries and the coast is but lately emerged, and its continuation may easily be traced beneath the waters of the Gulf of Mexico. The materials are principally clays and sandy clays, with intercalated beds and lenses of sand. During the time of their deposition the waters were busy all over the State, and lakes and streams abounded everywhere, in which were gathered the pebbles and gravel with their coverings of drift materials which are so abundant over the entire State. Among the greater of these lakes was that which occupied the site of what is now the Seymour plateau.

The broader features of the distribution of these formations is indicated on the accompanying map. First, along the coast is a narrow strip of Pleistocene deposits, then a broader belt of Tertiary, followed by the wide expanse of the Cretaceous. In the center, a comparatively small area of the older rocks, while to the north and west lie the Carboniferous and the Permian, crossed by a line of Cretaceous running east and west, and by another of Pleistocene extending north and south. Finally, the Tertiary of the Llano Estacado, with its fringe of Triassic. The formations west of the Pecos are not delineated.

Physical Geography.

A study of the physical geography of the State shows that the broader divisions are:

The Gulf Slope.

The Central Basin Region.

The Mountain Systems.

The Gulf Slope extends from the Gulf shore to the western and northern border of the Cretaceous highlands. Beginning in a slope so gentle that the rise of the level ground is inappreciable, the Coast Prairies spread inland over the Pleistocene belt a distance of 50 to 100 miles, and merge gradually into the undulating country of the upper Tertiary. Continuing towards the interior, the surface becomes more rolling, and by its varied topography evidences the varying beds of sand and clay of the Tertiary belt or plain. This is followed by the rolling slope of the Upper Cretaceous comprising the famous Black Prairie region, and finally by the broad expanse of Lower Cretaceous materials forming what is known as the Grand Prairie. On the east this is simply a continuation of the general slope, but westward it forms a broad elevated plateau.

West and northwest of the Grand Prairie lies the Central Basin region, the Carboniferous rocks of which have for the most part been exposed by the denudation of the Cretaceous and later formations which formerly overlaid them. The two principal bodies of later material which have so far escaped entire erosion are the Seymour plateau and the Llano Estacado. These, with the remnantal strip of Cretaceous, divide the basin into four denuded areas.

The mountain systems include the granite highlands of the Central Mineral region, a few remnantal peaks of like character in Greer county, and the large mountainous area of Trans-Pecos Texas with its old lake-basin valleys.

Thus it will be seen that the topographic features of the State are closely connected with the geological structure and distribution of the rock materials.

It must be borne in mind, however, that climatic conditions have much to do both with the formation of a soil and with its fertility, and that over so broad an area as that included within our State the differences of such conditions may always have been, as they are at present, very marked. As has been stated, many of these various belts of rock, with their resultant soils, stretch entirely across the State from the Sabine to the Rio Grande, from a region of copious rainfall to one of frequent drouth. Therefore, even if throughout the entire length of any belt the mineral composition of the rock material were identically the same, there would necessarily be difference in its weathering into soil and in the amount of organic matter it contained.

Residual Soils of the Coastal Slope.

As will be seen from the accompanying map, nearly one-half of the entire State is included in the Coastal Slope. It embraces the region of greatest rainfall and many of the most fertile soils. The various belts of rock materials which lie within it and which have been briefly mentioned in connection with the geology of the region, occur, as has been noted, in bands of different widths stretching from the Rio Grande on the west to the Sabine or Red River on the east, roughly paralleling the present Gulf coast, and each one furnishes its own characteristic soils and agricultural conditions.

SOILS OF THE COAST PRAIRIES.

So lately have the waters of the Gulf and its fringing bays receded from that belt of country known as the Coast Prairies, that Loughridge applies the term alluvial to all their soils.

The substructure of this plain consists of limy or sandy clays and sands. These were derived from the various beds of older material north of them, brought down by rivers and deposited in the bays which preceded those of the present.

The resulting soils, where the sandy deposits prevail and have not been removed by later denudation, are sands and gray silts; but where the clays appear at the surface black waxy soils result.

The soils in the immediate vicinity of the coast are for the most part sandy, while the gray silts are more abundant in the eastern portion of the belt and are covered with pines. Westward the clays predominate, and the prairies are interrupted only by motts of trees and the timber growth along the streams.

The eastern portion of the belt includes a small extent of marsh land, which is practically all of the sea marsh of our Gulf coast.

From its level nature this belt has been somewhat difficult of drainage, and, after heavy rains, water stands in low places for a considerable period. However, in places drainage ditches can be constructed to the various streams which cross the belt; or, where the expense of such a ditch is too great for a single farmer, he can always sink a well at the lowest point of his tract, to one of the beds of quicksand which almost universally underlie this area, and drain into that at moderate cost. This has proved a success in many instances, and is worthy of much more universal adoption.

Local peculiarities of soil are not wanting. Among them may be mentioned the small mounds that dot the prairies, presumably the result of former mud volcanoes such as are now common in the belt of the Mississippi, and the "bald spots," which have not yet been fully accounted for, but which are most probably due to "alkali."

The analyses given show the composition of the gray sandy loam as seen at Pierce Junction (No. 1) and the black waxy soil around Alvin, with its subsoil (Nos. 2 and 3). These both show potash and phosphoric acid in good proportion, if the soil and subsoil be taken together in the Alvin material, and there is a sufficiency of lime in both.

	1*	2†	3†
Insoluble matter	80.360	86.460 (Insoluble matter and Soluble silica together)	71.28
Soluble silica	3.613		
Potash	0.291	.093	.46
Soda	0.197	.175	.56
Lime	0.653	.958	6.33
Magnesia	0.272	.464	1.46
Manganese	0.174	....	....
Iron	2.401	0.850	1.94
Alumina	6.079	2.430	4.03
Phosphoric acid	0.156	.024	.22
Sulphuric acid	0.075	.090	.09
Carbonic acid	....	.399	5.06
Water	5.313 (Water and Organic and volatile together)	2.230	2.91
Organic and volatile		5.480	5.02
	99.584	99.603	99.39

*Cotton Production, Tenth Census, p. 31.
†Bulletin No. 35, Tex. Ag. Ex. Sta., p. 600.

SOILS OF THE TERTIARY PLAIN.

To the Tertiary or Lignitic belt, which succeeds the Coast Prairies in the interior, we are indebted for our great forest region, for vast deposits of iron ore and brown coal, and for large areas of very fertile soil, as well as for fertilizers adapted for the preservation and enhancement of their fertility.

While the soils of this great plain, derived from its numerous beds of sands and clays, may be classed in a general way as loams, they vary greatly, and are readily separable into several smaller belts corresponding to the geological divisions, and may well be designated by the names of their geological ancestry. These are, in the order of their occurrence from the Coast Prairies interiorward to the Black Waxy belt: The Reynosa, Oakville, Fayette, Yegua, Marine, and Lignitic.

THE REYNOSA OR LAFAYETTE.—The surface of this belt is somewhat more rolling than that of the Coast Prairies. East of the Colorado river the uppermost beds of this plain consist of sand and gravel, colored more or less by oxide of iron derived from the iron region of the Marine belt north of it. West of the Colorado, the iron is replaced by lime brought down from the Cretaceous area lying to the north, and this forms the "adobe" rock or white limy clay of the southwest. The lower beds are uniformly clays.

The Reynosa formerly occupied a much greater area than at present, for we find patches of it well up the sides of the iron capped plateau of Anderson and adjoining counties, while in Southwest Texas the adobe and limy conglomerate extend inward, in places, to the line of the Southern Pacific railway, and it usually forms the tops of all the more important divides. By reason of this overlap this plain extends over the greater part of the Neocene deposits of the Gulf Tertiaries.

In its central portion the belt comprising the Reynosa is hard to separate from that of the Coast Prairies, so closely do they resemble each other, but elsewhere the differences are more marked.

The soil derived from the more sandy eastern portion is principally of a brown sandy character, as seen in parts of Waller, Montgomery and Liberty counties.

The black waxy prairies of Washington and Fayette counties are largely derived from its lower or clay bed. All of these soils are fertile, and some of them are of the greatest richness. This is readily accounted for when their origin is known. Where beds of gravel occur an examination will show that by far the greater portion of the pebbles are granitic or feldspathic rocks from the Llano region, and these are usually strongly kaolinized. The soils represent the finer sediments from the same materials, to which have been added those derived from all the beds north of them.

Again, the period of their deposition was one replete with animal life, and the bones of the herds of horses, elephants, camels, etc., which were entombed with them have added greatly to their fertility.

In the southwestern portion of the State this is one of the most important, if, indeed, it be not the chief soil, since it is not only widespread itself, but in its denudation from other areas some of its remains have become incorporated with the underlying materials, altering them to a certain extent and aiding to form many of the black shelly prairies of the region.

Where the Reynosa is the surface material, and its sandy or clayey limestones or clays have been fully altered by weathering, it yields a dark brown or black waxy soil; as it is mixed with different amounts of sand it gives rise to chocolate or mulatto soils, all of them very fertile and many of them especially adapted to fruit culture.

This plain is principally a prairie region, but a scattering growth of oaks and mesquite appear on it in places.

Being more rolling than the Coast Prairies, drainage is much better, and its physical condition is such as to add greatly to its value as a soil.

Analyses Nos. 4 and 5 give the chemical composition of black waxy soils from Victoria and Chappell Hill, which are formed from the limy clays of the Reynosa plain, while Nos. 6 and 7 illustrate the extreme poverty of some of the sandy soils, as at Colmesneil.

	4*	5*	6†	7†
Insoluble matter	55.436	75.530	97.584	98.168
Soluble silica	22.415	12.183	....	....
Potash	.429	.235	....	....
Soda	.213	.145	....	....
Lime	1.050	.948	....	....
Magnesia	1.092	.447	.079	....
Manganese	.064	.056	....	....
Iron	11.280	2.266	.750	.780
Alumina	1.245	4.161	....	....
Phosphoric acid	.093	.108	....	....
Sulphuric acid	.280	.075	....	....
Water	} 5.914	} 3.741	.370	.300
Organic and volatile			1.180	.670
	99.511	99.925	99.963	99.918

* Cotton Production, Tenth Census, p. 32.
† Bulletin 25, Tex. Ag. Ex. Sta., p. 261.

OAKVILLE OR GRAND GULF.—Where the materials of the Oakville beds are exposed in East Texas they give rise to sandy soils and marly sands. These can be seen between Huntsville and Riverside in Walker county and north of Brenham. In the southwest they are exposed over a wider area, and the soils are loams, varying greatly, however, in the relative proportions of sand and clay that they contain. They may be classed as prevailingly sandy. The southern portion of Live Oak county furnishes typical bodies of these soils.

FRIO CLAYS.—In eastern Texas these clays are very limited in extent, occurring in a comparatively narrow belt in the northern parts of Newton, Jasper, and Tyler counties. They are covered in many places by deposits of later date, but may be recognized in limited areas west of the counties named, as at Riverside and southwest of Huntsville. They are more important west of the Colorado, and are found at the mouth of the Frio and in the valley of the Nueces in McMullen county. They yield black sticky to black waxy soils, and contain considerable lime and gypsum.

FAYETTE SANDS.—This belt, from five to twelve miles in width, gives rise to a very broken country. Its northern border usually presents a precipitous face and its forest-covered surface is quite rugged. Its soils as seen at Groveton and Trinity are gray sands, which are, however, often obscured or replaced by gray sands of still later date. The soils around Ledbetter, where not covered with the later gravel and sand, are also of this age.

To the west the Fayette belt yields sandy soils or sandy loams, usually timbered, and clay loams forming prairies or with only a meager growth of mesquite.

YEGUA CLAYS.—This belt is also largely covered with later deposits, and in the eastern part of the State the soils are less important than they are in the west. They underlie a wide area, however, from San Augustine county west, and where exposed form dark clay loams to light gray sands, while the subsoil is, of course, the sandy clays and lignitic clays of the formation.

In Brazos county they produce fine grained sandy loams of dark grayish color with considerable excess of sand. They readily leach to a pale yellowish gray or white. These gray sands frequently form extensive prairies.

Westward this belt furnishes brown and chocolate clay loams, with only a few comparatively narrow bands of light gray or brown sandy soils. In places the beds carry considerable lime and the soils become more marly, in certain localities forming black sticky if not quite black waxy soils. The light brown sands sometimes form level prairies entirely devoid of timber growth.

The gray upland soils of the Tertiary plain, as shown in analyses Nos. 8 and 9 of samples from Grimes county, are deficient both in potash and phosphoric acid; hence they are soon exhausted. When the subsoil is a clay like that at College Station, deep plowing would in some manner rectify this as shown by the amounts of potash and phosphoric acid found in the clay. (Analysis No. 10.)

	8*	9*	10†
Insoluble matter	93.700	71.750	76.170
Soluble silica	2.140	12.110	
Potash	.008	.062	.800
Soda	.144	.240	....
Lime	.180	.490	.600
Magnesia	.080	.460	.550
Manganese	.090	.060	....
Iron	.490	1.900	2.990
Alumina	.900	6.460	8.330
Phosphoric acid	.011	.008	.083
Sulphuric acid	....	....	.106
Carbonic acid	.130	.090	.470
Water	1.280	5.460	5.820
Organic and volatile	.750	.560	3.940
	99.903	99.650	99.859

* Fourth Annual Report, Geol. Sur. Tex., p. 25.
† Bulletin 25. Tex. Ag. Ex. Sta., p. 269.

MARINE BELT.—This belt, with its interbedded sands and clays, greensands and iron ore, is one of the most extensive of the belts of the Tertiary plain. While it shrinks to a narrow area in the vicinity of the Colorado river, it broadens to the east and west, until it attains a width of not less than sixty miles.

The alternating sands and clays give rise to red sandy, red clayey, or loamy soils of different characters; the greensand beds furnish mulatto, or dark brownish red, or black sandy loams; and overlying the iron ore ridges are gray sandy soils, which are the great fruit soils of the region.

The red sandy soils are usually deficient in potash and sometimes in phosphoric acid, elements which are found in the greensand marls which occur in connection with them, and therefore present the easiest means of supplying these essential elements of fertility to the soils requiring them. These elements are largely derived from the grains of glauconite, which have their origin in the wealth of minute animal life with which the waters of that portion of the Tertiary teemed.

West of the Colorado these soils appear as alternate belts of chocolate loam with a growth of mesquite and live oak, and fine brown sands or sandy loams with blackjack and hickory. The loams vary from sandy to clayey with the beds from which they are derived. Colors vary from gray to chocolate. Some of the brown sandy loams form prairies; at other places there is found on them a thick growth of cactus and mesquite with a few scattering live oaks. The red sandy soils of the eastern portion of the State occur here also, but in smaller areas.

The character of the soils of the Marine belt are represented in the analyses by Nos. 11 and 12, dark loam soil and subsoil from near Palestine; Nos. 13 and 14, mulatto soil and subsoil from Cherokee county; and 15 the red soil resulting from the decomposition of glauconitic beds in Lee county. All of them are rich in potash and phosphoric acid.

	11*	12*	13†	14†	15*
Insoluble matter	92.943	79.954	72.09	59.14	74.983
Soluble silica	1.009	1.251	.23	.25	3.885
Potash	.111	.067	.10	.23	.718
Soda	.093	.060	.39	.46	.131
Lime	.147	.168	.28	.16	.258
Magnesia	.077	.012	.22	.30	.530
Manganese	.051	.170	....	....	.032
Iron	1.614	8.478	16.99	25.73	9.333
Alumina	1.470	6.078	2.78	3.14	5.301
Phosphoric acid	.193	.194	.23	.44	.102
Sulphuric acid	.020	.006	1.54	.31	.028
Water and organic	2.201	4.109	6.10	10.39	4.717
	99.929	100.547	100.95	100.55	100.018

* Cotton Production, Tenth Census, p. 25.
† First Annual Report Geol. Sur. Tex., p. 37.

Lignitic Belt.—Three principal varieties of soil mark this the greatest of all the Tertiary belts.

1st. A coarse white to light gray sandy soil, which stretches from Cass county on the east to Carrizo Springs in Dimmit county on the west, and which through the greater part of its extent supports a fine growth of oak and hickory. While as soils these sands are not of much value, their importance is nevertheless very great, as they form the catchment area for water which may be had south of them for many miles, by wells, either shallow or artesian.

2nd. Light gray, brown and chocolate sands and sandy loams, with stiffer loams in the prairies. These are derived from the sands and clays accompanying the lignite deposits.

3rd. Black shelly to sticky soil, derived from the limy clays at the base of the Tertiary and usually forming a prairie country.

The lignitic soils are usually rich in phosphoric acid and often contain large percentages of potash, but this element is at times deficient. The analyses given are No. 16, sandy upland soil from Wood county; Nos. 17 and 18, light sandy soil and subsoil from Smith county; and 19 and 20 gray sandy upland soil and subsoil from Robertson county.

	16*	17*	18*	19†	20†
Insoluble matter	93.051	94.350	93.458	89.230	90.200
Soluble silica	3.364	.525	1.820	3.810	3.120
Potash	.114	.111	.148	.032	.044
Soda	.074	.105	.080	.232	.200
Lime	.031	.076	.090	.200	.240
Magnesia	.061	.061	.031	.120	.050
Manganese	.111	.140	.121	.040	.190
Iron	.611	2.052	2.337	.980	1.150
Alumina	.908	.303	.779	1.730	2.270
Phosphoric acid	.169	.237	.295	Trace	Trace
Sulphuric acid	.012	.031	.105	.006	.008
Carbonic acid				.110	.090
Water	.611	2.035	.911	1.870	1.740
Organic and volatile				1.670	.730
	99.117	99.926	100.175	100.030	100.030

* Cotton Production, Tenth Census, p. 26.
† Fourth Annual Report Geol. Sur. Tex., p. 78.

The Basal beds are represented by analysis 21, a brown loam from Tehuacana, and 22, a black sandy soil from Wills Point. Their richness and endurance is readily apparent from the composition.

	21*	22*
Insoluble matter	92.949	77.582
Soluble silica	1.421	10.180
Potash	.140	.265
Soda	.096	.130
Lime	.194	.323
Magnesia	.099	.257
Manganese	.030	.042
Iron	1.433	2.892
Alumina	.907	4.423
Phosphoric acid	.358	.115
Sulphuric acid	.081	.156
Water and organic	2.124	3.608
	99.832	99.973

*Cotton Production, Tenth Census, pp. 27 and 36.

SOILS OF THE BLACK PRAIRIE.

The black waxy prairies, comprising the main prairies of that name and a smaller strip of similar character just east of the Lower Cross Timbers, have for years been recognized as one of the finest bodies of agricultural land known. They are almost entirely prairie soil, and take their name from their waxy character when wet. While more difficult to till than some of the lighter soils, their fertility and endurance are such as to make them the favorite soils outside and bottom lands, even if they do not rival these in popularity.

As a whole the soils of the Black Prairie may be classed as marls, being usually more or less calcareous clays. The exceptions to this are the soi's of the Lower Cross Timbers which mark the western border of this plain from Red River to the Brazos near Waco.

The most easterly portion of this belt, which is occupied by the Navarro or Glauconitic beds, contains a considerable amount of greensand marl, and is somewhat lighter soil than that of the black waxy proper to the north or west of it.

Two examples are given of the soils produced by the glauconitic beds. The first of these, No. 23, is taken from near Corsicana, and is the dark prairie soil. No. 24 is a soil and its subsoil from Delta county.

	23*	24†	
Insoluble matter	87.557	79.68	58.22
Soluble silica	5.183	.08	2.28
Potash	.117	.18	.95
Soda	.070	.61	1.35
Lime	.320	.99	10.90
Magnesia	.191	Trace.	.24
Manganese	.083	....	....
Iron	1.638	2.85	3.51
Alumina	2.394	2.88	7.70
Phosphoric acid	.229	.02	.12
Sulphuric acid	.110	.17	.14
Carbonic acid	....	....	7.77
Water	2.623 (Water and Organic and volatile)	5.59	5.14
Organic and volatile		6.92	3.72
	100.515	99.25	100.12

* Cotton Production, Tenth Census, p. 27.
† Records Geol. Sur. Tex. Analyst, P. S. Tilson.

The black waxy soils overlie three distinct beds of rock material: The Ponderosa marl, Austin chalk, and Eagle Ford clay.

PONDEROSA MARL.—The soils of the Ponderosa marls are usually of a dense black color, running high in percentages of lime and clay. While analyses do not show very high percentages of phosphoric acid in these soils, it is present in sufficient quantity to render the soil highly fertile and enduring. Should they begin to deteriorate, it will only be necessary to resort to deep plowing and to mix the subsoil with the soil in order to restore fertility. These soils have high water absorptive and retentive power, and except that when wet they are very hard to work, they are all that could be desired. Their amelioration may be possible by the gradual addition of ash or organic matter from burning the stalks of cotton or corn or other coarse crops, or by plowing them under, preferably the former.

The soils of this portion of the belt cover an area of 10,000 square miles, with an exceedingly small amount of waste or unproductive lands.

In the black waxy soils the potash is very high, but the phosphoric acid is not usually so. The Thorndale soil, No. 25, is typical, and the Collin county specimen, No. 26, is from the best of its class.

	25*	26†
Insoluble matter	67.67	46.145
Soluble silica	1.38	17.241
Potash	.38	.619
Soda	.14	.186
Lime	8.81	7.484
Magnesia	....	.839
Manganese	....	.409
Iron	3.33	4.216
Alumina	3.18	11.073
Phosphoric acid	.05	.151
Sulphuric acid	.14	.104
Carbonic acid	4.31	1.875
Water	3.29	9.510 (Water and Organic and volatile)
Organic and volatile	8.86	
	101.54	99.852

*Third Annual Rept., Geol. Sur. Tex., p. 379.
†Cotton Production, Tenth Census, p. 36.

Austin Chalk.—The upper portion of this belt, geologically, forms waxy soils, which are brown to black when dry, but deep black when wet. Toward the interior border of the belt its limestones are more compact and less argillaceous, and form hills and bluffs which furnish only a scanty soil, owing to the rapidity with which the disintegrated material is removed from the surface.

In the soils from the chalk the phosphoric acid is higher than that of the clays on either side of it, as evidenced by analysis No. 27 of a soil from Austin and No. 28 of a soil and subsoil from Waxahachie.

	27*	28†	
Insoluble matter	74.58	59.90	53.17
Soluble silica	.15	....	....
Potash	.17	.35	.41
Soda	.23	.04	.24
Lime	2.23	5.17	10.62
Magnesia	.51	.67	1.41
Manganese	....	....	....
Iron	3.52	5.44	5.18
Alumina	5.25	6.81	6.32
Phosphoric acid	.13	.15	.65
Sulphuric acid	1.47	.14	.29
Carbonic acid	.33	3.98	8.11
Water	11.44 (Water and Organic and volatile)	9.06	7.64
Organic and volatile		7.77	5.80
	100.01	99.48	99.84

* Records Geol. Sur. Tex. P. S. Tilson, analyst.
† Bulletin 25, Tex. Ag. Ex. Sta., p. 265.

Eagle Ford Shale.—The soils of this belt differ but little from those of the two already described. The subsoil is a blue friable clay marl in a finely divided state, and on thorough weathering forms a deep soil. The surface is level or gently rolling where not cut by streams, and there is no waste land. It comprises the rich black lands about Hillsboro and between Hillsboro and Alvarado. Also eastern Denton, western Collin and western Grayson counties.

The Eagle Ford soils are very close to the Ponderosa in chemical composition, as shown by analysis No. 29 of a residual soil from Williamson county.

	29*
Insoluble matter	57.03
Soluble silica	.20
Potash	.65
Soda	1.06
Lime	3.78
Magnesia	.32
Iron	5.21
Alumina	10.52
Phosphoric acid	.03
Sulphuric acid	.13
Carbonic acid	2.73
Water	5.64
Organic and volatile	12.99
	100.29

* Third Annual Report Geol. Sur. Tex., p. 379.

Lower Cross Timbers.—The soils of the Lower Cross Timbers are of two kinds. The eastern third and more level portion gives sandy loams, which are well adapted to fruits and are more fertile than those of the western portion. The western soils have their origin in a fine grained friable sandstone, containing very little clay, and yielding in the hilly portions light sandy soils and in the lower and more level lands a deep loamy sand.

These lands are much better suited for orchards and vineyards than for cotton and corn.

A Dakota sandy soil is represented by analysis 30, from Tarrant county.

	30*
Insoluble matter	85.686
Soluble silica	5.313
Potash	.213
Soda	.079
Lime	.342
Magnesia	.174
Manganese	.015
Iron	2.469
Alumina	2.672

Phosphoric acid	.093
Sulphuric acid	.045
Water and organic	2.785
	99.886

*Cotton Production, Tenth Census, p. 29.

Difference of climatic conditions are well shown in the Black Prairie belt. The black waxy character of the soils extends to San Antonio, but in the more western portions of the State the soils from these beds do not show that waxiness so clearly nor are they always so black. The belt is quite narrow along the Southern Pacific railroad west of San Antonio until the Rio Grande is reached, when it again broadens out to a considerable width. A large amount of glauconitic material is found, and the soils, when irrigated, will doubtless sustain their reputation for fertility, which they so well deserve in the more humid portion of the State.

SOILS OF THE GRAND PRAIRIE.

The soils of the Grand Prairie are often shallow and rocky, but wherever they are perfectly formed and of sufficient depth and extent for cultivation they are very fertile.

Vola and Arietina.—Residual soils from the upper members of this belt are not extensive, since they are usually mingled with the sand from the Lower Cross Timbers in the region where they have the most available exposure. This commingling, however, adds to their value, making them lighter by the mixture of sand with their rich calcareous clays. They are unsurpassed for the production of grain, fruits, berries and garden products. The width of the belt varies from a few hundred yards to a mile, and has the Lower Cross Timbers for its eastern border.

Analysis 31 of a soil from Williamson county shows the richness of the residual soil from Arietina clay. It is high both in potash and phosphoric acid.

	31*
Insoluble matter	63.80
Soluble silica	.17
Potash	.51
Soda	.50
Lime	2.08
Magnesia	.58
Iron	4.66
Alumina	8.99
Phosphoric acid	.53
Sulphuric acid	.15
Carbonic acid	1.57
Water	3.89
Organic and volatile	12.81
	100.24

*Third Annual Report Geological Survey of Texas, p. 379.

WASHITA LIMESTONE.—These are the most extensive of the Grand Prairie soils, in its eastern portion, and occupy nearly its whole area north of the Brazos river. They comprise the rich prairie lands of the western parts of Hill, Johnson, Tarrant and other counties.

The character of the topography is such as to favor the accumulation of deep soils, except where cut by creeks, and is sufficiently rolling to afford good drainage.

The soils are dark brown marls, and even in the areas where the topography is most rugged form good pasture lands.

Their exceptional fertility does not appear to be caused by the percentages of potash and phosphoric acid that they contain, so much as by their fine physical condition.

The brownish black marl of the Washita is well illustrated by the analysis No. 32 from Johnson county.

	32*
Insoluble matter	60.354
Soluble silica	5.563
Potash	.365
Soda	Trace.
Lime	9.780
Magnesia	.708
Manganese	.030
Iron	5.346
Alumina	5.746
Phosphoric acid	.178
Sulphuric acid	.047
Carbonic acid	6.594
Water and organic matter	5.255
	99.966

*Cotton Production, Tenth Census, p. 36.

FREDERICKSBURG.—The soils of this division in the eastern portion are usually thin, as by reason of the sharpness of the topography the materials are carried away almost as fast as they are disintegrated, and consequently there is little chance for the accumulation of soil. Sometimes, however, these rocks occupy the summits of divides and give rise to dark brown or rich black residual soils.

Ordinarily the rocky surface is covered by a stunted growth of timber or by harsh grasses.

Residual soils from the Fredericksburg division are represented by analysis 33, from Travis county, and 34 and 35, soil and subsoil from Williamson county.

	33*	34†	35†
Insoluble matter	62.97	63.52	54.520
Soluble silica	.39	1.05	.227
Potash	.11	.35	.160
Soda	.13	.95	1.420
Lime	2.61	1.83	8.950
Magnesia	....	.37	.115
Iron	5.76	4.89	4.540
Alumina	9.21	9.99	9.140
Phosphoric acid	.19	.06	.094
Sulphuric acid	3.85	.12	.077
Carbonic acid	.28	1.20	5.570
Water	15.47	5.35	3.620
Organic and volatile		10.60	11.720
	100.97	100.28	101.053

*Records Geol. Sur. Texas. P. S. Tilson, analyst.
†Third Annual Report, Geol. Sur. Texas, p.379.

Bosque.—The soils of the Upper Cross Timbers are very sandy and are usually heavily timbered, but in the valleys some rich dark brown or chocolate soils are found, which are well adapted for the production of peaches and grapes. These latter soils are largely resultant from the limestone and soft arenaceous lime marl of the intermediate beds of the division, and are, in consequence, more important between the Brazos and the Colorado than north of the former stream.

The chocolate loams as developed in eastern Burnet county carry single trees and scattered clumps of live oaks on the hills, while in the valleys pecan, oak, and other hard woods abound.

While the sandy soils are hardly fit for cultivation, they are the great catchment area for the water which supplies the springs and artesian wells from Fort Worth to San Antonio and Del Rio. As soon as the timber is cut from any portion of this belt and the porous sandy soil is subjected to the plow, rapid erosion begins, and the area is not only destroyed for farming purposes, but loses its usefulness as a forest producer.*

A soil from the Upper Cross Timbers is given in analysis 36 of sample from Comanche county.

*These barren spots detract from the absorptive power of the belt, and permit a far greater proportion of the rain water to run off than was the case while it was forested. Therefore the policy should be to leave the entire strip in forest, so that the greatest possible amount of water could be taken up by the underlying sands. It is safe to say that a policy of clearing up this land and putting it in cultivation will in the end materially lessen the supply of water in the artesian wells in the artesian belt of North and Central Texas.

	36*
Insoluble matter	96.360
Soluble silica	1.176
Potash	.209
Soda	.058
Lime	.038
Magnesia	.206
Manganese	.081
Iron	.497
Alumina	.671
Phosphoric acid	.121
Sulphuric acid	.030
Water and organic	.889
	100.336

*Cotton Production, Tenth Census, p. 29.

Residual Soils of the Central Basin.

The Basin Region may be roughly defined as that portion of the State between the Upper Cross Timbers on the east and the Guadalupe mountains on the west, and lying north of 31st parallel of latitude. The Denuded areas are underlaid by rocks of the Carboniferous and Permian, while the dividing plateaus are Cretaceous, Tertiary, and later.

The soils derived from these various formations of course differ greatly. The soils of the Denuded areas comprise both marls and loams; the Cretaceous plateaus usually yield only thin soils suitable for pasturage; and the later plateaus furnish fertile loamy soils.

This region lies for the most part west of the humid belt, in the subhumid and dry region. With proper seasons the productiveness of the soils is all that can be desired, but these are not always certain. For this reason preparation is now being made for irrigation both from streams and storage reservoirs, and there is every reason to believe that the results will be of the greatest benefit.

SOIL OF THE DENUDED AREAS.

Coal Measures.—Much of the area over which the rocks of the Coal Measures and Permian are now exposed was formerly covered also by the rocks of the Cretaceous formation. In their disintegration and removal they have left some imprint on the underlying beds, and, in places, have helped to make the soils what we now find them.

The rocks of the Coal Measures being principally sands and clays with some limestones, naturally yield a greater proportion of loamy soils, with here and there a belt of sand or marl. The admixture of limy material from the Cretaceous has given a marly character even to some of the soils derived from the alternating clays and sands of this district.

The lowest or Bend division forms a very rich and black soil, almost waxy in its character, as developed in the valley of the San Saba and on Richland creek. Where it forms the subsoil of the residual soil of the overlying Strawn standstones it adds greatly to their usefulness.

The soils of the Milsap division are principally clays and clay loams.

The residual soils of the Strawn division comprise sandy soils, which are of little value when not underlaid by or mixed with clay, and all gradations of loams to a stiff clay soil. The greater part of them are fertile and well adapted for tillage. The colors both of the sand and clay soils are often dark or even black.

In the Canyon division, owing to the fact that more sand and less clay is present, the loams are lighter. The soils from the Cedarton clays of this division are quite rich, and where the soils are sandy, subsoiling will usually make them stronger.

The clays of the Cisco division yield dark heavy loams and form large areas of fine farming lands. The percentage of phosphoric acid is good, while the potash is very large—much above the average. The upper portion of this belt containing more limestone, gives dark brown to black marl soils.

Analysis No. 37 shows the composition of the red loams of the Canyon division as developed in Jack county, while No. 38 represents the lighter soil of this division, and No. 39 that of the Cisco.

	37*	38†	39†
Insoluble matter	74.495	95.98	90.03
Soluble silica	8.651	.16	.41
Potash	.425	.72	1.80
Soda	.163		
Lime	.125	.19	.59
Magnesia	.882	....	.82
Manganese	.150	....	....
Iron	5.050	.33	1.34
Alumina	5.076	.27	2.04
Phosphoric acid	.095	.13	.15
Sulphuric acid	.047	1.16	....
Water and organic	4.805	1.76	3.16
	100.354	100.70	100.34

* Cotton Production, Tenth Census, p. 37.
† Records Geol. Sur. Tex. P. S. Tilson, analyst.

PERMIAN.—In the southern portion of this belt the lower beds of the Permian are clayey limestones and the resultant soils are dark brown to stiff clayey marls, very fertile and well adapted to the growth of grain. These are well shown in the western part of Coleman county. Where the clays predominate they yield stiff brown or chocolate colored loams.

In the northern portion these limestones and clays are replaced by more sandy material, and these give rise to sandy loams of deep red color such as occur near Wichita Falls.

In the middle division, which contains much limestone, the soils are usually dark colored or black marls. The soils near Abilene are of this division.

The upper division is largely composed of sands and clays, and its residual soils are red or chocolate loams.

The chocolate loam of the Wichita division is apparently low in phosphoric acid, as shown by analysis No. 40. The potash and lime are sufficient, however, for all needs. The same is true of the black loam of the Clear Fork division, the analysis of both the soil and subsoil of which is given in Nos. 41 and 42.

	40*	41*	42*
Insoluble matter / Soluble silica	88.46	73.78	64.30
Potash	.43	1.14	.59
Soda	.14	.96	.31
Lime	.74	4.04	9.32
Magnesia	Trace.	1.40	1.09
Iron	2.06	1.78	2.23
Alumina	3.82	6.51	5.05
Phosphoric acid	Trace.	Trace.	.10
Sulphuric acid	.58	.15	4.22
Carbonic acid	....	2.25	5.20
Water	1.62	4.52	4.80
Organic and volatile	3.01	3.05	2.69
	100.86	99.57	99.90

* Bulletin 25, Tex. Ag. Ex. Sta., p. 266.

SOILS OF THE PLATEAUS.

Cretaceous.—The soils of the Cretaceous plateaus are comparatively thin and unimportant, although they furnish a certain amount of pasture land. Their service to the underlying materials has already been mentioned.

Llano Estacado.—This great plateau, comprising as it does an area of over 30,000 square miles, has soils of most excellent quality. The materials of which they are composed are the sediments of a great lake, which existed here in late Tertiary times, only a single point of the eastern shore of which has so far been discovered. This is in the range of Cretaceous hills in the southern part of Garza county.

Four principal kinds of soil are recognized, one of which probably belongs to the drift soils.

The chief soil of the plain is a rich chocolate loam. Next in importance is a black sandy, sometimes waxy soil, which is similar to if not identical with that of the Reynosa of the Coastal Slope. There is also a red loam, which very closely resembles some of the valley soil of the Colorado and Brazos rivers, and finally a loose red sandy soil. Of three former varieties the subsoils are practically the same materials as the soil itself. The last, however, has various subsoils, being in some measure the product of the winds.

The adaptability of these soils for fruit farming and grazing purposes has been fully demonstrated, and although the rainfall is sometimes deficient, the porosity of the soil is such that the greater amount of that which does fall finds its way downward until stopped and held by the impervious bed of clay which underlies the plain, whence it is accessible by means of wells and pumps. The little irrigation that has been done by means of pumping this water has been very successful.

Seymour Plateau.—The soil of this plateau might almost be classed among the drift soils of the area but for its extent and importance. It is a rich brown loam, whose great fertility is due to the many different beds which have furnished their portions of its materials. It is as near an ideal soil as can be found, and with proper water supply will be one of the most fertile soils of the State.

Similar soils are those of Lipan Flat, etc.

We have only a single analysis of Plains soil, and that is from Carson county. It is as follows:

	44*
Insoluble matter	76.17
Soluble silica	.16
Potash	.06
Soda	.11
Lime	.78
Magnesia	.51
Iron	4.08
Alumina	6.08
Phosphoric acid	.09
Sulphuric acid	.34
Water	6.01
Organic and volatile	4.50
	100.87

* Records Geological Survey of Texas. P. S. Tilson, analyst.

Residual Soils of the Mountain Regions.

CENTRAL MINERAL REGION.

The soils resulting from the weathering of the granites and other siliceous rocks of this district are red loams, varying from sandy to claycy, and are of excellent quality where they lie in bodies of sufficient extent for tillage.

In the areas occupied by the newer limestones black loamy and marly soils are found.

TRANS-PECOS REGION.

In this area the principal soils are those of the ancient lake basins or flats which separate and surround the various peaks and mountain ranges.

The soils are usually red loams, with variable proportions of sand and clay, and sometimes with sufficient lime in them to take on a marly character.

The materials of which they are composed have been derived from the disintegration of the rocks of the mountains among which they lie. These consist of sandstones, limestones, clays, granitic and various eruptive rocks which are often rich in potash. The analyses of the soils of this area clearly show the effect of such a mingling of materials, and the percentages of those important plant foods, potash and phosphoric acid, are much above the average. Their fertility is proved by the fine grasses they produce, and with a proper water supply these flats could be made the granary of the State.

While the rainfall is not sufficient to render farming as ordinarily followed a possibility in this region, it is sufficient to furnish a water supply for a large amount of irrigation, and numerous localities exist within the mountains where, at comparatively small expense, dams and storage reservoirs can be constructed which in the aggregate will furnish, in ordinary seasons, enough water for irrigating thousands of acres of these fertile flats. It is only a question of time until they will be so utilized, and add their proportion to the agricultural productions of the State.

Two analyses of the soils of the Trans-Pecos basin region are given. One of them (No. 44) of the red loam proper, the other, No. 45, of the more calcareous soil from south of Sierra Blanca.

	44*	45*
Insoluble matter	78.63	66.55
Soluble silica	.44	.17
Potash	.52	.47
Soda	.46	.29
Lime	.57	13.65
Magnesia	....	.96
Iron	7.44	2.88
Alumina	2.22	1.45
Phosphoric acid	.34	.21
Sulphuric acid	.38	Trace
Carbonic acid	Trace	9.52
Water and organic	8.33	3.10
	99.33	99.25

*Bulletin No. 2, Geol. Sur. Texas, p. 11.

Soils of Transportation.

The Transported soils are readily divisible into two general classes:
Drift soils, or Transported soils of the uplands.
Alluvial soils, or Transported soils of the lowlands.

DRIFT SOILS.

In addition to the soils which have been directly derived from the various belts of the different plains as already described, and to the Alluvial soils of the river valleys and their tributaries, there is a third class of soils which occupy comparatively large areas in various portions of the State. These are the Drift soils. They represent local accumulations of materials deposited at later times than the original beds. They frequently, if not generally, are underlaid by deposits of gravel and boulders, and their soils, although sometimes very similar to those of the surrounding area and directly derived from them, are often quite different.

Without entering into extended details, a few examples will explain their occurrence and character better than can be done in any other way.

Coastal Slope.—In Houston county, such prairies as Tyler, Nevill's, Mustang, etc., are occupied by two to four feet of dark gray, almost black, sandy soil resting on thin beds of siliceous pebbles and fossil wood. This is underlaid by Tertiary materials. Similar bodies occur at various places in the area.

In Williamson county, the greater part of the area which is underlaid by the materials belonging to the Upper Cretaceous or Black Prairie belt is covered with drift soil. It has its origin in the debris derived from rocks both of Lower and Upper Cretaceous age, and often there are bodies of undecomposed drift materials underlying these soils to a depth of several feet. A thin mantle of drift of flint and limestone pebbles remains upon the surface and characterizes the soil As a rule they are fertile, and are often inseparable by surface appearance from the purely residual soils of the region.

Central Basin.—The Drift soils of the Central Basin are fully as abundant as those of the Coastal Slope, and they are of even greater importance than in the latter region.

The Seymour plateau, Lipan Flat and similar bodies are of this character, and are among the best soils of the entire area.

A good example of one of these areas occurs at the town of Memphis, in Hall county. The town is located between the prongs of Parker creek, and the flat on which it is situated is a Quaternary deposit resting in a basin eroded in the sandy clays of the Permian.

The following analyses, Nos. 46 and 47, soil and subsoil, from Tyler

Prairie, Houston county, show the character of one of these soils. As in all other cases, their fertility depends upon the sources from which they were derived, and when, as in this case, they are formed from materials rather low in potash and phosphoric acid, and in the process of transportation and deposition these substances are still further depleted by solution, we naturally expect to find them lacking in these essential ingredients, and therefore lacking in endurance.

The drift soil from Williamson county, analysis No. 48, gives still further evidence of this fact. Having its origin in the richest materials of the black waxy prairies, it possesses all their fertility, so far as mineral plant foods are concerned, and being frequently of a somewhat lighter character than the original, is therefore more easily tilled.

	46*	47*	48†
Insoluble matter	96.50	96.75	80.94
Soluble silica	.12	.18	.21
Potash	.06	.11	.23
Soda	.41	.33	.20
Lime	.23	.33	1.92
Magnesia	Trace.	Trace.	.31
Iron	1.07	.75	1.92
Alumina	1.13	Trace.	2.78
Phosphoric acid	.03	Trace.	.07
Sulphuric acid	.08	.14	.11
Carbonic acid	....	....	.81
Water	.20	.36	2.26
Organic and volatile	1.44	1.34	7.89
	101.27	100.29	99.55

* Third Annual Report, Geol. Sur. Tex., p. 23.
† Third Annual Report, Geol. Sur. Tex., p. 379.

ALLUVIAL SOILS.

For a proper understanding of our alluvial soils, a few words are necessary regarding the river systems which have been the vehicles of their transportation and deposition.

A glance at the map will show that the rivers of the State are separable into the following groups:

Rivers having their origin outside the State: Canadian, Red, Pecos, and Rio Grande.

Rivers rising in the Central Basin: Trinity, Brazos, Colorado.

Rivers of the Grand Prairie: Sabine, Neches, Guadalupe and Nueces.

Rivers of the Reynosa: San Jacinto, Buffalo, Bernard, Lavaca, etc.

Streams of the Coast Prairies.

These rivers have each carved its own valley, which varies in width with the character of materials through which it has passed and the erosive power of the water. The present river channel, as a rule, occupies but a small portion of its valley, and all of the principal rivers have what are known as first and second bottoms, lying between the channel and the uplands, in strips of varying width as the river winds its tortuous way through them.

The materials of these bottom lands are partly local and partly foreign. That is, they are derived not only from the washings brought down from the uplands in the immediate vicinity, but also contain the sediments taken up by the river in its higher reaches and deposited with these in times of flood or overflow. Thus as we follow a long river in its course toward the sea we may find a greater and greater mixture in the materials of its sediments.

Coast Prairie Streams.—The streams which lie entirely within the Coast Prairies could therefore have an alluvial soil of only those materials which are found in the immediately adjacent prairies. They are, indeed, so lately cut as to be little more than drainage channels.

Streams of Reynosa Plain.—The rivers of the Reynosa Plain, however, bring down into the Coast Prairies the sediments they derive from the plain in which they have their origin, and their alluvial soils will be different from those of the Coast Prairie streams to that extent.

Rivers of the Grand Prairie.—The rivers of the Grand Prairie, with the exception of the Guadalupe, have wide and fertile bottoms and are all well timbered.

The Sabine and Neches have in their upper portions dark waxy soils, but after reaching the Tertiary plain a larger mixture of sandy material gives rise to dark sandy loams.

The soil of the Nueces valley is a sandy loam, easily tilled. It is black, brown or gray in color, with reddish or yellow loam or clay subsoil. This river proves its wanderings through its valley in the past by numerous lakes which still exist along it in some portions of its course, especially in LaSalle county. Its former lake condition is clearly evident in its lower course.

Rivers of the Basin Region.—The Trinity river, while it rises in the basin region, does not reach as far west as the "red beds" proper, and hence its sediments do not include materials from them. Through the Grand and Black Prairies the valley soils are principally a dark loam or silt, but through the Tertiary plain the washings from the Black Prairies give a black waxy soil for the bottoms, although in the immediate vicinity of the river the soil is lighter and more silty. The valleys of the lower portion vary from one to five miles in width and are well timbered with oak, ash, etc.

Red River, the Brazos, and the Colorado all have their origin west of the red beds of the Permian, and cross all the more important formations in their journey to the gulf. These are therefore the largest rivers, their valleys are the most extensive, and their soils the richest in the State. The "red rises" of these rivers, from the rains which fall in the area of their headwaters, add a considerable amount of most fertile soil to their bottom lands yearly.

Red River in the eastern part of its course has in its first bottom deep red sandy or waxy soils, heavily timbered with cottonwood, elm, ash, walnut, pecan, etc. Beyond this the second bottoms of sandy loam extend back to the bluffs. These bottoms are from one to two miles wide, and are succeeded by high rolling uplands.

The Brazos in its course gulfward crosses the various formations almost at right angles to their strike, and encountering beds of very unequal hardness, is turned this way and that until its course is exceedingly tortuous. In places its valley is of considerable width, with bluff hillsides bordering it on either side, while at others the hills draw nearer and nearer together until the valley and the channel are nearly coextensive.

In passing through the Grand Prairie the valley has a width of from five to eight miles, timbered with oak, pecan, etc. On reaching the softer materials of the Black Prairie the valley widens, and the first bottom occasionally attains a width of two miles, while the second bottom spreads five miles on either side of it.

In the Tertiary plain its bottom lands are also wide, with a growth of large timber, oak, elm, ash, pecan, etc. In this area occurs a feature that is repeated in the Coast Prairies. In Robertson county the Brazos valley not only includes the river itself but that of the Little Brazos as well. In other words the latter occupies a portion of a former channel of the river. The same is true of Caney creek, in Brazoria county.

Of all our alluvial soils those of this river are considered the most valuable, both for fertility and endurance. It is the largest body in the State, and will compare favorably with the richest alluvial land in the world. The valley has a length of about 300 miles and its average width in this distance is four miles or more. In the upper portion the soil of the first bottom is a red or chocolate loam and that of the second bottom a dark sandy loam. The principal soil throughout its whole length is this red or chocolate loam, which occurs in belts from one-half mile to a mile or more in width. On account of its perfect drainage and great fertility it is most highly regarded. In the southern portion of the valley canebrakes, a dense timber growth and bowers of grape vines almost cover the land, and it shows no diminution of fertility after being under cultivation for fifty years. The black peach soil, so called from its abundant growth of wild peach, is also easily tilled and is especially adapted for sugar cane.

The Colorado river, between the mouth of the Concho and Austin, has a much narrower valley than the Brazos, and its alluvial soils in that distance are therefore less important, although where the valley is wide enough for their accumulation they are of excellent quality.

Below Austin it widens out and the bottoms are heavily timbered with cottonwood, elm, ash, walnut, etc. The soils vary from reddish sandy loams to chocolate and darker clay loams.

In its flow through Bastrop and Fayette counties numerous instances may be observed of the prevalency of lakes along its course in the earlier stages of its growth. This condition may be noted along many of the Texas rivers, and indicates that at some period of their history they were simply chains of lakes. These were gradually silted up by the overburdened stream, and when in later time the river received fresh erosive power, it again cut its channel through them, and now parts of the old basins may be seen clearly defined.

These lake basins and the second bottoms are closely related in many ways to the drift soils of the uplands.

The valleys of the tributaries of these streams will present variations of soil under the general principles already stated, in accordance with their extent and the variety of materials over and through which they pass. The soils vary from black hummock on the smaller streams to chocolate loams on the larger.

We have analyses of the bottom soils of the rivers in various portions of their courses. Of the Brazos in the Grand Prairie and Coastal Plains, of the Colorado in the Black Prairies and Tertiary, of the Trinity and Red River in the Black Prairie, and of the Rio Grande in the Coastal Plain.

Grouping these together, and considering them in connection with the rocks over which they flow and from whence their sediments are derived, the variations are readily accounted for, not only as among the different rivers, but along the course of the same river.

The length of this article precludes a discussion of these variations at this time, but attention is called to the exceptional richness of the soil from the Rio Grande valley, No. 59, which Loughridge says "seems to be nearer to what many thought to be a 'perfect soil'" than any other in the State.

Space also forbids the notice of the valleys of the smaller streams, especially those of the Basin region, which furnish soils of great fertility, and they must be left for subsequent presentation.

The alluvial soil of the Brazos in the Grand Prairie is shown by the following analysis of sample of red soil from the second bottom of the river at Granbury, Hood county:

	49*
Insoluble matter	88.177
Soluble silica	2.151
Potash	.298
Soda	.081
Lime	.413
Magnesia	.343
Manganese	.040
Iron	2.076
Alumina	2.508
Phosphoric acid	.094
Sulphuric acid	.020
Water and organic	2.735
	98.936

*Cotton Production, Tenth Census, p. 45.

The character of the soils of the different rivers in their course across the Black Prairies is given in the analyses below.

No. 51 is from the first bottom of Red River, Indian Territory, opposite Lamar county. No. 52 is from the Trinity, two miles west of Dallas. No. 53 is from the Colorado bottom, four miles east of Austin, and by its percentage of lime shows the influence of the soft limestones of the Cretaceous just north of it.

	50*	51*	52*
Insoluble matter	68.050	36.065	62.306
Soluble silica	9.863	16.553	10.357
Potash	.345	.509	.591
Soda	.066	.225	.118
Lime	1.116	16.344	7.793
Magnesia	1.217	1.602	1.379
Manganese	.126	.054	.126
Iron	5.274	3.857	2.934
Alumina	8.367	5.205	3.288
Phosphoric acid	.209	.152	.207
Sulphuric acid	.030	.158	.033
Carbonic acid	.952	12.008	5.075
Water and organic	4.906	6.270	5.028
	100.521	99.002	99.225

*Cotton Production, Tenth Census, pp. 43, 44, 47.

The analysis No. 53 is a red loam soil from the Brazos bottom four miles west of Hearne, and No. 54 is a valley loam from the Colorado at Bastrop.

	53*	54*
Insoluble matter	69.391	71.082
Soluble silica	11.291	12.275
Potash	.258	.444
Soda	.084	.168
Lime	2.050	.675
Magnesia	.604	.090
Manganese	.109	.153
Iron	3.454	3.058
Alumina	3.589	6.291
Phosphoric acid	.370	.258
Sulphuric acid	.290	.208
Carbonic acid	1.047	....
Water and organic	6.800	5.028
	99.337	99.730

* Cotton Production, Tenth Census, pp. 45 and 47.

The soils of the Brazos river valley in the Coastal Plain are shown in the following analyses.

The red or chocolate loam in Nos. 54 and 55. The former from Oyster creek, the latter from a point 50 miles by river channel from the Gulf.

No. 56 is a Peach soil from the San Bernard, and No. 57 a similar soil from the same locality as No. 55.

The sandy loam No. 58 is also from this locality.

	54*	55*	56*	57†	58†
Insoluble matter	66.461	78.59	80.806	76.45	84.31
Soluble silica	13.950	....	6.203	....	....
Potash	.781	1.09	.441	.54	.46
Soda	.226	.85	.085	.32	.37
Lime	1.876	1.66	.596	.60	2.74
Magnesia	1.907	.13	.607	.73	.24
Manganese	.013	....	.069	....	....
Iron	3.697	2.80	2.179	2.60	2 36
Alumina	4.020	6.05	3.685	3.51	3.87
Phosphoric acid	.148	.136	.055	Trace.	.166
Sulphuric acid	.034	Trace.	.030	.079	Trace.
Carbonic acid	1.901	2.04	....	.34	2.24
Water	4.042	3.04	5.748	4.62	1.17
Organic and volatile		3.09		9.39	1.54
	99.116		100.504		

* Cotton Production, Tenth Census, p. 45.
† Bulletin 25, Tex. Ag. Ex. Sta.

The rich soil of the Rio Grande valley is shown by the following analysis of sample taken from near Brownsville:

	59*
Insoluble matter	36.041
Soluble silica	17.255
Potash	1.308
Soda	.218
Lime	14.433
Magnesia	1.532
Manganese	.069
Iron	4.085
Alumina	9.114
Phosphoric acid	.204
Sulphuric acid	.041
Carbonic acid	9.912
Water and organic	6.008
	100.220

* Cotton Production, Tenth Census, p. 45.

Preliminary Classification.

Based on the facts as given above, the following preliminary classification of Texas soils is offered:

COASTAL SLOPE.

Coast Prairies:
- Residual .... }
- Transported .... } Sands, gray silts, black waxy.
- Alluvial .... }

Tertiary Belt:
- Residual.
  - Reynosa.........Brown sandy, black loam, black waxy.
  - Oakville ....Sandy loams and marls.
  - Frio ....Black sticky to black waxy.
  - Fayette ....Gray sands or sandy loams.
  - Yegua ....Dark clay loams to light sands.
  - Marine..........Red and gray sand and red clay, mulatto or dark sandy loams.
  - Lignitic.........Gray sands and sandy loams, black shelly, etc.
- Transported.
  - Drift ....Sandy loams.
  - Alluvial.........Loams,

Black Prairie:
  Residual.
    Glauconitic ...... Black sandy to black waxy.
    Ponderosa ...... Black waxy.
    Austin chalk..... Brown to black waxy.
    Eagle Ford...... Black waxy.
    Dakota .... Sandy loams and light sandy.
  Transported.
    Drift .... Marls and loams.
    Alluvial......... Loams.
Grand Prairie:
  Residual.
    Vola-Arietina ... Marls.
    Washita .... Dark brown marls.
    Fredericksburg... Brown to black marls.
    Bosque.......... Sands and chocolate loams.
  Transported.
    Drift .... Marls.
    Alluvial......... Marls and marly loams.

BASIN REGION.

Denuded Areas:
  Residual.
    Bend .... Black sticky.
    Milsap .... Clay loams.
    Strawn.......... Loams.
    Canyon .... Loams and sandy loams.
    Cisco .... Dark loams to black marls.
    Albany .... Brown or black marl, chocolate loams.
    Clear Fork ...... Dark or black marls.
    Double Mountain. Red or chocolate loams.
  Transported soils.
    Drift .... Loams and marls.
    Alluvial......... Loams.
Plateaus:
  Cretaceous.
  Tertiary.
    Seymour ... . Chocolate loam.
    Llano Estacado .. Chocolate loam, red loam, black sandy and waxy.
  Transported.
    Drift .... Loams and sands.
    Alluvial......... Loams.

MOUNTAIN REGION.

Central Mineral Region:
- Residual ....Red loams, black loams, and marls.
- Transported.
  - Drift.
  - Alluvial.

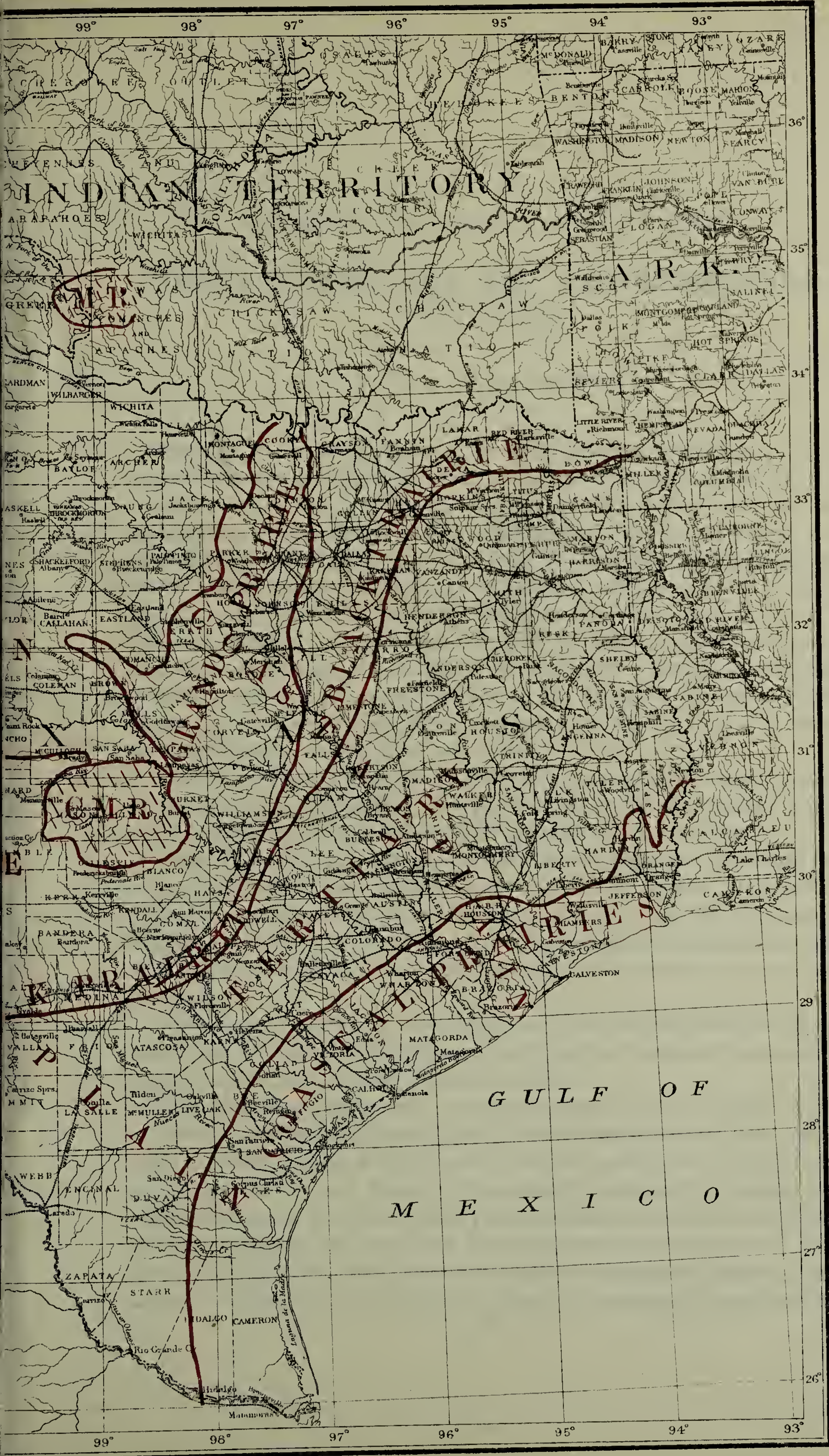
Trans-Pecos Texas:
- Residual ....Red loams and marly loams.
- Transported.
  - Drift ....Sands.
  - Alluvial. ....Adobe and sandy loam.

CONCLUSION.

In this brief review it has been impracticable to touch on all that is of interest or importance in connection with the soils. Their physical condion, power of water absorption, percentage of humus, details of plant growth, and other particuiars have had to be passed over almost without notice, but it is hoped that the presentation made will prove a start in the right direction and be followed by closer studies of the various soils of the State and a combined effort for such an understanding of our agricultural capabilities as will result in the rapid improvement of everything connected with the farming interest, which can be effected by agricultural geology or agricultural chemistry.

DEPARTMENT OF AGRICULTURE INSURANCE, STATISTICS AND HISTORY
GEOLOGICAL SURVEY OF TEXAS
E.T. DUMBLE, STATE GEOLOGIST.
PROGRESS MAP
Scale of Miles.
0 10 20 30 40 50 75 100 Miles
NEW MEXICO
PUBLIC LAND
LLANO ESTACADO
TRANS-PECOS MOUNTAIN REGION
BASIN
REGI
GRAN
PRAIR
COAST
TE
RIO ARRIBA
TAOS
COLFAX
MORA
SAN MIGUEL
SANTA FE
CHAVES
EDDY
DOÑA AÑA
LINCOLN
EL PASO
REEVES
PECOS
PRESIDIO
BREWSTER
BUCHEL
FOLEY
JEFF DAVIS
CROCKETT
VAL VERDE
SUTTON
EDW
KINNEY
OLDHAM
POTTER
CARSON
GRAY
DEAF SMITH
RANDALL
ARMSTRONG
DONLEY
PARMER
CASTRO
SWISHER
BRISCOE
HALL
BAILEY
LAMB
HALE
FLOYD
MOTLEY
COCHRAN
HOCKLEY
LUBBOCK
CROSBY
DICKENS
YOAKUM
TERRY
LYNN
GARZA
KENT
STONE
GAINES
DAWSON
BORDEN
SCURRY
FISHER
ANDREWS
MARTIN
HOWARD
MITCHELL
NOLAN
LOVING
WINKLER
ECTOR
MIDLAND
GLASSCOCK
COKE
WARD
CRANE
UPTON
IRION
SCHLEICHER
DALLAM
SHERMAN
HANSFORD
OCHILTREE
HARTLEY
MOORE
HUTCHINSON
ROBERTS
Santa Fe
Albuquerque
Bernalillo
Socorro
Las Vegas
Los Lunas
Lincoln
Roswell
Eddy
Los Cruces
Rincon
El Paso
Pecos
Ft. Stockton
Marfa
Del Rio
Chihuahua
Amarillo
Tascosa
Colorado
Big Spring
Snyder
Rio Grande
108° 107° 106° 105° 104° 103° 102° 101°
36° 35° 34° 33° 32° 31° 30° 29° 28° 27° 26°

JULIUS BIEN


99° 98° 97° 96° 95° 94° 93°
36° 35° 34° 33° 32° 31° 30° 29 28° 27° 26°
INDIAN TERRITORY
CHEROKEE OUTLET
CHICKASAW NATION
CHOCTAW NATION
ARK.
M.R.
C.M.R.
GULF OF MEXICO
GALVESTON
HOUSTON
MATAGORDA
CALHOUN
CAMERON
HIDALGO
STARR
ZAPATA
WEBB
ENCINAL
DUVAL
LA SALLE
McMULLEN
LIVE OAK
ATASCOSA
KARNES
GOLIAD
VICTORIA
WHARTON
BRAZORIA
COLORADO
AUSTIN
WASHINGTON
LEE
WILLIAMSON
BLANCO
KENDALL
COMAL
BANDERA
KERR
WILSON
GUADALUPE
CALDWELL
HAYS
FAYETTE
BURLESON
MADISON
WALKER
MONTGOMERY
LIBERTY
HARRIS
CHAMBERS
JEFFERSON
ORANGE
HARDIN
TYLER
POLK
TRINITY
HOUSTON
ANGELINA
SABINE
SHELBY
PANOLA
RUSK
CHEROKEE
ANDERSON
FREESTONE
LIMESTONE
HENDERSON
SMITH
VAN ZANDT
HARRISON
MARION
CASS
BOWIE
RED RIVER
LAMAR
FANNIN
GRAYSON
COOKE
MONTAGUE
WICHITA
WILBARGER
ARCHER
BAYLOR
JACK
PARKER
PALO PINTO
STEPHENS
SHACKELFORD
EASTLAND
CALLAHAN
ERATH
COMANCHE
BROWN
COLEMAN
MILLS
SAN SABA
McCULLOCH
MASON
LLANO
BURNET
LAMPASAS
CORYELL
BOSQUE
HOOD
JOHNSON
ELLIS
NAVARRO
HOPKINS
WOOD
BENTON
WASHINGTON
MADISON
NEWTON
CARROLL
BOONE
MARION
SEARCY
JOHNSON
VAN BUREN
POPE
CONWAY
LOGAN
SEBASTIAN
SCOTT
MONTGOMERY
POLK
HOT SPRINGS
PIKE
CLARK
SEVIER
LITTLE RIVER
HEMPSTEAD
NEVADA
MILLER
LAFAYETTE
COLUMBIA
CALCASIEU
CAMERON
PRAIRIES
LITH. N.Y

Read before the Texas Academy of Science, Nov. 1, 1895.

GENESIS OF CERTAIN ORE VEINS, WITH EXPERIMENTAL VERIFICATIONS.

BY W. H. VON STREERUWITZ.

Geology, as far as it refers to the azoic ages, is a speculative science; the worker in this field has to build conclusions on premises which frequently are also but conclusions. It is a very interesting field, but the geologist following up this branch of the science, which is intimately connected with mining geology, is at a certain disadvantage as against the worker in stratified formations, in formations of which even the single horizons of every period are distinctly labeled by fossils and ready for systematic classification. True, nature now and then kindly allows us to guess, and even understand, the secrets of her wonderful workings in rocks and minerals, but in most cases denying us the means to reproduce in the laboratory on a small scale those phenomena which the geologist meets and investigates in mountains and mines.

One of the principal agents at nature's command is absolutely denied to the student and most skillful experimenter: the length of time, which only in few cases may be replaced by increased energy of forces.

Other agents of equal importance are heat and pressure. No doubt our powerful dynamos may produce heat high enough to melt and even to vaporize all the elements of which our globe, of which the universe, is built; but we have no crucibles, no retorts, that could withstand the heat and pressure which may have been required to form rocks and rock constituents.

Nevertheless, some successful experiments in this direction have been made; as, for instance, Daubres, in Paris, produced some of the so-called igneous rocks, and changed some into others.

Very few experiments have been made referring to the origin of ore veins and deposits, and less written on this subject than any other geological question. Most writers on this subject explain the origin of the ore deposits as we find them in the mines by very astute chemical and physical theories, in more or less plausible manner; and if in metallurgical processes we get occasional hints how some ores might have been formed, for instance, from the beautiful galena crystals in furnaces, these facts do not explain the peculiar, we might say seemingly capricious, arrangement of ore veins and ore deposits in general, nor their outcrops, outblows, and so on.

If we will not swear blindly *in verbum magistri*, *in dicta* of one of the accepted authorities, the theories and hypotheses hitherto advanced leave us in doubt. Shall we accept the lateral secretion theory, so ably defended by Sandberger, or the ascension theory advanced by many others, or shall we believe in filling of the veins from above?

Now I, for my part, think that there is a difference between authority and infallibility; and having stumbled accidentally on a new idea about certain ore veins, I shall lay this idea, and conclusions from it, synoptically before the Academy. Perusing many years ago a book printed in the year 1689, I found there, among other things, a chapter treating of alchemistic work, and in this chapter a passage which reads: "Dicis Glauberus quod crescunt calces metallorum in liquore silicum." This passage became the starting point of my experiments.

Some months later, working one evening in my laboratory, I dropped by accident a piece of sulfate of iron into a beaker containing a solution of silicate of soda. Next morning I found in this beaker a number of greenish gray strings about one millimeter thick, grown up to the surface of the liquid, spreading there and covering an irregular space of more than one centimer square. This part of the growth was of yellowish brown color, and fully three millimeters thick.

This recalled the above mentioned quotation to my mind. At the same time I perceived that this brown growth bore a remarkable resemblance to certain vein outcrops known as "Gossan," a Cornish name.

The analysis of the strings as well as of this gossan showed a silicate of iron; the strings contained the iron in the shape of protoxyd, the gossan as hydrated oxyd.

I charged now four test tubes with pieces of copperas and a 10 per cent solution of soda silicate, at a temperature of nearly 25° centigrade.

Two of the tubes I set aside. Two of them I submitted for 15 minutes to a heat of 90° C., and then let them cool down to the temperature of the air (25° C.).

After two hours I found there were grown in the two first mentioned tubes five sprouts. In one three, 3 and 7 millimenters long; in the other two, 6 and 11 millimeters long; all of them about 1 millimeter thick, nearly straight, their color greenish gray, faintly transparent.

The growth in the heated tubes was quite different in appearance. One of the tubes contained one sprout, which was crooked and knotty, about 4 centimeters long. Its thickness varied from 2 to 4 millimeters. From this trunk, which was of dark greenish brown color, thin smooth strings of slightly transparent greenish color were grown to lengths of 0.5 to 1 centimeter—their thickness about 1 millimeter.

The other tube had three shorter sprouts, equally knotty and crooked, besides a flat string running up 5 centimeters on the glass.

The first two tubes I set again aside; the two heated ones I put back into the water bath and kept them for about fifteen hours at temperatures between 50° and 60° C. After this time the growth in all the tubes had reached the surface of the liquid, and there formed considerable deposits of gossan.

The strings in the cool tubes were nearly straight and of uniform thickness from top to bottom, the strings in the heated tubes in their whole lengths irregularly bent, unequal in thickness, and of dark color. Two of the strings formed pockets of about 6 millimeters diameter, one of the pockets sending out two thin strings, the other as many as four.

These experiments self-evidently removed every doubt about the truth of Glauber's saying, at least as far as the growth of copperas in an alkaline solution of silica is concerned; though copperas is not exactly a calx in the language of alchemists.

According to experience, quartz must be counted among the best gangue matter; and since the peculiar growth in my test tubes, and also the artificial gossan, were very similar to certain ore veins and outcrops, I inferred therefrom that certain silicious lodes might be the result of such growth. I reasoned, though numerous, the existing hypotheses leave room for one more—maybe a bridge to some truth, maybe a trail leading into a swamp.

Holding this in view, I went on experimenting with various metal salts. Some of them grew more readily than iron; for instance, nitrate of cobalt, vanadium chloride; others not at all; others very slowly, for instance, sulfate of copper, of nickel, of uranium. Of the last one I got, after six months, a few sprouts, about 8 millimeters long and 2 to 3 millimeters thick. Six months later hardly any changes were perceptible. Most of the ore veins carry more or less iron with the other metals. The Cornish miner regards the gossan as one of the best indications, the Mexican trusts in his almagres, the South American prospector in his pacos and colorados, and the German in his eisernen Hut. So I added iron to the other metal salts, and after a few experiments I had the satisfaction of seeing that even refractory growers were carried on by the iron, and many of the free growers, if combined with iron, grew more rapidly, forming larger or smaller, richer and poorer pockets of the respective metal combination. These pockets sent out veins and veinlets of iron only, or of iron and the other metals; all, however, terminated invariably in an iron outcrop as soon as they reached the surface of the liquid.

I also found that most of my oldest veins began to be wrapped up in silicious deposits, which, if the tubes were kept filled with silicious solutions, filled by and by the whole tube, thus forming a miniature silicious gangue with ore veins and iron outcrop.

Up to this time I had observed that temperature, also light, had strong influence on the growth of my experimental veins, and I began now to introduce electrical currents into my experiments, which, as expected, caused interesting modifications, but in many cases not as far-reaching ones as I had anticipated. For this purpose I substituted ¾-inch glass tubes for the test tubes, of which I closed one end with corks soaked in paraffin, with pieces of copper or platinum wires inserted through the corks, in order to have conductors for the currents. Numerous experiments carried on for about three years I regarded a sufficiently strong foundation for a tenable hypothesis; and to secure the priority of the idea I hurried a short essay, "On the Genesis of Certain Ore Deposits," into the School of Mines Quarterly, No. 3, vol. XII.

The conclusions published there, based on the above-mentioned experiments, require some modifications on the strength of observations made on a number of more recent experiments, though I hold them tenable in principle.

After having worked with salts of most of the heavy metals, I began to experiment with alkalies and their salts, up to date without satisfactory results.

Of the salts of earth metals, I tried only sulfate of magnesia, resulting in a satisfactory growth. Lime salts, as far as tested till now, invariably gelatinized the silica, and I found a number of well developed azurite crystals in a test tube containing copper, silica solution and lime, after eight months.

Aluminum and alumina salts gave highly satisfactory results regarding their growth and their capacity to carry on with them other metal solutions, or to absorb them after the alumina vein is fully grown.

Now I introduced also gases into my work, and have experimented up to date with sulfurated hydrogen, chlorine and carbonic acid. I constructed for this purpose an inexpensive apparatus, by which the influx of gas or liquid saturated with gases can be reliably regulated.

But most of the veins are very delicate in their structure, and therefore easily destroyed by the commotion of the mother liquid, and it is in such cases important not to admit more gas than can easily be absorbed, though it may take a long time to change the character of a vein; in a tube two years old, the veinlets were only partly changed. Larger quantities of gas may be admitted if the object of the experiment is not so much to change the character of the vein, as to study the effect of the gases or liquids on the silica solution, which in these experiments must be regarded as the matrix, the material in which the veins will be formed.

So, for instance, will 3 cubic centimeters carbonic acid per minute, under slight pressure, forced into a test tube containing 8 to 10 cubic centimeters of silicate of soda solution gelatinize the silica in a few minutes, and then cut its way through the gelatinized mass, forming sinuous rows of larger and smaller cavities, partly connected with each other, partly isolated.

Similarly formed cavities on a larger scale are evidently the places in quartz where in the course of years, perhaps thousands of centuries, the ores, etc., had the opportunity of being deposited in crystalline or amorphous masses, thus forming pockets and druses so conspicuous in the Comstock lode and elsewhere, which are otherwise hard to explain.

But it would take too much time to enumerate all the experiments I made, and all the successful and adverse results which I had to book.

I compared the results with the phenomena observed at a number of mineral deposits, and I found they compared favorably.

I dare say every one here present is familiar with the Comstock lode and the Washoe district of Nevada, at least as far as the name goes. Bold as my assertion may seem, I think the processes going on in these little tubes may help to solve some of the most important problems we meet in the Comstock lode, and to explain them without unduly straining chemical and physical laws. The ore resources of the Comstock lode are at least quantitatively unparalleled. The country rock in which the immense fissure is rent does not hold the metals found in the lode, and never could have held the quantity of ore and gangue contained in the lode. Besides, a number of experiments I had made with reference to the lateral secretion theory and impregnations resulted all and every one against the hypothesis that ore veins might have derived their ore from the surrounding country rock. In every case the material surrounding the artificial fissure absorbed the metal solution contained in the fissure and got impregnated, even if there was considerable pressure on the absorbing material; and up to date I could not reverse the process, though the surrounding material was moderately coarse sand and contained the metal salts in solution, which no doubt justifies the conclusion that solid rock holds still more tenaciously metallic impregnations.

Sand was mixed with 2 per cent of carbonate of lime, and during the absorption of the copper sulfate solution the pressure of the carbonic acid on the absorbing sand was strong enough to loosen repeatedly the airtight paraffin capping; but in spite of this, in the course of eleven days the last trace of copper sulfate was in the sand, in the shape of copper carbonate. These two facts are against lateral secretion. A filling from above is out of the question, and we must consequently appeal to the ascension from greater depths to those accessible by mining.

This is also the opinion of J. T. Preiker, who, for the U. S. Geological

Survey, made an exhaustive examination of the Washoe district and its mines; but like von Richthofen he calls principally on fluorine as a solvent, and leaves it an open question, what finally became of all the fluorine? Every chemist knows its great affinity for nearly all the elements, and that not all the fluorine and chlorine combinations are readily volatilized. None of the rocks of the Washoe district analyzed by Woodward, Moore, Mixter, Güntzler, Korman, Johnson contained any fluorine, and it is very difficult to think that all the fluorine necessary to dissolve the immense quantity of material required to fill the Comstock fissure escaped in gaseous shape, where so many elements were present and ready for chemical union. If we, however, accept an alkaline solution of the silica by hot water, which solution, no doubt, was facilitated by great pressure, then the present combinations of the rocks and lodes (sound or decomposed) shows up all the elements of the rocks dissolved, and of the solvents. And since it can be demonstrated by experiments that in such alkaline solutions of silica most, if not all, acid metal salts grow freely in the shape of veins and veinlets, and form pockets in the experimental vessels till they reach the surface of the liquid, forming there deposits, and that these veins grown in the vessels have the faculty of absorbing the solutions of other metals brought in contact with them, it is more rational and more natural to presume that the veins grew up in alkaline silica solution, and were afterwards changed by heat, steam, liquids, gases, vapors, in short by such agents as are shown by the analysis, than to suppose a solution by chemical or other agencies of which we find no traces in the subsequent deposits and precipitations, not in the veins, not in the gangue, and not in the surrounding country rocks.

I admit an antecedent, simultaneous, or subsequent presence and action of gases. In the Comstock lode, more so nearer the surface than at greater depth, large ore deposits were struck in cavities in the quartz, the origin of which cavities can easily be accounted for if we accept an alkaline solution of silica.

A tube containing such an alkaline solution, gelatinized by carbonic acid gas, shows in miniature such cavities as you see on charts of the Comstock lode.

We can easily imagine that such cavities were subsequently filled by metal solutions and vapors which were directly formed or were subsequently changed into that shape in which they finally were mined.

There were ducts left by the gelatinizing gases in the gelatinized silica, which ducts, forming lines of least resistance, were the channels by which liquid solutions, gases, and vapors reached the cavities; or if ore strings, whose growth and absorptive faculty I demonstrated by experiment, had reached such cavities, they might have also been filled by those.

It would take too much time to investigate here what forces had caused the tremendous fissures, and all the possible and probable chemical, physical, and mechanical processes which were active in changing and rechanging the original combinations into others; therefore I confined myself to showing how these cavities in the quartz may have been formed and filled with nearly any kind of ore or mineral.

For the formation of the quartz gangue from an alkaline hydrous then gelatinized magma argues also the fact that the white color of the quartz, its opacity, is caused by microscopic cavities containing mostly carbonic acid, which is easily retained in a viscous gelatinized material, but not in a crystalline or amorphous precipitation to which Von Ruhshofen, Becker and others refer.

Becker mentions in his monograph on the Comstock lode the prevailing existence of the ore along the hanging wall, and the presence of clayey deposits there. Both these phenomena can be reproduced in vessels.

Alumina salts, like the salts of other metals, grow up in veins, only some of them quicker and more massy than others, which supports the conclusion that clayey deposits could be formed along the hanging wall before the veins of other metals were grown up; or we may also accept the possibility that the aluminous veins absorbed gradually the other metals, just as they did in my experiments.

Not to tax too severely your patience, I shall mention only a few more cases in which this particular mode of ascension can be applied, and these cases briefly.

At the Hazel mine, in Trans-Pecos Texas, the fissure is rent in a red sandstone, which is underlaid by granites, porphyritic rocks, and diabase. The rock surrounding the fissure holds no silver or copper, which are the ores of this mine. We have also here to abstract from the lateral secretion idea.

Considering also here the quantity of ore and the character of the vein in this mine, it is absurd to suppose that a fissure of an average width of 35 feet and of a traceable length of more than two miles, together with other parallel veins, was filled from ore deposits above like the one directly under the carboniferous limestone, which limestone holds no silver and no copper.

It is rather probable that this deposit was formed by a vein or veins grown up in fissures through the sandstone, terminating on its surface, and forming there the horizontal deposit.

A similar deposit here directly on crystalline igneous rock, I found in Mexico.

In Mies, Bohemia, the ore-bearing quartz gangues run up between barren clay slates, and are filled in a similar way by ascension.

In Transylvania, in the mountain Paren Dracubis, the lode is ore-bearing only where the gangue is silico-ferruginous.

The phenomena in many lodes of the French central mining district seem to point to an origin by ascension in the above mentioned modus, with subsequent alterations.

To be short, the unprejudiced observer may find many cases in nearly every mining district of the world where this peculiar ascension process may be admitted without laying a great strain on the well established laws of nature, and without risk of losing logical equilibrium.

The hypothesis that many, if not most, of the ore veins in silicious gangues are the result of the demonstrable growth of acid metal salts in alkaline silica solutions, by no means excludes circulating metal solutions, gases, metallic vapors, etc. It admits also, but only locally, lateral secretion, but it helps to explain phenomena which without this hypothesis can be explained only by straining to the utmost chemical, physical, and mechanical laws.

These veins may grow up in the middle of the gangue or along the walls, or that they meander from wall to wall; the hypothesis explains the irregularities in shape, size, and contents of vein and gangue matter, the growth of pockets and of horizontal and inclined deposits (lager), and that the veins invariably terminate in iron cappings or gossan on the surface if iron is present, even if the veins themselves contain only little iron.

We will have to call for the assistance of circulating solutions, of gases and vapors to explain chemical changes, and we may admit lateral secretion locally where the capillary force to absorb is stronger in the gangue than in the surrounding rock, or where elements and elementary combinations may be forced by chemical affinity to combine with those contained in gangues and veins.

If, and how far, continued experiments will throw light on the genesis of other than quartz gangues and on the origin of certain dykes, is hard to predict; but I think I should mention here the copper deposits of Chessy and Saint Bré, near Lyons, in France. The copper ores of the mine, grise and noir there, are imbedded in a whitish-gray gangue, partly changing into aphanite. The ore bodies are rounded masses, recalling the cavities in the quartz of the Comstock lode. The gangue is a wedge between other crystalline rocks and triassic sandstone.

At present I shall venture to uphold only the following conclusions:

1. It is a property of most, if not all, salts of the heavy and earth metals, and more so of combinations of these salts, to grow up in alkaline silica solutions, and to form in them veins, veinlets, pockets, and other shaped deposits, and thus were brought up from greater to (by mining) accessible depths the ores in most of the silicious gangues.

2. In most of the silicious gangues carrying iron with other metals,

the iron grew up in and with the veins, and reaching towards the surface formed the outcrops known by the name of gossan, almagres, eiserner Hut, etc.

3. The fissures could be charged with veins in comparatively short time, since under the influence of heat and galvanic currents the growth of most of the metal salts is a very rapid one.

4. Ore-bearing and barren quartz gangues are mostly not the product of igneous eruptions, but were formed from aqueous solutions in which the silica was gelatinized by acid gases, vapors or fluids. This explains the existence of larger and smaller ore pockets in cavities in the quartz formed by the ascending gelatinizing gases and filled by the growth of metal salts or by metallic vapors and solutions. It accounts also for the innumerable microscopic and larger cavities filled with gases and liquids, which hardly could have been retained in crystalline or amorphous precipitations.

5. Indisputable igneous phenomena in such silicious gangues are the result of subsequent igneous action.

6. Alterations of the rocks next to such silicious gangues are not necessarily the result of igneous action, but can be caused by leaching as well as impregnation from the gangue.

7. The formation of banded agates does not always take place in rock cavities by osmosis, but can also take place free in solutions, the growth progressing from a center outwards.

ON THE BIO-GEOGRAPHY OF MEXICO, TEXAS, NEW MEXICO, AND ARIZONA,

WITH SPECIAL REFERENCE TO THE LIMITS OF THE LIFE AREAS, AND A PROVISIONAL SYNOPSIS OF THE BIO-GEOGRAPHIC DIVISIONS OF AMERICA.

BY C. H. TYLER TOWNSEND.

During the past five years I have enjoyed the good fortune of having constant and abundant opportunities for making observations on the features and boundaries of the life areas in various districts throughout what is now known by Dr. Merriam as the *Lower Sonoran*, in Mexico, New Mexico, Arizona, and Texas; the *Upper Sonoran* and *Transition* to the north, in New Mexico and Arizona; and the *Tropical* to the south, in Mexico and the West Indies. This paper is intended to record the more important of these observations, with the view of aiding in the solution of the difficult problem of the proper boundaries between these areas. It is well understood that the flora of these regions is of great importance in arriving at a correct sense of their limits. Further than this, the possibilities of the flora in an economic or agricultural sense are of prime importance. This paper therefore takes into consideration all pertinent observations on the flora, both introduced and native. In fact, it should be stated here that the native and economic flora and the meteorology of the regions have been made large use of, in defining the limits of the life areas. It must also be stated that I have paid especial attention to the distribution of the insect fauna in the above mentioned areas, and that any available conclusions to be drawn therefrom are made use of, as well as significant facts relating to the vertebrate fauna. For a clearer understanding of these remarks, the reader is asked to compare them with Dr. Merriam's admirable maps of the life areas of North America. (Second and third Provisional Bio-geographic Maps of North America. Washington: March, 1892, and December, 1893.) I wish only to add that, unless otherwise noted, I have personally visited all of the localities regarding which statements occur in the text, and thus speak directly from my own observations. A considerable part of the observations on Mexico, and most of those on Texas, were made inci-centally while engaged in the field under the Entomological Division of the U. S. Department of Agriculture, in the fall of 1894, and spring and summer of 1895.

In the Report of the Department of Agriculture for 1893, pp. 228, 229, Dr. Merriam writes as follows, except that I have substituted his later nomenclature of the zones (Nat. Geog. Mag., 1894):

"The number of life zones that have been defined in this country north of the tropical is six. They may be grouped under two heads: Northern or *Boreal* and southern or *Austral*. In Eastern North America these zones may be briefly characterized as follows, beginning at the north:

"(1) *Arctic or Arctic-Alpine Zone*, above the limit of tree growth; characterized by the arctic poppy, dwarf willow, saxifrages, gentians, and many other plants, and by the snow bunting, snowy owl, white ptarmigan, polar bear, arctic fox, and barren-ground caribou or reindeer. This zone is of no agricultural importance.

"(2) *Hudsonian Zone*, comprising the northern or higher parts of the great transcontinental coniferous forest—a forest of spruces and furs stretching from Labrador to Alaska. Among the numerous inhabitants of that zone are the wolverine, woodland caribou, moose, great northern shrike, pine bullfinch, crossbills, white-crowned sparrow, and fox sparrow. Like the last this zone is of no agricultural importance.

"(3) *Canadian Zone*, comprising the southern or lower part of the great transcontinental coniferous forest, and inhabited by the porcupine, varying hare, red squirrel, white-throated sparrow, yellow-rumped warbler, and numerous others. Counting from the north, this zone is the first of any agricultural consequence. Here white potatoes, turnips, beets, the Oldberg apple, and the more hardy cereals may be cultivated with moderate success.

"(4) *Transition Zone*, or belt in which the outlying Boreal and Austral elements overlap. Here the oak, hickory, chestnut, and walnut of the south meet the maple, beech, birch, and hemlock of the north. The same is true of mammals and birds, for here the southern mole and cottontail rabbit, the oriole, bluebird, catbird, thrasher, chewink, and wood thrush live in or near the haunts of the hermit and Wilson's thrushes, solitary vireo, bobolink, red squirrel, jumping mouse, chipmunk, and star-nosed mole. In this zone we enter the true agricultural part of our country; here the apple (Oldberg, Baldwin, Greening, Seek-no-further, and others), the blue plums, cherry, white potato, barley, and oats attain their highest perfection.

"(5) *Upper Austral Zone*, where the sassafras, tulip tree, hackberry, sweet gum, and persimmon first make their appearance, together with the opossum, gray fox, fox squirrels, cardinal bird, Carolina wren, tufted tit, yellow-breasted chat, and gnatcatcher. In this zone the Ben

Davis and wine-sap apples, the peach, apricot, quince, sweet potato, tobacco, and the hardier grapes, such as the Concord, Catawba, and Isabella, reach their best condition.

"(6) *Lower Austral Zone*, where the long-leaved pine, magnolia, and live oak are common on the uplands and the bald cypress and cane in the swamps. Here the mockingbird, painted bunting, red-cockaded woodpecker, and the chuck-wills-widow are characteristic birds, and the cotton rats, rice field rats, wood rats, little spotted skunks, and freetailed bats abound. This is the zone of the cotton plant, sugar cane, rice, pecan, and peanut; of the oriental pears (LeConte and Kieffer), the scuppernong grape, and of the citrus fruits—the orange, lemon, lime, and shaddock. In its western portion (the Lower Sonoran) the raisin grape, olive, and almond are among the most important agricultural products, and the fig ripens several crops each year.

"Still further south is the *Tropical* region, which, in the United States, is restricted to southern Florida and extreme southeast Texas, along the lower Rio Grande and Gulf coast. Among the tropical trees that grow in southern Florida are the royal palm, Jamaica dogwood, machineel, mahogany, and mangrove; and among the birds may be mentioned the white-crowned pigeon, Zanaida dove, quail doves, Bahama vireo, Bahama honey-creeper, and caracara eagle. The banana, cocoanut, date palm, pineapple, mango, and cherimoyer thrive in this belt."

It should be stated that Dr. Merriam has since added to the *Tropical* a third district in the U. S., the lower Colorado river valley (Nat. Geog. Mag., 1894).

It will be understood that, from the part of the country treated in this paper, we have to do with in the main, with the exception of the *Boreal* and *Tropical* regions, only the arid portions of North America. By arid is meant those portions west of the 97th to the 100th meridian, where rains are rare, infrequent, or irregular; in other words, where normal humidity ceases and rains can not be depended upon for agricultural purposes, thus necessitating the employment of irrigation for the raising of crops.

Referring again to Dr. Merriam's zones, as quoted with descriptive details above, I would substitute the following defining elements in the economic and native flora. It must be borne in mind that Dr. Merriam's data refer particularly to Eastern or humid North America, while the following refer particularly to Western (or mostly arid) North America; but there should be no differences between the east and the west in ordinary crops and fruits, sensible temperatures being equal, except with those naturally adapted to an arid region, and all those mentioned above by Dr. Merriam for the humid region do equally well and often better in the arid region under irrigation.

(1) *Arctic or Arctic-Alpine Zone.* Above the limit of tree growth.

(2) *Hudsonian Zone.* Characterized by forests of spruce (*Picea* spp.). In the *Hudsonian Alpine* zone of the mountains of Arizona and New Mexico, the species of spruce is *Picea engelmanni*, and there occurs mixed with it the fox-tail pine, *Pinus aristata.*.

(3) *Canadian Zone.* Forests of Douglas fir, *Pseudotsuga douglasii*, interspersed with aspen, *Populus tremuloides.* In the *Canadian Alpine* zone of the Rocky Mountains, *Pinus flexilis macrocarpa* also occurs with the fir and aspen. White potatoes, turnips, beets, and hardy cereals do moderately well.

(4) *Arid Transition Zone.* Characterized by *Pinus ponderosa* or yellow pine above, and *Pinus edulis* (piñon or nut pine), and *Juniperus* spp. (juniper or so-called cedar) below. Certain oaks occur sparingly and locally with the yellow pine, as *Quercus undulatus gambellii* and other species; below with the piñon and cedar there occurs the more southern form of the mountain mahogany, *Cercocarpus paroifolius*, while a somewhat hardier species, *C. ledifolius*, is more characteristic of the yellow pine belt.

The apple (Oldberg, Greening, etc.), cherry, white potato, barley, and oats attain highest perfection. Plums grow and fruit.

(5) *Upper Sonoran Zone.* Characterized in a general way by *Sarcobatus*, *Atriplex*, *Dasylirion*, *Robinia neomexicana*, *Fallugia paradoxa*, *Celtis occidentalis*, *Quercus undulata wrightii*, and *Agave heteracantha* and *parryi* above; with scrub mesquite (*P. juliflora*), *Yucca augustifolia* and *baccata*, *Echinocactus*. *Ephedra*, *Opuntia*, *Larrea tridentata*, *Krameria*, *Zizyphus*, and *Fonquiera splendens* on lower mesas; and *Populus fremontii wislizeni*, *Salix*, *Prosopis pubescens*, etc., in river valleys. It must be stated that these data refer most particularly to the southern half of New Mexico, western Texas, and northern Chihuahua, and that the distribution of these plants may in some cases be somewhat different in other places.

Here the Ben Davis and wine-sap apples, pear, peach, apricot, quince, sweet potato, and grape (Concord, Catawba, Isabella, Mission, etc.), attain highest perfection, especially in the lower portions. Plums do exceeding well. Cotton will grow fairly well from seed in certain localities in the lower portions, as in the Mesilla valley, but it would be an uncertain crop at best, on account of early and late frosts.

(6) *Lower Sonoran Zone.* Here we have the tree yuccas, *Y. arborescens*, *Y. filifera*, larger specimens of *Y. australis*, and *Y. treculeana;* tree cacti, *Opuntias* of various species which attain an immense growth; and the mesquite (*P. juliflora*) attains tree-like dimensions.

The date palm, orange, lemon, lime, olive, pomegranate, cotton, sugar cane, raisin grape, almond, fig, and maguey (*Agave americana*) reach highest perfection. Bananas and plantains grow, but do not fruit well. Tobacco attains best quality for manufacture of smoking and plug brands (as with Virginia tobacco of the corresponding eastern region). On the north the limit of the date palm and the limit of the Lower Sonoran zone are nearly or quite identical.

(7) *Tropical Zone.* Here grow the mangrove, mahogany, royal palm, (*Oreodoxa regia*), orchids, and hosts of brilliantly-flowering trees, plants and shrubs, forming a luxuriant vegetation, such as is only to be found in a low, moist, and very warm country, which frost never reaches.

The cocoanut palm, banana, mango, guava, pineapple, sapote, papaw, custard apple, etc., attain highest perfection. The date palm, sugar cane, orange, etc., grow well. Coffee attains highest perfection at 2000 to 4000 feet above sea. Tobacco attains best quality for manufacture of cigars (as witness the Vera Cruz and Havana tobacco). The northern limit of the cocoanut palm and the northern sea-coast limit of the *Tropical* zone are identical.

It has already been hinted that some of the above native desert plants named as characteristic of the *Upper* and *Lower Sonoran* vary locally somewhat in their distribution. The data under these heads must be taken as a whole, and in a general way. For instance, as conclusively shown by Dr. Merriam's admirable work, the Mohave Desert region, although covered with *Larrea tridentata*, is to be considered as *Lower Sonoran.* In New Mexico, and south on the Mexican plateau, *Larrea tridentata* is characteristic of lower levels of the *Upper Sonoran.* In the region around the Mohave Desert, Dr. Merriam has made full investigations of the limits of the tree yucca, *Y. arborescens*, showing, as he points out, that this plant there marks the upper limit of the *Lower Sonoran.* It also invades the *Upper Sonoran* more or less, and is even in places found in company with junipers, which latter suggests that either the *Upper Sonoran* fades out in such places, or the juniper has a different distribution from that shown in New Mexico and invades the *Upper Sonoran* from above. Such local intricacies, variances, and disturbing elements of distribution need careful study over the whole country, before their meaning can be made out. They will be found largely dependent upon meteorologic and soil conditions, no doubt.

I will now apply the above and other data to the elucidation in detail of the boundaries and outlying portions of these life areas in the region mentioned in the title, beginning at the north.

TRANSITION AND BOREAL.

New Mexico and Arizona.—*Rio Grande Valley to Continental Divide of New Mexico and Grand Canon of the Colorado.* In the summer of 1892, I made a trip across the country from Las Cruces, in the Mesilla

Valley of the Rio Grande, to the Grand Cañon of the Colorado river in northern Arizona, the itinerary of which was as follows: Las Cruces northwestward to Rincon and Hatch, then north to Las Palomos, following the Rio Grande Valley all the way, then across the mesa northwest to Cuchilla Negra, west of north to Cañada Alamosa, up the Cañada and out on to the elevated plain at Ojo Caliente; north to Horse Camp and Seboy Horse Ranch, west to Horse Spring and Patterson; then west across the Continental Divide, north of west to Gallo and Apache Springs, generally west through the mountains down into Johnson's Basin (N. M.), Pratt's Ranch (Ariz. line), Coyote Spring, and Springerville (Ariz.); northwest to Concho, Woodruff, Holbrook, Winslow, and the San Francisco wash (north of Cañon Diablo), following the Colorado Chiquito all the way from a little below Concho; south of west to Turkey Tanks and Flagstaff, then west of north to A1 Ranch, Hart Little Spring, Cedar Ranch, and the Grand Cañon at Hance's, and down into the cañon to the Colorado river. Returning, the same route was retraced as far as Holbrook, with a side trip from Hart Little Spring to the summit of San Francisco mountain, then from Holbrook northeast to Carrizo, Billings, and Navajo Springs; following the railroad and the Rio Puerco of the west, and visiting Chalcedony Park on the way; from Navajo Springs to Zuni, by way of the Squaw Spring, Wabash Ranch Headquarters, G Bar Ranch, and the Zuni river; then east to Ramah, Inscription Rock, Tenaja, across the Continental Divide and down through the mountains to Grant; south of east along the railroad to Los Lunas in the Rio Grande Valley; and then following the Rio Grande down to Las Cruces, only leaving its valley to cross the Jornado del Muerto.

The *Transition* was encountered on this trip at the following places: First between Horse Spring and Patterson, on the hills crossed; next on the summits of the hills and ridges to the west of Patterson, 6 miles west on the road from Patterson bringing one to the crest of the Continental Divide, at an elevation of over 7000 feet. Here the *Transition* is well marked, but disappears as the road descends. Then the road goes up over a large bare *mal pais* hill, and descends to Gallo Spring. Getting into the mountains to the southwest and west of here, and striking the Rio Tularosa, the *Transition* obtains throughout except in the bottoms of the lower cañadas or water courses. It continues until the road winds down through the mountains and runs out into the beautiful valley known as Johnson's Basin. The higher portions of all the mountains in sight from this valley, which surround it completely, are *Transition*, and after passing Gatlin's Ranch near the end of the valley, we again enter the *Transition* at Manguitos Spring. From here westward to where the road goes down the frightfully steep hill to the Mormon settlement of Luna, it is *Transition* in all except the lower valleys, until the Arizona line is reached at Pratt's Ranch. Beyond here patches of *Transition* occur all the way to Coyote Spring and beyond, being strongly marked for some distance before the latter place. It is left on descending into the valley at Springerville, which is on the headwaters of the Colorado Chiquito. It does not reappear on the road now until within some ten miles of Turkey Tanks, where it sets in for good and continues all the way to Flagstaff. It also continues all the way from Flagstaff to Hance's (Cañon Springs), except for about ten miles to the north of Cedar Ranch, where the road crosses an arm of the *Upper Sonoran* running in from the Painted Desert of the Colorado Chiquito to the east. In this San Francisco Mountain region there are of course characteristic and true *Boreal* zones on the higher slopes, while a slight *Boreal* element invades the *Transition* in places.

I insert here the following diagnosis indicating the interpretation I put upon the seven zones which Dr. Merriam has defined in the San Francisco Mountain region and Desert of the Little Colorado (N. Am. Fauna, No. 3, 1890):

Zones.	*Dr. Merriam's Belts.*
Arctic Alpine	1. Arctic Alpine.
Hudsonian Alpine	2. Subalpine or Timberline. 3. Hudsonian or Spruce.
Canadian Alpine	4. Canadian or Balsam Fir.
Transition	5. Neutral or Pine. 6. Piñon.
Upper Sonoran	7. Desert Area.

In the Grand Cañon, at Hance's, the *Transition* extends down from the top of the east rim (7500 feet above the sea) for about 1500 vertical feet, or to a point about 6000 feet above sea, differing according to slope exposure. Above this on the edge of the rim, when a north or northeast exposure obtains, there occurs a trace of the *Boreal.*

Retracing the line to Holbrook, the remainder of the return was by another route. The first *Transition* is met with between Squaw Spring and the Wabash Ranch Headquarters, or west-southwest of Jacobs' Well. The next is on the high hills and plateaus east of Zuni, being well marked on the hills at Ramah. It continues to Inscription Rock, except in the lower open plains, and covers the top of El Moro (Inscription Rock) itself, as well as the tops of the many similar high sandstone cliffs of that picturesque region. It is entered in earnest at Tenaja, where the road goes into the mountains, crossing the crest of the Continental Divide and going down the east slope, and disappears on reaching the *mal pais* or black lava plain which stretches eastward. The last seen of it was in the distance on the slopes of Mt. Taylor.

Gila Headwaters and Black Range Mountains in New Mexico.—In the summer of 1894, a trip was undertaken from Las Cruces to the falls of the West Fork of the Gila headwaters, in southwestern New Mexico. The itinerary was as follows: From the Rio Grande valley westward to Florida station, by way of Picacho, the Lineas (a range of low hills), Mason's Ranch, the Madelina Mountains, and Carpenter's Wells. Then northwest to Hadley and Cook's Peak, west to the Rio Mimbres, up the Mimbres valley in a general northerly direction to Mimbres Mill, with a side trip from latter west through mountains to Georgetown; from Mimbres Mill still up the Mimbres valley to a ranch some ten miles up, where valley forks. Here the main valley was left, and turning northwest the divide between the Mimbres and Rio Sapillo was crossed, and the valley of the latter followed nearly west to Hill's Ranch on the Sapillo; then northwest over the mountain and down a most formidable road into the valley or cañon of the Gila, and on up to Gila Hot Springs (or Hill's Ranch on the Gila). From here north to the confluence of the West Fork, and then northwest up this fork to the falls of the West Fork. Returning to Gila Hot Spings, an entirely different and, as it proved, better road was taken back, going up the East Fork of the Gila in a general northeasterly direction to the DD Bar Ranch; then northward above here, climbing a tongue of land where the cañon forks, and through mountains up and down hill, coming out into a beautiful level basin or plain, at the head of which the V Cross T Ranch is reached. From here eastward, climbing at once into the Black Range Mountains, crossing the Continental Divide, and then going down into Corduroy Cañon. Following up Corduroy Cañon north to its end, where it opens out on the plain in two long draws, the eastern draw was followed about two miles, when a northeasterly course was taken over hills and through vales, up and down, until about twenty-five miles further on we emerge from the mountains and later reach Fairview. From Fairview southeast to Willow Spring and Cuchilla Negra, east to the Rio Grande valley, across the latter and on to Engle; then south along the railroad to Las Cruces, except to cross the Jornada del Muerto from Upham to Leasburg.

During this trip, the *Transition* was encountered at the following points: A touch of it on higher portions of Coop's Peak, and on hills around Georgetown; it was struck in earnest on the divide between the Mimbres and Sapillo valleys, and continued down the sides nearly to the bottom of the cañon of the Gila. It covers all the country up the West Fork of the Gila, except the bed of the cañon as far up as the falls. Above the falls, the whole is *Transition.* The *Boreal* is quite well marked on the higher portions of this upper West Fork country, and *Ursus* occurs commonly, as it does also up the Middle Fork. *Cariacus virginianus* and *C. macrotis* both occur here on the West Fork, also *Meleagris mexicana*, and the stream is full of mountain trout (*Salmo* 2 spp). Below the

Gila Hot Springs, and from there up the East Fork the *Transition* obtains on the crests of the hills and ridges. It does not extend so far down the sides of the cañon in the East Fork as in the West Fork. For about five miles before reaching the D D Bar ranch, the country is more open and the *Transition* nearly or quite disappears.

Above there it stretches from the Tongue of Land to the basin of the V Cross T Ranch. Then immediately to the east of this ranch, it begins abruptly in the steep sides of the Black Range Mountains, and continues down Corduroy Cañon to its outlet upon the plain. It is entered again on climbing the hill or ridge about two miles up the east draw on the left hand side, and here in July, 1894, was one of the most beautiful stretches of country that I ever remember seeing. The rolling, park-like country was carpeted with newly grown green grass about two inches long, and looked like a well kept lawn, while graceful pines stood here and there or congregated in clumps. The *Transition* continues now until shortly before reaching Fairview. Immediately beyond the last named place it is crossed again in a not very high range of mountains, and again left on entering the plain below. The last seen of it is on the spurs of the latter mountains. There is little or no trace of the *Boreal* in the Black Range where we crossed.

Organ Mountains, New Mexico.—In *Science* for December 8, 1893, pp. 313-315, I outlined five very well marked vertical life belts in the flora of the region, which occur between the Rio Grande at Mesilla, N. M., and the peaks of the Organ Mountains about fifteen miles to the eastward. Of these, as there defined, the two called "juniper or cedar" and "pine" represent the *Transition*, with a touch of the *Boreal.* The "pine" belt, as there described, should be split into "Pine belt," 7500 to 8000 feet (west and south slopes), with *Pinus ponderosa* as characteristic; and "Fir belt," 8000 feet, and over, with *Pseudotsuga douglasii* as almost sole representative. Of the plants mentioned on northeast slope, Nos. 13 (*P. edulis*) to 15 inclusive, 6200 to 7000 feet, belong to Juniper belt; and 16 to 17, 7000 feet (top of ridge), to Pine belt.

The tops of the peaks (8800 feet) are bare rock, with no soil for five to eight hundred feet. Not only does the Douglas fir on the highest ridges and slopes indicate the presence of the *Boreal*, but this is borne out by the former occurrence of the mammalian genera *Ursus* and *Ovis.*

Various Localities in New Mexico.—The San Andres Mountains, stretching northward from the north end of the Organs, have the *Transition* on their higher portions. It is a low range.

The Sacramento Mountains, across the San Augustine plain northeast from the Organs, have the *Transition* well marked, with also a good touch of the *Boreal.* *Ursus* abounds, and deer, trout, and turkeys are plentiful. The same may be said of the White Mountain, or Sierra Blanca, which lies north from the Sacramento, and on which the *Boreal* is quite strongly marked.

The Florida Mountains, southeast from Deming, show the *Transition* on their higher portions.

The Potrillos or Colt Mountains, south from Afton on the Southern Pacific Railroad, and near the Mexican line, show only a touch of the *Transition*, and the same may be said of the Madelinas, west from Mason's Ranch. The Doña Anas, north from Las Cruces, show likewise but a faint trace on their highest portions.

The Sandia Mountains, east of Albuquerque, possess a well marked *Transition*, and likewise a well marked *Boreal* showing the *Canadian* and *Hudsonian* zones.

MEXICO.—The *Transition* extends throughout the Sierra Madre Mountains, in the States of Sonora, Chihuahua, and south into Durango about as far as latitude 24° or 25°. The Sierra Madre is a broad plateau from 6000 to 9000 feet above the sea. The *Boreal* obtains on the crests and summits, a number of which rise to 10,000 feet and over. Though I have seen these mountains both from the east and from the west, I have never penetrated them.

There are reported to exist in the northern portions of the Sierra Madre dense, unbroken coniferous forests of great extent. In these *Ursus* abounds, and the streams contain mountain trout. Deer and mountain lion abound throughout the Sierra Madre. Some of the portions of the plateau are said by Schwatka to rise to 12,000 or even 15,000 feet (La Sierra de los Ojitos). This, however, needs verification, as Schwatka's information may have been unreliable. The writings of Lumholtz, Remington, and Schwatka may be read with interest in this connection.

The Sonora Railway line passes through *Transition* in northern Sonora, just south of Nogales, Arizona.

The only other *Transition* in Mexico known to me is that in the vicinity of the high volcanoes of the southeastern and southern portions of the plateau region. The highest of these are Orizaba or Citlaltcpetl (about 18,000 ft.), Popocatepetl (17,800 ft.), Ixtaccihuatl (16,705 ft.), Toluca (about 16,000 ft.), Malintzi (15,840 ft.), Cofre de Perote (13,403 ft.), and El Pinal (11,220 ft.). On all of these peaks except the last the *Boreal* in all its zones is well marked above the *Transition*. In the neighborhood of Ozumba and Amecameca the Interoceanic Railway actually passes through firs, which indicate a touch of the *Boreal* even this low down, about 9000 feet or lower. This is just west of Popocatapetl. There is probably, therefore, considerable of the *Boreal* on El Pinal as well, and also on the other peaks to be mentioned presently. In the region comprised between Orizaba, Perote, and Malintzi there is much of the *Transition* in the higher portions. It extends over the crests of the outlying spurs and ridges in most of the region around all the volcanoes above named.

Other lower peaks to the west, in the lower southwestern limits of the plateau and mostly on the Pacific slope, all over 10,000 feet, are Nevada de Colima (12,728 ft.), Patamban (12,290 ft.), Zampoaltepetl (12,100 ft.), Ajusco (11,800 ft.), Colima (11,140 ft.), Quinceo (10,895 ft.), Gigante (10,653 ft.), Las Llanitos (10,113 ft.), etc. These peaks I have not visited, but they have a well-marked *Transition* undoubtedly, together with a touch of the *Boreal.* Colima is stated to be snow-clad in winter, but not in summer.

TEXAS.—The only *Transition* in this State is in the Guadalupe, Limpia, Chisos, and Eagle mountain ranges of Western Texas; on the higher ridges and bluffs of the Great Bend of the Rio Grande as far north as the Southern Pacific Railroad, on the forks of the Nueces river, and along the edges of the high plateau known as the Llano Estacado or Staked Plain. These touches of the *Transition* are borne out by the well marked occurrence of *Pinus ponderosa*, *P. edulis*, and *Juniperus* (exclusive of *J. conjungens*). *Pinus ponderosa* and *P. flexilis* occur in the Guadalupe and Limpia Mountains. *P. edulis* occupies the Chisos Mountains exclusively. The *Boreal* touches but one locality in the State, the heights of the Guadalupe Mountains, as attested by the presence of *Pseudotsuga douglasii.* There is only a faint touch of *Transition* on the Chinate Mountains, thin clumps of *P. edulis* occurring on their northern face. These statements are based on facts obtained from Havard (Proc. U. S. Nat. Museum, 1885, vol. 8, pp. 492 and 503).

Guadalupe Peak, the highest in Texas, is about 900 feet above sea. Limpia Peak and the dome of the Chinates are 500 to 800 feet lower, and the Chisos Mountains are still lower. These mountains all lie west of the Pecos river, between the latter and the Rio Grande.

UPPER SONORAN.

NEW MEXICO AND ARIZONA.—*Grand Canon and Gila Routes.*—On the routes already described from Las Cruces, N. M., to the Grand Cañon and return, and to the headwaters of the Gila and return, all portions not mentioned as *Transition* (or *Boreal*) are considered by me as *Upper Sonoran*, only excepting that within the Grand Cañon of the Colorado river below 4500 feet.

In a paper read before the New Mexico Society for the Advancement of Science, November 3, 1892, I provisionally referred to the portion of the Grand Cañon, along the Hance trail, below the *Transition*, or in other words, below 6000 feet elevation, as the "subdesert" belt (4500 to 6000 feet), and the "Gila" belt (2500 to 4500 feet). (See American Naturalist, 1893, p. —.) The zone there called "subdesert," I consider *Upper Sonoran.*

Mesilla Valley.—The Mesilla Valley of the Rio Grande is about forty miles long from north to south, and has an average width of four or five miles. It extends from the vicinity of the town of Doña Ana to within a few miles of El Paso, thus reaching into Texas territory in its southern extent on the east side of the river. This valley is emphatically claimed by Dr. Merriam, according to his maps, to be *Lower Sonoran*, and unscientific people often assert it to be "semi-tropical." I am perfectly convinced, however, that it is to be considered wholly *Upper Sonoran.* Some few *Lower Sonoran* forms may reach it from below by following up the river valley, but they are not numerous enough to give it a decided tinge of that fauna. Date palms can not flourish here, even though protected through the winter, as has been proved by some sent by the Department of Agriculture to Las Cruces in 1889. Some of these are still alive, having been carefully bound up and protected every winter, but they grow smaller and become stunted rather than larger, and left unprotected in the winter would speedily die from frost. At least one fall of snow occurs every winter as a rule. Oranges are out of the question, as well as all sub-tropical fruits. Cotton will not grow to best advantage. On the other hand, grapes (except the raisin grape) and peaches attain greatest perfection. Every character points distinctly to this region as *Upper Sonoran.* While *Larrea tridentata* grows on the mesas of this region, and even farther north, its distribution in southern New Mexico, as has been hinted, is different from what it is in southern California. It can not therefore be taken as a criterion of Californian conditions in the New Mexico region.

Organ Mountains.—In the article in *Science*, already referred to under this head, the belts there called "Dasylirion or Scrub Oak," "Mesquite," "Tornillo or Cottonwood," ranging from about 6800 ft. down to 3500 ft., all belong to the *Upper Sonoran.*

Other Localities.—All portions of New Mexico below the *Transition* are *Upper Sonoran.* The same may be said of the southeastern and northeastern corners of Arizona and the east central portion. The latter is, however, mostly *Transition* and *Boreal.* Thus New Mexico possesses within its confines only five life-zones: *Arctic*, *Hudsonian*, *Canadian* (the true *Boreal*), *Transition* and *Upper Sonoran.*

The antelope and prairie dog are more or less characteristic of the *Upper Sonoran.*

Mexico.—A more or less well defined zone of *Upper Sonoran* extends around and throughout the Sierra Madres below the *Transition.* It extends lower on the eastern side, going down on the plain and including the whole region around and far to the eastward of Chihuahua City. It becomes diluted in southern Chihuahua State. At Santa Rosalia Hot Springs fine peaches and grapes are raised. Cotton is also grown, but the characteristics of the neighborhood are mostly *Upper Sonoran*. At Chihuahua City fine grapes and peaches are raised. Date palms can not grow, and orange trees left exposed through the winter perish.

In Sonora, that portion northeast of San Ignacio is mostly *Upper Sonoran*. At San Ignacio peaches yield extraordinarily, and side by side with them oranges grow and yield well. Pomegranates and figs yield abundantly, but grapes do not. To the south of here six miles large date palms may be seen in Magdalena. This San Ignacio region is therefore distinctly *Lower Sonoran*, but it combines also the characteristics of the *Upper Sonoran* to a certain extent, and thus shows the meeting of the two zones.

Following the line of the Mexican Central Railway south from Chihauhua State, we enter the distinct *Upper Sonoran* in the hilly region around Zacatecas; and again, much farther south, around Leña station, which is south of San Juan del Rio and is the highest point on the line, being 8133 feet elevation.

The *Upper Sonoran* runs southward from northern Mexico in a long, ramifying, tongue-like prolongation, widened at first, continuing down the highest part of the plateau. Its first great narrowing is to be observed between Aguas Calientes and San Luis Potosi, from about La Honda to Solana stations. As it widens northward from here, its eastern boundary line goes nearly north, but its western line goes northwest. Southward it extends on the higher portions in branches to the lofty volcanic regions terminating the southeastern and southern ends of the plateau proper. This tongue is partially bisected by the *Lower Sonoran* in the latitude of Torreon, one of the greatest cotton producing regions of Mexico, as here occurs a low east and west stretch across the tableland, somewhat paralleled by the one occurring at El Paso. Saltillo is included in the tongue on the east, where an inferior variety of apple is raised.

Texas.—In Texas the *Upper Sonoran* occurs pretty well throughout the western portion, except for the little *Transition*. It extends down the Rio Grande to near the mouth of the Pecos, leaving a wide area of *Lower Sonoran* in the lower valley of the Pecos, which narrows rather rapidly northward and extends about two-thirds of the way up to Pecos City. The lower boundary of the *Upper Sonoran* then extends east from the Pecos about two-thirds of the way to San Antonio, when its eastern boundary extends irregularly north, filling out the whole Panhandle of Texas, otherwise called the Llano Estacado or Staked Plains. Its eastern boundary here is very irregular, on account of being cut into by the cañons of the headwaters of various Texan rivers and their tributaries. In the south it is prolonged farther to the eastward than in the north, and conforms here pretty closely to the 2000 feet contour line.

LOWER SONORAN.

ARIZONA.—I do not consider that there is any actual *Lower Sonoran* whatever in New Mexico, that can be classed as such. In Arizona this zone follows rather broadly the valley of the Colorado river up to southern Nevada. Here it gradually narrows and finally becomes confined to the bed of the cañon, extending up in a dilute condition as far as the mouth of the Colorado Chiquito and into Marble Cañon. It also extends up the cañon of the Colorado Chiquito, and embraces to a greater or less extent the lowest parts of the Painted Desert contiguous thereto.

In the paper on the Grand Cañon already referred to, the belt called "Gila" (2500 to 4500 feet) is dilute *Lower Sonoran.*

The *Lower Sonoran* also very broadly follows the Gila up to a point well above Phœnix and Florence, spreading out in its lower course to join the *Lower Sonoran* of the lower Colorado valley, which on the other side of that river extends into the Mohave region and still farther westward into Central California. Farther up the Gila and its confluents, the *Lower Sonoran* narrows and is then confined to the lowest parts of the valleys or cañons, but falls short of the New Mexico line. In southern Arizona it extends eastward to Tucson and vicinity.

MEXICO.—From near Tucson the eastern boundary of the *Lower Sonoran* extends in a general southerly direction into Sonora, then southeasterly to a little north of San Ignacio, and soon afterward strikes the Sierra Madre, where it becomes identical with the lower limit of the *Upper Sonoran.* It enters the Sierra Madre on the western side of the range at various points, following up the larger cañons, notably the Grand Barranca of the Urique, a gorge which is destined to rank among the famous scenery of the North American continent, when the Sierra Madres of Mexico become better known.

The northern limits of the *Lower Sonoran* in Mexico are of course the same as already described in general for the southern limits of the *Upper Sonoran.* Its southern, or rather southeastern, limits are in the Isthmus of Tehuantepec. It takes in the Guadalajara region, and extends all the way from Puebla to Oaxaca, along the line of the Mexican Southern Railway. It is lost to the westward of this latter region in the more humid lowland-valley region directly south of the City of Mexico, but its western boundary farther north approaches gradually nearer the sea, taking in all but the lowest land, and reaching the sea coast at Guaymas. On the east it follows the irregular edge of the plateau line northward to about the 23rd degree of latitude, where it slopes off obliquely to the northeast, striking the Soto la Marina river and following it to the sea. From here northward up the coast it gradually merges into the *Austroriparian*.

Texas.—From the Soto la Marina river in Tamaulipas, the *Lower Sonoran* follows the proximity of the seacoast northward to near the Nueces river in Texas, and includes the lower Rio Grande valley to somewhat above the mouth of the Pecos. The *Austroriparian* should be considered as having its main southwestern termination in the Nueces valley, but a considerable touch of it reappears in the lower Rio Grande valley; and this occasional reappearance of the *Austroriparian* in valleys of streams near the coast undoubtedly obtains still farther south, gradually becoming fainter until it dies out altogether. The *Lower Sonoran* extends northward from the Nueces valley region, includes the region around San Antonio, and reaches still north to the Colorado river region of Texas.

TROPICAL.

Mexico.—On the west coast of Mexico the *Tropical* region ends at Guaymas, where cocoanut palms grow well. From Guaymas south it occupies only a very narrow strip along the coast, widening only as it gets well southward. The valleys from Cuautla to Jojutla, on the Interoceanic Railway, south of the City of Mexico, are tropical in the main. Royal palms grow in the plaza of Jojutla. The deep barrancas to the west of Guadalajara are also mainly tropical.

On the humid east and southeast slopes of the territories of the high plateau region of Mexico, from the latitude of Tehuacan to that of Jalapa, the *Tropical* reaches up to the 3000 and 4000 feet line, or even higher. It follows northward in this way to Cardenas, and then northeasterly to the Soto la Marina river.

It will be well to note here the relation between the biogeographic zones and the three principal life regions of Mexico, long ago recognized and given distinctive names by the inhabitants. The *Tierra Fria* or *Terre-Fraude* (above 7000 or 8000 feet) comprises the *Boreal Transition*, and *Upper Sonoran* zones; the *Tierra Templada* or *Terre-Temperee* (about 4000 to 7000 feet) comprises when arid *Lower Sonoran*, and when humid corresponds to the *Austroriparian*, though the *Tropical* then enters it largely in its lower extent. The *Tierra Caliente* or *Terre-Chaude* (sea level up to 3000 or 4000 feet) comprises the *Tropical*.

Texas.—The *Tropical* region (*neotropical*) does not actually enter Texas at all. A good touch of its fauna reaches the lower Rio Grande valley, and even the Nueces valley, but the percentage is not large enough to enable us to classify even the former with the *neotropical* region. The Lower Rio Grande valley is about one-fourth *Tropical* in the general aspect of its insect fauna, so far as my present data go. This includes also a maritime *Antillean* insect fauna on Padre Island, indicated by *Macrancylus* sp., *Oxacis* spp., etc.

ADDITIONAL REMARKS.

UPPER AND LOWER SONORAN.—The generally accepted idea of the *Lower Sonoran* is that it comprises all arid territory in which the subtropical fruits flourish. This point is of much importance from an economic standpoint. The date palm is most characteristic of subtropical arid regions the world over. It is thus particularly valuable in defining the northern limits of the *Lower Sonoran*.

In the *Lower Sonoran*, light frosts often occur, but heavy frosts and snowfalls are extremely rare and very exceptional to the general rule. In the *Upper Sonoran* killing frosts and snowfalls are usual, the frosts alone in the exceptional absence of snow being sufficiently severe to kill subtropical fruits if left exposed.

In the *Lower Sonoran* the mesquite (*P. juliflora*) assumes tree-like proportions, while yuccas become arborescent, and in the warmest and dryest portions cacti attain their greatest development. The pitahaya cactus is an example in point. It grows in Sonora and Arizona, as well as in the region of Oaxaca. The arborescent tuna cactus obtains more in the north of the tableland proper. Arborescent yuccas occur in the latter region also, and *Y. arborescens* is found in the highest parts of the *Lower Sonoran* on the west side.

In North American Fauna No. 7 (Part II., Report on Death Valley Expedition, 1893), p. 286, Dr. Merriam says: "The creosote bush (*Larrea tridentata*) is the most conspicuous, most widely distributed, and best known bush of the torrid deserts of the southwest, where it covers the gravel soil up to a certain line, which probably marks the southern limit of killing frost. The *Larrea* belt is the most important of all from the horticultural standpoint, because it is suited to the requirements of the citrus fruits, the olive, almond, fig, and raisin grape." I have reason to believe that this is very true of the Californian and western Arizona region, but its application wholly ceases when applied to the Atlantic slope, or the region east of the Continental Divide, in New Mexico, Chihuahua, and Texas. In New Mexico, the *Larrea* withstands both snows and killing frosts every winter; and in Chihuahua and Texas, killing frosts at least, if not always snows. So far as my observation goes, *Larrea* never descends into the *Lower Sonoran* on the Atlantic slope.

Tropical.—Any coast region where cocoanut palms can survive must be conceded to be strictly *Tropical*. This tree can not withstand frost. It can not survive on the Gulf of Mexico coast at Brazos de Santiago, near the mouth of the Rio Grande.

A preliminary examination of the Coleopterous and Dipterous faunas of the lower Rio Grande valley, representing not less than 500 species, indicates about 25 per cent of *Tropical* forms. The Hemiptera and other orders show, if anything, a less percentage; so that, so far as our present knowledge goes, it appears that there is about 25 per cent of *Tropical* forms of insects occurring here, divided between the *Mexican* and *Antillean* provinces.* The district, therefore, can not be considered tropical, which would require at least 50 per cent. A small percentage of its flora is *Tropical*, while some is *Austroriparian*, and a large part is *Lower Sonoran*. As for the *Tropical* forms of mammals, birds and reptiles which occur, such as *Felis onca*, *Totusia*, *Dicotyles*, *Felis eyra*, *F. yaguarandi*, *Ortalis* (penelope or chachalaca), *Elaps* (coral snake), etc., none of them is *Tropical* in its absolute needs. They all range out of the *Tropical*, and some of them are as much *Lower Sonoran* as *Tropical*.

Going southwest from the Nueces river, where the fauna and flora attain a marked change from the *Austroriparian*, we find outside of valleys of streams a more or less arid extra-tropical region until we reach the Soto la Marina river in Tamaulipas, 150 miles south of the Rio Grande. Here another change occurs, that from sub-arid (or *Lower Sonoran*) to *Tropical*. To the north of the Soto la Marina river, the summer nights are nearly without dew, and rains are extremely irregular and scant. This whole region, from the Nueces to the Soto la Marina, has to depend on irrigation for the raising of crops. The meteorologic conditions of this region are peculiar. Ordinarily, light frosts are more or less common throughout it in the winter. On an average, snowfalls and heavy frosts visit it once in about thirteen to fifteen years. Heavy wind storms or hurricanes come with about equal frequency. For a year or two after such storms, sometimes for several years, rains are more frequent, and by taking chances crops can be raised during such years without irrigation. Otherwise than this the climate is a dry one, and irrigation is on the whole a necessity.

All these conditions are changed to the south of the Soto la Marina. The nights are heavy with dew, rains become regular, irrigation is unnecessary, and frosts are unknown. Even the whitish soil of South Texas and North Tamaulipas is exchanged for a black and richer one on

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* The author has in preparation a detailed paper on the insect fauna of the Lower Rio Grande valley, in which he will endeavor to show with more exactness, and from a much larger amount of material, the various bio-geographic affinities of that district.

the south side of the Rio Soto la Marina. This, then, must be taken as the dividing line, or *parallel of transition*, of the *Tamaulipan* fauna and flora, separating the more *Tropical* from the more *Temperate* region. I here acknowledge with pleasure my indebtedness to Mr. Thomas B. Barbour, Inspector of the Bureau of A. I., at Brownsville, for the information on the country in the vicinity of the Soto la Marina river.

Oaxaca and its vicinity are not *Tropical.* The city lies in a valley about 5000 feet above the level of the sea. It is, with all the country round it, distinctly *Lower Sonoran.* The country between Oaxaca and Puebla, along the line of the railway, must be considered entirely *Lower Sonoran.* At one place only does it approach the *Tropical*, where the Grande and Solado rivers join their waters to form the Rio Quiotepec, which in its lower course is known as the Rio Papaloapam. This point is less than 2000 feet above the sea. In other places along the railway, the tall cacti, bare and rocky hill-sides, and dry air speak for themselves and betoken the *Lower Sonoran.*

On the west coast of Mexico, the *Tropical* extends much farther north than on the east. It is also confined to a very much narrower strip. The *Lower Sonoran* likewise extends much farther north on the west. The most potent reasons exist for this great difference in the east and west coast regions. The warm Pacific ocean currents are uniformly quoted as reasons for this much greater warmth on the west coast. But this is not all; another and opposite cause produces the other result on the east coast. The whole Atlantic slope bordering the west side of the Gulf of Mexico, extending up through Texas, Eastern New Mexico, Oklahoma, and Kansas, is liable during the whole year, except from June to August, to strong and continued cold winds from the north, known to the inhabitants as "northers." The influence of these is felt on the Mexican coast far to the south of Vera Cruz. Speaking from my own experience, "northers" are not felt in Kingston, Jamaica. The reason is that the warm waters of the sea intervene to warm the winds before they reach that latitude. But on the Gulf of Mexico slope these winds sweep down from the far north, gaining strength across the great plains, but gaining little heat, and follow the Mexican coast southward until they become warmed and lost in the heated air of the tropics. On the Pacific coast no such conditions prevail; the ocean currents traveling northward oppose their warming influence to north winds, and the physical conformation of the country prevents the birth of "northers."

COMMENTS ON DR. MERRIAM'S LAST PAPER.

Dr. Merriam's last paper, "Laws of Temperature Control of the Geographic Distribution of Terrestrial Animals and Plants," being the annual address before the National Geographic Society (December, 1894), marks a real advance in our knowledge of the biogeography of North America. I most heartily concur in all of the views there laid down, excepting only the following points:

The law that *the northward distribution of animals and plants in the northern hemisphere is determined by the sum of the effective temperatures* (*or total quantity of heat during the season of growth and reproduction*) finds its complement in the following, which modifies it and acts as a constant check to it:

Animals and plants are restricted in northward distribution in the northern hemisphere by low temperatures during the season of hibernation (or winter season).

For example, there is a sufficient total of heat during the season of growth and reproduction in most portions of Dr. Merriam's *Lower Austral* zone (Nat. Geog. Mag., vol. vi, 1894, pl. 14) to satisfy the proper growth and fruiting of the date palm, but in many of the same portions there is not a sufficient total of heat during the winter season to prevent it from perishing of cold. I notice that Dr. Merriam refers in a footnote to killing frosts, thus touching upon this point, but it is not a few "sensitive species" that are affected, especially when it comes to the region along the natural boundary between the *Upper* and *Lower Sonoran*, but a very large percentage of them.

In running his isotherms and computing the total quantities of effective heat in the southwestern United States, Dr. Merriam has overlooked a most important factor in the climatic conditions of the arid region. It is well known that the same "apparent temperature" in degrees affects animals and plants in an arid climate very differently from what it does in humid climates, the actual difference in effect being equal to 25° or even more. Therefore any plan of the total effective temperatures which does not take into consideration this factor of the absence of humidity is wide of the mark. What we need to deal with is not the "apparent temperature," but the "*sensible temperature.*" The latter is obtained by the reading of the wet bulb, and represents the actual amount of heat felt by animals and plants, especially the former. Thus we see the presence here of very important counter-conditions which bend the isotherms of "sensible temperature" out of the course they would otherwise follow. As an illustration of this I cite the statement of Capt. Glassford, that the very highest official record of heat ("apparent") at Yuma, Arizona, is 116° F., but the "sensible heat" at the same time was only 84° F. This is a difference of 32° between the "apparent" and "sensible" temperatures. In the Eastern States, 84° of sensible heat are not uncommon when the thermometer stands only as high as the nineties. The same "apparent temperature" is in effect cooler in the summer and warmer in the winter in an arid climate, but the "sensible temperature" is identical in both. It thus follows that animals and plants are subjected to a more limited range of sensible temperature between the same parallels of latitude in the arid region than in the humid, conditions of elevation being equal. Therefore, aided greatly by the peculiar configuration of the country, which at first stretches southward in a gradually rising mountain chain and then in a very long, broad, and gradually rising plateau, the transcontinental life zones widen in the arid region to a remarkable degree. Enough has been said above to demonstrate that only isotherms representing the "sensible temperature" can be used in biogeographic work.

Dr. Merriam's two fundamental laws of temperature control of the geographic distribution of terrestrial life, modified so as to agree with the above, and including a wider application of the second, would thus read as follows:

I. The northward or higher distribution of life in the northern hemisphere is determined by the total quantity of sensible heat during the season of growth and reproduction, checked by low sensible temperatures during the season of hibernation.

II. The southward or lower distribution of extra-tropical life in the northern hemisphere is determined by the mean sensible temperature of the hottest part of the year.

The frost line should be used for the southern boundary of the *Lower Austral* zone. The line marking the southernmost limit of frost, during a period of any twenty or even ten consecutive years, would define the actual southern limit of the *Temperate* region more nearly than any other. Temperature observations are needed at various points on the frost line to determine the approximate total of sensible heat expressing the temperature control.

Dr. Merriam gives the least total quantity of apparent heat required by *Tropical* species as 14,400° C. or 26,000° F. I believe that 27,000° F. of apparent heat expresses it more nearly, as being the least total with which the majority of *Tropical* species can exist. The mean daily temperature (apparent) of Kingston, Jamaica, for the ten consecutive years from June, 1880, to May, 1890, was 78.1° F. On no occasion did the temperature sink to 6° C. Therefore 365 times 78.1° F. gives the sum of the effective apparent temperatures, or over 28,500° F.

I believe that Dr. Merriam's totals of temperature control are too low for the southern limits of the *Upper* and *Lower Austral*. I consider the *Tropical* region to actually exist in the United States in but one locality, the extreme southern coast district of Florida. It runs north on the east coast to but little beyond Biscayne Bay. Wherever else it enters the United States, as in the extreme south of Texas, it is so greatly diluted as to preclude its classification with the *Tropical* region. If it enters the United States at all on the lower Colorado river, it must be still more dilute and possess still less claim to recognition. So far as temperature goes, Yuma can lay no claim to being *Tropical*. Its mean annual apparent temperature is from 71° to 72° F., and it usually has more or less severe frosts from December to February, sometimes killing frosts. This cuts its total of effective apparent temperatures below 26,000° F. I am convinced that the isothermal marking the mean annual apparent temperature of 74° F., without frost, or in other words the 27,000° F. total of effective apparent temperature is nearer to the proper boundary of the *Tropical*, though it should doubtless be much higher here on account of the absence of humidity. It is evident that it is almost useless to discuss these isotherms in connection with life zones, until they are drawn from sensible temperatures.

It is highly important to recognize all these overlapping or transition faunas, but they can not be correctly referred in the whole to either the one zone or the other. The correct way to treat them is to map them separately, showing on one map the limit of the zones and provinces, and on another the limits of the faunas. Overlapping faunas and floras possess what may be termed a *center of transition*, where about an equal percentage of forms occur which belong to each of the life zones or provinces contributing thereto. This *center of transition* is bisected by what I shall term a *parallel of transition*, which runs more or less irregularly east and west across the transition fauna, and divides it into two portions. The latter fall in their respective provinces, according to what provincial elements preponderate in their fauna and flora. This is the only plan that can be adopted to define the normal limits of the larger life divisions.

For example, the Tamaulipas fauna and flora, or the area of overlapping of *Temperate* and *Tropical* types along the coast of the Gulf of Mexico, as very correctly defined by Dr. Allen, extends from north of the Nueces river, in Texas, to south of the Pánuco river in the State of Vera Cruz. It has its *parallel of transition*, as already pointed out, in the neighborhood of the Soto la Marina river, where the *Tropical* types comprise about fifty per cent of the fauna and flora. Only the portion south of that parallel can be mapped with the *neotropical* region, or with the *Mexican* province of that region. It would, of course, be an excellent plan to devote a separate map to each life zone, and show its outlying dilute extensions in all directions, indicating also the percentage of dilution in the various localities.

In the case of transition faunas between humid and arid provinces, the dividing line runs nearly north and south, and may then be termed a *meridian of transition.* This distinction is necessary in the case of certain faunas which present both a *parallel* and a *meridian of transition.* A *parallel of transition* may run very irregularly, according to the topography of the country, but it will be borne in mind that it always tends to run at a right angle to the *axis of spread.* The latter term may be used to denote the main line along which forms from two zones or provinces approach each other until they meet and intermix. A *meridian of transition* likewise tends to run at a right angle to the *axis of spread* of a mixed humid and arid fauna. If 50 per cent of each fauna prevails for any distance in one direction, then the various *centers of transition* can be taken to determine the *parallel* or *meridian of transition.*

There remains only to notice the principal changes in Dr. Merriam's last map (Pl. 14, vol. 6, Nat. Geog. Mag., December, 1894), from his third biogeographic map (Annual Report Dept. Agric. for 1893, map printed December, 1893). They are three: The introduction of the *Tropical* along the lower Colorado valley, which has been already discussed; the extension of the *Transition* along the Pacific coast strip, which is the happy result of Dr. Merriam's excellent investigations on the laws of temperature control, and marks a long stride in the correct interpretation of the fauna and flora of the Pacific slope; and the extension of the *Tropical* across the peninsula of Florida. The latter I do not agree with, believing, as already said, that it is properly restricted to the narrow coast region of the peninsula south of the latitude of Biscayne Bay.

Note.—The question often arises among zoologists as to what class of animals is of the most importance for the determination of faunal regions. Now faunal and floral regions must necessarily coincide very closely. If we wish to obtain biogeographic data for economic use in relation to the raising of crops, we naturally turn to the flora for the exact and careful limitation of regions. In such a case we can not go astray by taking certain characteristic plants as criteria to the limits of provinces, zones, and regions, for many plants are obviously more sensitive to climatic influences than are animals. The mesquite and many other plants can not survive too much humidity, while others perish in arid regions unless irrigated. The date palm can withstand a moderately hard frost, while the cocoanut palm can withstand none. Therefore, if by these means we mark off life divisions, it follows that we must be approximating the fauna at the same time, as the latter conforms in general to the same meteorologic conditions.

SYNOPSIS OF THE LIFE DIVISIONS OF AMERICA.

Referring to the tabular synopsis, it will be seen that all America is divisible into five grand divisions, which should be known as regions. Each of the American continents is divisible into three broad temperature belts or regions, running in a general way with the isothermal lines of greatest heat in summer, least heat in winter, and total of effective sensible temperatures for the year. These three belts are best characterized by the adjectives boreal, temperate and tropical. I have thus designated the five regions as the Boreal, Neotemperate, Neotropical, Austrotemperate, and South Boreal. Only two of them, the first and the last, extend outside of America. A certain extent of the northern portion of North America, as is agreed by prominent writers on geographic distribution, can not be considered other than a circumpolar region. Some favor considering only the circumpolar *Arctic* zone (see tabular synopsis) as forming the region, and give it the name of the Arctic region. But this is too circumscribed an area, without a sufficient number of the forms of life and with no diversity of distribution, so that it would be incapable of subdivision into zones or provinces. Others favor uniting the whole temperate and boreal area of the northern hemisphere into one region. But this, on the other hand, contains too many diversities of distribution and would prove too unwieldy and misleading. I have therefore adopted a mean between the two, which moreover indicates more truly than can any other classification the actual distribution of life in the northern hemisphere. It is wholly unnecessary to go into the reasons which support this view, as the field has been well discussed from all standpoints by a score of writers—Sclater, Wallace, Cope, Packard, Allen, Merriam, Gill, Osten, Sacken, and many others.

The nomenclature adopted in this paper for the regions is the result of an effort to employ the Wallace-Sclaterian terminology so far as it harmonizes with the facts of American biogeography. I should state here that the terms Nearctic and Palaearctic have long since been discarded as misnomers by American writers. Besides the unfortunate application of the terms, the division between the regions does not accord with the facts of distribution, and thus there is double reason for dropping the names. But I believe that the Sclaterian term *Neotropical* is eminently available for the purely tropical portions of America, and, moreover, I believe that the preservation and use of this term are highly advisable. It is absolutely correct, and can not be misleading when accepted in its proper meaning of a purely tropical region. Sclater's neotropical included also temperate South America, but that is no reason why we should sink a comprehensive and valuable term when we can properly restrict it. For the North American temperate region (Austral of Merriam), I propose the name NEOTEMPERATE, to distinguish it from the other life regions of the globe. It is absolutely necessary, in the light of our present knowledge of biogeography, to separate the temperate portions of South America from the tropical, and for this region I propose the name AUSTROTEMPERATE. There is even a very distinct boreal element in South America, which must also be separated. Like its northern equivalent, which I name the BOREAL, it is a circumpolar. It may be termed the SOUTH BOREAL. In the division and subdivision of the regions, the terminology is made to conform as closely as possible to that adopted by Merriam and Allen for North America, and Wallace, Sclater, and others for South America.

For the second class of divisions, I employ the descriptive term zones, as indicating the transcontinental character which they assume. Of these zones we have fifteen that can be recognized: *Arctic*, *Hudsonian*, *Canadian*, *Transition*, *Upper Austral*, *Lower Austral*, *Tropical Transition*, *Brazilian*, *South Tropical*, *Lower Temperate*, *Upper Temperate*, *South American Transition*, *Patagonian*, *Fuegian*, *Antarctic*. These zones in South America become apparent on the study of the fauna in general. The transcontinental character of the above divisions disappears with their subdivision into provinces. The latter result from the natural subdivision of zones by reason of aridity and humidity, separation by sea or mountains, etc. Subprovinces are still smaller divisions, while faunas and floras are the ultimate biogeographic subdivisions.

The tabular synopsis itself follows.

BROWNSVILLE, TEXAS.
Sept. 23, 1895.

Provisional Tabular Synopsis of the Recognized Life Divisions of America.

	Regions.	Subregions or Zones.	Provinces.	Subprovinces.	Faunas and Floras.
North America.	BOREAL (a Circumpolar Region).	Arctic or Arctic Alpine (circumpolar).			Barren Ground.
		Hudsonian (a Subalpine Zone).			Alaskan. Hudsonian.
		Canadian.			Canadian. Aleutian. Sitkan.
	NEOTEMPERATE.	Transition Temperate.	Appalachian.		Alleghenian.
			Arid Transition.		San Francisco Mt.
			Pacific Coast Transition.		Californian.
		Upper Austral.	Carolinian.		
			Upper Sonoran.	Great Plains.	Staked Plains. Chihuahuan.
				Continental Divide.	New Mexico Cordilleran. Sierra Madre.
				Great Basin.	
				Pacific Slope.	Grand Cañon.
		Lower Austral.	Austroriparian.		Floridian. Louisianian. Tamaulipan.
			Lower Sonoran.		Lower Colorado River. Sonoran s. str. Lower Californian. South Mexican Plateau. Coahuilan.

Provisional Tabular Synopsis of the Recognized Life Divisions of America.

	Regions.	Subregions or Zones.	Provinces.	Subprovinces.	Faunas and Floras.
North America.	NEOTROPICAL.	Tropical Transition.	Antillean.		Floridian Maritime. Cuban. Jamaican. Mexican Maritime.
			Mexican.	East Lowland.	Tamaulpian. Campechian.
				West Lowland.	Saint Lucas. Sinaloan. Tehuantepec.
			Central American or Isthmian.		Guatemalan. Costa Rican.
South America.		Brazilian.	Amazonian.		
			Orinocan.		Llanos. Venezualan Coast.
		South Tropical.			Brazilian Coast. Paraguayan.
	AUSTROTEMPERATE.	Lower Temperate.	Lower Chilian.		Gran Chaco Desert. Chilian Coast.
			Brazilian Plateau.		Matto Grosso. Minas Geraës.
		Upper Temperate.	Upper Chilian.		
			Pampas.		
		South Am. Transition.			
	SOUTH BOREAL (a Circumpolar Region).	Patagonian.			
		Fuegian (a Subalpine Zone).			
		Antarctic Alpine (Circumpolar).			Andean Alpine.

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COMMITTEE ON PUBLICATION.

W. W. Norman. G. B. Halsted. E. T. Dumble.

[*Read before the Texas Academy of Science, December, 1895.*]

MOLECULAR THEORIES OF ORGANIC REPRODUCTION.

BY DR. EDMUND MONTGOMERY.

Organic reproduction may well be called the supreme marvel of physical nature. Out of a single nucleated cell, structurally all but undifferentiated, issue in preconcerted order the myriads of specifically diversified constituents that build up the wondrously organized frame of higher organisms. And the various reproductive germ-cells of these, hardly distinguishable one from the other, contain in some way prearranged with rigorous precision the potential forecast of the entire series of evolutional changes that lead in the one case, say to the construction of a tiny mouse, in another to the construction of the huge and most dissimilar elephant.

Now what can be the nature of the peculiar process through which so minute and homogeneous a speck of matter is made to reproduce thus faithfully the complexly organized being from which it is derived?

To find a scientifically valid solution of this great problem of reproduction and heredity has been the assiduous endeavor of many of our foremost biologists.

The problem has various aspects. Manifold results are reproductively attained; physical and psychical, physiological and morphological. But among these it is chiefly on the morphological outcomes that biologists have at present fixed their attention. Starting, as is usually done, from the tenets of what is known as the cell-theory, two disparate views of the reproductive process undergone by germ-cells have each been advocated by eminent scientists. The one view finds its most elaborated expression in Darwin's theory of Pangenesis, the other in Weismann's theory of the Continuity of the Germ-plasm.

The cell-theory maintains, that the diversified tissues of organic beings are all derived from the reproductive germ-cell by a process of cumulative cell-division; the fully developed organism consisting thus altogether of a vast aggregate of more or less differentiated descendants of the original germ-cell. The organic individual is consequently looked upon as a conglomerate of a multitude of autonomous beings, all the progeny of the simple germ-cell.

In keeping with this view, the fundamental question of reproduction presents itself in the form of the following riddles: First, how do the vast number of differentiated cell-beings that enter into the formation of a complex organism manage to become potentially represented in the initial germ-cell from which they emanate? Second, how do the potential differentiations inclosed in the germ-cell manage to evolve the adult organism?

If, in agreement with the cell-theory, the germ-cell is itself looked upon as an elementary unicellular being, it would, as such, originally, be able to reproduce by means of fissiparous division only its own exact kind. How then has it happened that in the course of phylogenetic evolution it has been rendered capable of evolving a series of cell-generations becoming, as organic development in the animal scale proceeds, more and more unlike itself, leading ultimately to the formation of such incommensurably higher tissues as muscle and brain?

These fundamental biological questions are no doubt extremely perplexing. But it is clear that organic evolution, as we trace it in its manifest morphological outcomes, reveals to us only the gross results of a developmental process that is taking place in the hidden sphere of molecular activities. Adequately to explain organic evolution, productive and reproductive; and, indeed, fully to explain any kind of organic process, necessitates, therefore, a correct insight into the secret ways by means of which molecular activities build up organic forms, and maintain their vital functions.

No one was more fully alive to this supreme scientific desideratum than Darwin himself. He devoted more intense thought to the elaboration of his "provisional hypothesis of Pangenesis"—as he modestly calls it—than on that of natural selection. No wonder, for it required a gigantic effort of visualizing imagination to make the evolutions of a host of separately specific molecules account for the complex of biological facts connected with reproduction and heredity.

This is the way Darwin puts the leading question, he asks: "How can the use or disuse of a particular limb or of the brain affect a small aggregate of reproductive cells, seated in a distant part of the body, in such a manner that the being developed from these cells inherits the characters of either one or both parents?" He adds: "Nothing in the whole circuit of physiology is more wonderful." "Even an imperfect answer to this question would be satisfactory."

Let us then see by means of what hypothetical devices he himself seeks to answer this perplexing question. He takes, above all, for granted that the complex organism consists of autonomous units, as taught by the cell-theory. And he goes, as he says, one step farther, and assumes that these autonomous cell-beings throw off reproductive gemmules.

Of course, if the complex organism is really composed of a vast aggregate of disparate autonomous beings, then, of necessity, in order that each of these may be reproduced from one and the same germ-cell, they must all separately manage to send into this germ-cell specific representatives of themselves. Darwin's gemmules are assumed in order that this representative feat may be performed by them.

Here it will be well to point out at once the shortcomings of this initial assumption of Pangenesis. A gemmule is conceived as reproducing by fissiparous division only its own kind. Consequently, under this assumption, there exists really no such entity as a "cell." A cell can be, then, only a cluster of equal gemmules, and not a molecularly highly organized being, as long ago maintained by Bruecke, now by most biologists; and, in fact, as revealed by direct observation. It is, therefore, not correct to imagine with Darwin that such unorganized formations as he conceived cells to be can throw off reproductive gemmules in the same way as a complex organism throws off reproductive germs. Nor can it be rightly said that the hypothetical gemmules reproduce the cell in the same way actual germs reproduce the adult organism. With the assumption of gemmules we get in verity no farther than a heaping up of their own kind, and not the reproduction of a more highly organized being than themselves.

But the principal flaw, the evident petitio principii involved in this leading assumption of Pangenesis, is that the entire problem of reproduction is shifted unsolved into the region of invisibility; for it is clear that the individual gemmules being imagined as containing everything that imparts specific characteristics to particular cells must in consequence conceal within themselves the entire riddle of reproduction they were invented to explain. They are the only reproductive agents of Pangenesis, and they reproduce only themselves. The way their own reproduction is effected is left completely in the dark. Consequently, reproduction in general remains altogether unexplained.

Thus, inadvertently, has the egg of the canker-worm been deposited in the very heart of the bud of this hypothesis of reproduction. It is, therefore, easy to foresee that the entire hypothesis must come to grief during its process of unfolding. And, indeed, it is pathetic to witness the desperate straits Pangenesis is put to in order to gather within the reproductive cell a complete assortment of gemmules of every diversified cell of the organized body. Gemmules of every kind are believed to be thrown off into the general circulation. Myriads of them must be thus coursing along in promiscuous confusion. What known agent can be invoked to pick out from the jumbled multitude, and cluster together in proper order, the exact set of gemmules fit to reproduce with all but unfailing fidelity the adult organism. In man this miraculous feat would in fact amount to the production of a veritable homunculus; a manikin molecularly preformed in shape and otherwise, awaiting to be enlarged to adult stature by mere interstitial fissiparous division of his constituent gemmules. And what strange powers are furthermore summoned into existence to evolutionally marshal the host of self-multiplying gemmules. Occult powers unheard of in nature are here invented to serve a physical purpose. The explanatory machinery turns out to be far more mysterious than what it is called upon to explain. Pangenesis is thus proved to be utterly inefficient to solve the secret of reproduction.*

Yet, nevertheless, if we start with the conception that the complex organism is but an aggregate of autonomous cell-beings, it seems to follow with necessity that in order to be reproduced, each of these separate beings has to send a separate germ of itself into the general or collective germ-cell. Pangenesis seems to be thus inevitably implied in the cell theory.

It will, however, presently be shown, that Weismann and his followers attempt to circumvent this logical implication of the cell theory by advancing a theory of original and continuous preformation of all developmental agencies in the reproductive germ itself.

Here I may be allowed to remark that my own biological studies have led me long ago to the definite, and I believe demonstrable conclusion, that the complex organism is not, as generally believed, composed of myriads of autonomous elementary beings; but that it constitutes, in truth, a single, indiscerptible vital unit. Of this, however, later on.

Haeckel, Darwin's illustrious pupil, excuses himself for being compelled to antagonize his master's hypothesis of Pangenesis by advancing a hypothesis of his own which he calls Perigenesis, or more explicitly Perigenesis of the Plastidule. This is meant to imply genesis of the elementary constituents of the organism, and reproduction of the entire organism, by means of a complex configuration of wave-motions.

Haeckel starts likewise from the foundation afforded by the cell theory. In introducing his hypothesis of Perigenesis he says: "We have to regard the microscopical cells as independent vital beings, as physiologically and morphologically autonomous." "The higher organism forms thus a social unity, a state whose sundry citizens are the cells."

The germ-cell is conceived by Haeckel as being composed of an aggregate of equal vital molecules. These molecules are held to be of an exceedingly complex nature. He calls them plastidules, and maintains that it is the variously definite modes of their grouping that gives rise to the differentiation of the cells and the tissues constituting the complex organism.

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*For a more explicit criticism of Pangenesis see Jenaische Zeitschrift für Naturwissenschaft, vol. xviii, page 701.

How then does he imagine the generation of new plastidules and their diversely specific grouping to be effected ? It is well known that Haeekel, though he profcsses the purely mechanical view of nature, is really a hylozoist. For he attributes to every atom entering into the composition of natural objects psychical properties, sueh as sensation and volition.

His vital molecules, the plastidules, he endows with an additional psychical faeulty. He ascribes to them memory of an unconscious kind, which implies reproduction of former experience. This reproduetive memory he believes to be that which imparts vitality to them. By dint of it, his plastidules are held to possess the power of continuously reproducing their own specific motion, together with such modifications as are wrought upon it by external influences. This is believed to enable them not only to maintain their own highly complex identity, but moreover, to transmit their inherent motion to adjaecnt pabulum, which, coereed thereby into like vibrations becomes converted into new plastidules. An organism propagatcs thus its own kind merely beeause its ultimate vital molecules convert foreign material into their own likeness by transmitting their speeific motion to it. Propagation of kind is therefore in the last instanee propagation of speeifie motion.

Growth takes plaee, in accordance with this view, simply by intrinsie aceretion of newly formed plastidules. When then, by aecumulation of more and more sueh plastidules, the plastide or cell has increased so much in bulk as to overreach the limit of its eohesive forec, division occurs. It is obvious that the two cells resulting from the division, however equally endowed they may start on their separate eourses, will eventually become exposed to different modifying influences. These influences will gradually change their respective plastidule motions, thus differentiating the constitution of the two cells. These again divide, and again dissimilar influences eause further deviation from the parent type. In this manner the diversifying operation proceeds from cell-generation to eell-generation; the entire series of differentiated individuals representing at last a many-branehed genealogical tree.

This attempted solution of the problem of reproduetion by means of speeific effieiencies attributed to eonjectural modes of motion is undeniably anti-mechanieal, not to say anti-scientific. A spontaneous psychical activity is here held to produee motion. And it is assumcd that in vital units there may occur an ever renewed creation of highly specifie cnergies out of such merc ideal or mental stuff as memory is made of.

But let all this pass. Take everything that Perigenesis assumes for granted. Allow the multieellular organism to be eonstructed by means of the propagation of multifariously diverging plastidulc motions imparted to pabulum. Say we have thus actually succeeded in produeing the complex organism. How then, it must be asked, is the *re*-production of this organism effected? How are the diversely modified properties of its myriads of plastidules at last collected in the single receptacle of the germ-cell? To this decisive question the theory gives no answer. We receive no clue whatever as to how the plastidules of the germ-cell can have possibly registered all the multitudinous impressions received by the progeny of its precursers, so as now to be fit to reproduce by memory or otherwise the entire evolutional series of differentiated autonomous beings believed to make up the complex organism. Vulnerable otherwise at almost every point, Perigenesis fails thus to give any kind of solution to the most essential part of the problem of reproduction. It keeps silent as to how the diversified properties of the autonomous cell-beings come to be represented in the germ-cell. Omitting in this way to show from what source the germ-cell receives its reproductive efficiency, the theory loses altogether its raison d'être. It is nowise what it pretends to be, certainly no theory of reproduction.

Not to squander all my critical ammunition on one particular case, I have reserved what I think would have proved the most fatal objection to the theory of Perigenesis, in order to apply it to Herbert Spencer's theory of "Physiological Units," and therewith to every theory which makes new vital units be generated through mere contact of pabulum with vital units already formed. Assimilation is a very convenient term. But to how many biologists does it remain more than an utterly occult operation?

No one can more sincerely admire the consummate knowledge, the laborious and fruitful investigations, and the highly suggestive biological speculations of the celebrated Jena professor. Nevertheless, I venture to assert, that whoever believes even the most primitive living being to be composed, like crystals, of a mere aggregation of equal molecules, has not in the remotest degree gained an insight into the constitution of the living substance. Nor can such a one form on so loose a foundation an approximately correct conception of the intimate vital process that underlies the functions of organic beings.

When a biologist has before him under his microscope the germ-cell of a high organism, he knows that in this insignificant-looking spherule the vast, supremely momentous secret of vitality lies enshrined. Here, minimized to the utmost, rest gathered together the cumulated results of ages upon ages of phylogenetic elaboration. Presently, in but a few weeks or months, will be unfolded from out its microscopic confines to open view the matured living being, whose marvelously complex organic structure generations of anatomists and microscopists have sought in vain fully to unravel. And this astonishingly differentiated structure will be vitalized through and through, will display in all its organically interdependent parts the wondrous functions that so strikingly distinguish living beings from non-living things. And infinitely more marvelous than the rest, the dawn of consciousness will break from its sense-lit summit; will open on the immensity of the universe, understandingly to mirror its multitudinous formations; will in its inward workings shake its habitation with emotions of love and hate, of hope and fear; and will make of its vital abilities subservient tools to satisfy its desires and to realize its heaven-scaling aspirations.

No wonder that, this in mind, we investigators of life feel drawn day after day, month after month, year after year, to watch with scrupulous attention every least sign of vital activity manifested by the living substance. Thus it happened that a few years ago observers became fascinated with the so-called karyokinetic phenomena — phenomena displayed by the nucleus of cells while in process of fissiparous division. The compactly coiled constituents of the cell-nucleus are seen gradually to display, so as to form regular bi-polar figures. Exposed to tincturing, a number of beaded filaments were rendered prominent in the making-up of the spindle form figures. These were named chromosomes, and every slightest change in their position and constitution was eagerly noticed.

Concentrating thus one's attention exclusively on these salient evolutions of the nuclear substance, it lay near to conclude that the entire process of fissiparous division, and therewith of reproduction, was initiated and controlled by it.

Weismann's famous theory of heredity is wholly based upon this interpretation of the karyokinetic phenomena. He takes the substance of the chromosomes, of those beaded filaments, to be the sole bearer of the properties that are transmitted from parents to their offspring, and he names it, in consequence, germ-plasm. Starting from this foundation, believed to be given by directly observable facts, he formulates with great ingenuity and commanding biological knowledge a view of reproduction differing toto genere from those of Darwin and Haeckel. We have seen that both these theories, that of Pangenesis and that of Perigenesis, were governed by the conception that the variations from the present type occurring in the successive cell-generations which build up the complex organism were mainly induced by external influences at work upon them during phylogenetic evolution. And as each cell thus differentiated was taken to be a separate autonomous being, it had of necessity to convey centripetally a reproductive element of itself into the general or collective germ-cells.

Weismann, in opposition to this, teaches that all variations from the parent type, which eventually lead to the widely disparate differentiation of cells and the tissues they constitute; that, in fact, all organic development is wrought exclusively by influences emanating from within the germ-plasm; that, consequently, the reproduction, as well as the production of organic beings is due to a process of veritable evolution, to a gradual unfolding of what is originally and exclusively inherent in the germ-plasm itself, and nowise to anything that has got into it from without.

It is easy to perceive to what extremely divergent consequences these opposite views of reproduction must necessarily lead. In the one instance we have development mainly through direct functional, and eventually consciously aimful, interaction of the entire organism with the manifold influences of its enviroments. In the other instance we have, either development altogether by means of fortuitous variations of the germ-plasm, upon which the vital labor of the organism as a whole exerts no influence whatever; or, in case the variations are held, not to be fortuitous, but aimfully preconcerted in the primordial germ-plasm, we and all other living beings have to be regarded as petalistically involved in a process of predestined evolution, which no vital activity on our part can influence in the least degree.

Now to whatever scientific decision we may ultimately arrive as to the great burning question of the transmission or non-transmission of individually acquired structural modifications and their functional outcomes, it is certain that the foundation of Weismann's particular theory has recently been effectively overthrown. It has, namely, been positively demonstrated, that it is not the nuclear substance of the cell; but, on the contrary, the substance of the cell itself, that initiates and controls the process of division, and therewith reproduction in general. Of this not the slightest doubt remains. It has been established by verifiable proof on the testimony of such foremost investigators as Strasburger[1] and Guignard[2] on the part of botanists; as Van Beneden,[3] Boveri,[4] Fol,[5] and many others on the part of zoologists. And even Flemming,[6] who had been a strong advocate of the nuclear view, has lately been forced to arrive at the same conclusion. And I may be allowed to add, that I was among the first to interpret fissiparous division in this extranuclear sense.[7] I had distinctly observed the occurrence in the case of a

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[1] E. Strasburger: Ueber Zellbildung und Zelltheilung, 3d Aufl. Jena, 1880.

[2] L. Guignard: Sur l'existence des sphères attractive dans les cellules des végetaux. Comptes rendus. Acad. Sci., Paris, 1891.

[3] E. van Beneden: Recherches sur la maturation de l'oeuf, la fécondation et la division cellulaire. Gand et Leipzig, 1883.

[4] T. Boveri: Zellen-Studien. Jenaische Zeitschrift für Naturwissenschaft, vol. 22, 1888.

[5] H. Fol: Die "Centrenquadrille." Ana. Anz., 1891. Jen. Zeit. für Naturw., vol. 7, 1873.

[6] W. Flemming: Ueber Zelltheilung. Verhandl. der Ana. Gesellschaft, München, 1891.

[7] E. Montgomery: Ueber das Protoplasma einiger Elementarorganismen. Jen. Zeitschrift für Naturwissenschaft, vol. xviii, page 677.

very transparent Epistylis, as minutely described in the Jenaische Zeitschrift für Naturwissenschaft, 1883.

This incontestable state of things disposes irretrievably of the germ-plasm theory by depriving it of its foundation. But my object here is to show the utter untenability of all molecular theories of reproduction; of all such theories as attempt to build up the complex organism by means of hypothetical molecules, conceived as separate, multiplying vital units. I will, therefore, taking Weismann's own assumptions for granted, try to expose in detail and in final outcome the fatal fallacies intrinsically involved in his array and marshalling of such separate molecules; and I will seek to render apparent the impossibility of the evolutional and organizing feats imagined to be performed by his Biophores, Determinants, Ids, and Idants.

If it turned out to be an insoluble puzzle how to collect into the general receptacle of the germ-cell representative elements of all the diversely autonomous cell-constituents of the complex organism; the puzzle now before us is how to evolve all these disparate autonomous cell-beings by dint of efficiencies constitutionally inhering in the nuclear germ-plasm.

Nothing easier, provided our biological knowledge be sufficiently extensive to allow us to bear in mind all the ascertained facts to which our theory is to be fitted. If, for instance, we desire a man to be evolved, we simply construct in imagination an ultra-microscopic homunculus out of hypothetical vital units, assert that this homunculus is actually present in the chromosomes of a human ovum; and then, by means of molecular groupings, divisions and multiplications of whatever kind the explanation of the actual facts calls for, we evolve the visibly complex organism of the adult being.

Weismann's Ids are in truth the organism minimized in all its details. His Determinants are imaginary embodiments of metaphysical ability believed to impart to each cell its peculiar characteristics. His Biophores are hypothetically individuated vital material out of whose multiplications and groupings the complex organism is constructed.

Weismann furnishes thus his germ-plasm beforehand with all necessary constituents, and endows these with all necessary qualifications, enabling them to accomplish what they are designed for. The scientific value of the theory is solely derived from the once seemingly valid conclusion, that the chromatic substance of the nucleus is actually the bearer of all reproductive properties.

If such were really the case the tenets of the germ-plasm theory would be logically necessiated by it. And in this light it was an eminently appropriate scientific task to seek to discover what theoretical assumptions were required in order to formulate an explanation of reproduction under these given conditions. But, even had the initiative influence of the nuclear substance in the cell-division not been positively disproved; if, as the theory now stands, it can be clearly shown that its logically necessitated assumptions are untenable, it follows inevitably that the original conception which necessitated them must be itself untenable.

The germ-plasm or idioplasm derived from the parent is, according to Weismann, composed of a number of aggregated Ids believed to be incorporated in the chromosomes. An Id is held to contain, grouped in definite order, the full assortment of vital units, which by self-multiplication, and the determining influence of certain of its groups have to evolve the adult organism. These most efficient vital units, of which the Id is supposed to be composed, are called by Weismann Biophores. As their name indicates, they are constituted bearers of the vital properties. It is conjectured that these life-bearers were originally of equal consistency, but have in the course of organic evolution come to vary among themselves to such an extent as to be efficient to serve singly and collectively as bearers of all the manifold qualities which distinguish one cell from another—a brain-cell, for instance, from an epithelial cell. And as nothing but nutritive material can possibly enter into the vital units of the germ-plasms from outside, the developmental differentiations of the Biophores, so astonishingly significant in relation to the life of the organism as a whole, can be solely due to the natural selection of accidental nutritive modifications affecting the chemical structure of the Biophores composing the Ids.

Here the first fatal flaw of the theory starts into view. For Weismann conceives not only the nuclear plasm to be composed of Biophores, but also the cellular plasm. Now it is evident, that if the Biophores of the nuclear plasm are apt to vary, offering thus favorable opportunities to natural selection, surely the Biophores of the cellular plasm must also be allowed to vary, and to offer selective chances; for they are exposed to exactly the same nutritive and selective influences. The nuclear substance thus deprived of its exclusive privilege of being the carrier of the differentiated properties of the complex organism, can no longer fulfil its appointed mission as sole reproductive substance. The germ-plasm theory is therewith proved to be self-destructive.

Furthermore, leaving for brevity's sake out of sight all the fanciful modes of grouping, multiplication, and division Biophores have to undergo in order to accomplish their assigned task, let us examine for a moment in what way Weismann makes those special groups of Biophores called Determinants exceed their determining influence. Determinants are believed to be the agents which impart to cells their sundry specific qualities. Weismann seems to think that it is sufficient to call these specific agents "Determinants" in order to settle the matter. We may, however, be pardoned for showing some curiosity as to how this astonishing influence is exerted. We desire to know how Determinants manage to determine. To be told that the cellular plasm is to them what clay is to the potter, is hardly satisfactory. Arrived by devious and miraculous ways at their proper local destination, the bond which constituted the Determinant a special entity suddenly snaps, and its constituent Biophores disperse among the Biophores of the cellular plasm. And now, it may be asked, how does this minimal number of germ-plasm Biophores diffused among the vastly larger swarm of cellular Biophores succeed in imposing their specific characteristics upon them? Nothing but nutritive influences can possibly and avowedly enter the otherwise firmly occluded Biophores. The problem, therefore, resolves itself into the simple practical question as to which kind of Biophores will eat the other up. And it stands to reason, if any nutritive action is here to take place, that the greater number are likely to conquer, and nothing will then be determined save the digestive process of the victors.

Thus flimsy are these renowned molecular theories.

But the germ-plasm theory breaks down, not only theoretically, but also in its application to some of the most significant biological facts. For instance, single cells of the leaves of begonia are known to reproduce the entire plant. Each such cell would consequently have to hold in reserve an entire Id, consisting of all Determinants needed to impart to other cells during regeneration their distinguishing properties. An earth worm can be artificially divided anywhere throughout its entire length, and each section will regenerate the entire individual. This would necessitate, according to the germ-plasm theory, in the cells of each possible section two sets of supplementary Determinants. In Hydra the case is still more complicated. Here three sets of supplementary or reserve Determinants are everywhere called for, one for oral, one for aboral, and one for lateral regeneration.

Weismann, inspired by the supreme scientific importance of a correct interpretation of reproduction, is so completely absorbed in following up the explanatory exigencies of this theory, as not to perceive that such extremely fanciful demands upon it amount to its reductio ad absurdum.

Finally, most fatal to all such molecular theories, is the invalidity, the utter sterility of the common device of smuggling, excessively minimized, all that has to be explained into hypothetical elements. A moment's calm reflection renders it evident that the self-multiplication of the smallest conceivable vital unit presupposes already everything that reproduction implies: assimilation of pabulum, growth and division, leaving thus the entire secret unsolved.

I have dwelt at some length on the germ-plasm theory because its learned and ingenious author has taken all imaginable pains and used all possible precautions to appropriately fit it to the vast array of ascertained biological facts.

Surely something fundamentally wrong must be the matter with the leading conceptions of vitality and organization, when the explanatory attempts of our most prominent biological thinkers turn out to be so lamentably at fault.

In winding up this critical review, I will quite briefly show how, under the sway of the conception of molecular vital units, another foremost expounder of evolution is forced glaringly to contradict the leading principles, which gives unity and direction to his entire system of development. It is Herbert Spencer to whom I allude. After emphatically declaring in opposition to spontaneous generation that "construed in terms of evolution every kind of being is conceived as a product of modifications wrought by insensible gradations on a pre-existing kind of being," he allows shoals of most highly constituted beings to be spontaneously generated out of nutritive material. His physiological units, like the gemmules of Darwin, the plastidules of Haeckel, and the biophores of Weismann, are supremely endowed vital elements through whose specific modes of aggregation organisms are believed to be built up. In their peculiar constitution are supposed to be inwrought the divers characteristics to be imparted to the adult organism. The evolutional toil of endless ages has at last succeeded in elaborating them. And now the theory demands that vast multitudes of these highly wrought beings be newly and most speedily created, in order to afford sufficient living material for the construction of the adult organism. Unlike Darwin and Weismann, Herbert Spencer, and with him Haeckel and others, desiring to give a more mechanical aspect to their view, refrain from endowing their vital units with the full-fledged faculty of self-multiplication. They are thus driven to the monstrously anti-evolutional assumption, that mere pabulum, through nothing but contact with preformed vital units becomes at once creatively transformed into their exact likeness. To this the fanciful transmutations of the alchemy of the medieval goldmakers were as child's play.

After having tried to lay bare the insufficiency of the molecular theories of some of our most distinguished biologists, I beg leave to give an outline sketch of the interpretation of reproduction my own studies have led me to form. These studies were carried on during a number of years, and their principal object was to ascertain by what intimate process structurally unorganized, or only partly organized beings, such as protozoa, were empowered to perform all essential vital functions; such as motility, assimilation, depuration, growth and reproduction.

I would have refrained from assuming the invidious part of a faultfinder, if I was not convinced that I could replace what I have sought to overthrow by a more valid construction.

Reproduction can not be explained without having first gained a correct conception of the constitution of the living substance.

First of all, then, my observation of the living substance, or so-called protoplasm, has taught me that it is not like crystals, composed of merely aggregated units or molecules, held together by the physical bond of cohesion. On the contrary, it forms a single indiscerptible unit, whose constituent elements are all interdependently united by definite chemical bonds; such bonds as determine the specific nature of substances as a whole. The many different hydrocarbons, for instance, are all composed of the same constituent elements, but receive their distinguishing qualities from the manner these elements are chemically combined. In the living substance, likewise, only a few essential elements enter into its composition, but these form by means of chemical coherency a most specifically individuated unit.

The living substance being thus a definite chemical compound of an exceedingly complex constitution, its vital functions prove to be independently due to a definite cycle of chemical activities involving all parts of the living unit. This chemical solidarity of all essential functions of life can be most readily ascertained by watching with unbiased mind what takes place in amœbæ when in motion. The granular structure of their substance reveals by means of the motion of the granules the direction and extent of the vital movement.

Now, how is this vital movement of the protoplasmic being set going and kept up? In some favorable specimens it becomes quite evident that the vital movement depends on a chemical process of alternate disintegration and reintegration undergone by the living substance. When the protoplasm of an amœba flows out, so as to form what is called a process or pseudopodium, it encounters in the resistance of the medium a disintegrating influence. Thereupon its substance shrinks within itself. It is obvious that, in order to be rendered fit to flow out again, the disintegrated substance has to reintegrate itself. Consequently, this fundamental function of alternate disintegration and reintegration draws with it, on the one hand, the elimination of the waste products of disintegration seen to be effected by means of depurative vesicles; and, on the other hand, the restitution of the disintegrated individual by means of complemental material furnished by the medium. Assimilation, hitherto so occult an operation, turns out to be simply the reintegration of the living substance through combination with complemental material. When the living substance assimilates foreign material or pabulum it does not do this, as generally believed, by transmuting it into other separate living beings like itself, or into other vital units of which it is believed to be composed; but simply by combining with the complemental material so as to restitute its own functionally deteriorated chemical structure.

This much being positively ascertained by direct observation, let it be clearly borne in mind that living activity, in all stages of development, necessitates the direct interaction of these three different and yet indivisible functions; first, the functional play with the medium on which its vital motion depends; then, on the one hand depurative elimination of the waste products of functional disintegration, and on the other hand nutritive restitution by means of complemental pabulum. However intricately differentiated into organs, tissues, and components of tissues an organism may appear, its structure is out and out the visible substratum of this manifoldly related and yet indivisible activity. It is this indiscerptibly correlated threefold disposition of the unitary movement of life, that governs organization from its first beginnings to its complex development.

That it is a specific chemical constitution of the living substance, aided by its concomitant vital activity, which determines the shape and structure of an organism, becomes evident when we contemplate the highly differentiated substance of such infusoria as, for instance, Stentor, the well known trumpet-animalcule. Here, with but very little firmly fixed structural organization into tissues, the mostly still fluent protoplasm manages to sustain, by dint of its specific chemical construction and living motion, the remarkably complex disposition of the differently functioning parts of its body.

The functional differentiation and disposition of the living substance is determined by the particular location occupied in the chemical cycle of protoplasmic activity. This is directly and distinctly observable in higher amœbæ; such, namely, as form with their entire substance one single process. We have then an ovoid bilateral being, whose shape is steadily maintained by out-and-out fluent protoplasm. Its oral pole—distinguished from the granular part of the body by being composed of hyaline substance—keeps always foremost in space during locomotion. This is effected by newly integrated substance constantly flowing out, and replacing thereby the functionally disintegrated and shrinking substance. This foremost part of the body not only plays the role of a structurally unformed mouth, by allowing nutritive material, with which it comes into contact, to penetrate into the interior, where it forms nutritive corpuscles with what may be termed entodermic substance; but its essential function is to carry on, together with the other surface-protoplasm the functional play with the medium, the life of outside relations, as it is called in higher organisms. Depuration and defecation take, visibly, place at the aboral pole. Now mark, all essential functions of individual life are here already definitely located in a still perfectly fluent protoplasmic being.

The ectoderm of higher organisms represents the structural elaboration of the relations of the living substance to the sundry stimulating influences of the medium. The entodermic organs constitute the structural fixation of the relations of the living substance to its nutritive or restitutive resources. The office of the depurative organs is, first, to eliminate the waste products of ectodermic functions, and then also, those of the entodermic functions.

Having gained some little scientific insight into the unitary constitu tion of the organic individual, the solution of the problem of reproduction will naturally conform to it.

Let us, as has often been done, artificially slice into several pieces our highly differentiated trumpet-animalcule. Every slice, however shapeless, will be seen to reproduce the complete animalcule. How is this effected? There is no other way rationally to account for this astonishing fact of reconstruction than by regarding it as an extreme case of chemical reintegration.

We have seen that the fundamental function of the living substance consists in alternate disintegration and reintegration. The shapeless slice of the trumpet-animalcule is left a fragment of a chemical whole. By dint of its unsaturated chemical affinities it manages by degrees to reconstruct through assimilation of complemental material the chemical whole of which it forms part. This, indeed, is sufficiently wonderful, but it is what actually and visibly occurs.

When an infusorium, such as Paramecium aurelia, the little slipper-animalcule, undergoes fissiparous division, its upper half reconstructs a lower half, and vice versa. If reproduction is effected by budding, the bud has to be regarded as a chemical fragment capable, by force of inwrought affinities, to reintegrate the adult organism. The same with every other reproductive germ.

This gradual process of reintegration is what is called growth; another hitherto occult occurrence which receives here its natural explanation.

Adherents of the cell-theory will object, that, though even all this were true so far as unicellular organisms are concerned, the reproduction of multicellular beings would demand a different explanation. The answer to this is, that the complex organism is not a multicellular being, not a being pierced together by numberless animalcules, called cells, which unconsciously and most miraculously co-operate in performing the aimfully interdependent functions of life.

A highly organized infusorium, a so-called unicellular being, encompasses within its unitary structure all differentiations essential to life. Some lower kinds of turbellaria have hardly more specialized structures than such infusoria. Yet because a number of nucleated bodies are discovered as constituents of their structures, it is believed that, though constructed after the exact model of our unicellular infusoria, this has been accomplished by a swarm of autonomous cell-beings ranging themselves into exact organic position, so as to faithfully imitate the model. This organizing feat could be achieved by them only by means of an inconceivable and therefore miraculously aimful activity, which to assume is contrary to reason. In my opinion such a miraculous requirement imposed upon elementary beings is itself a sufficient reductio ad absurdum of the cell-theory—of the theory that we are not ourselves autonomous individuals, but a whole city full of independent citizens.

Some turbellaria multiply like infusoria by spontaneous fissiparous division. Other kinds form strings of only partly divided individuals, which keep fastened together though they have separate mouths and alimentary canals. In others again the different individuals forming a chain are less divided from one another, being indeed so blended together as to form segments of a compound individual, with but one mouth and a continuous alimentary canal. If this complex worm be divided anywhere along its length, each segment will reproduce the entire being with its exact number of segments, a certain indication that complete unification of its entire living substance has been established. Its functional reproduction is effected by definite germs specialized and localized for the purpose, but constituting chemical fragments just the same as any artificially divided part.

During further phylogenetic elaboration each segment of the complex organism undergoes additional structural and functional specifications. The muscular layer of the ectoderm, for instance, at first undifferentiated, becomes split up into a transverse and a longitudinal layer; these into special muscular bands, and these again into a number of fibres.

I ask, if it is even remotely plausible that the reverse has been the case; that separate muscular cell-units have intelligently ranged themselves so as to gradually compose more and more complex and molecularly efficient muscular structures?

The order of phylogenetic development from homogeneity of the substance of the muscular layer to its gradual differentiation into separate muscles, and these eventually into separate fibres, disproves sufficiently the assumption of autonomous cell-beings.

It is the same with regard to all differentiations and specifications occurring in the entodermic layer, as well as in the ectodermic layer of the organic individual.

That worms, formed of individuals blended together during arrested fissiparous division, afford the groundwork for highest modes of differentiation and specification is proved by their being the foundation upon which the highly complex organization of insects is notably wrought.

I am happy to say that prominent biologists are beginning to realize, that despite ontogenetic appearances to the contrary, the complex organism is not a mere aggregate of inferior beings, but an essentially indiscerptible and infinitely higher individual.

Professor Frommann, in the article "Zelle," published 1890 as part of the Real-Encyklopædie der gesammten Heilkunde, sums up our present knowledge regarding cells in the following words: "According to what has been brought forward, we can no longer, as was formerly the case, regard the body as being formed by a mere conglomerate of cells, completely separated from one another by membranes and having independent lives. There exist, on the contrary, in the tissues and organs such numerous connections between equal and disparate cells, that it is entirely justifiable to regard the body as a unitary mass of living substance, as a synplasm."

And Strasburger in a recent inaugural address acknowledges the unity of the organic individual. He says: "Until recently it was accepted that there existed no communication between the plasma of plant-cells. It had to be asked, how under such conditions is the co-operation of the sundry cells in the service of the organism as a whole at all possible, and how can the plant as a unitary being be thus formed. The problem found its solution in the discovery that the plasm of the different cells is connected by protoplasmic filaments. These traverse from cell to cell, and cause thus the living substance of a plant to be continuous. The plant, therefore, like the animal, constitutes a unitary living organism."

This is a good beginning in the right direction, and I confidently await further corroboration of the views forced upon me, long ago, by the diligent study of the living substance.

[*Presented to the Texas Academy of Science, April 5, 1895.*]

THE CRITERION FOR TWO-TERM PRISMOIDAL FORMULAS.

BY DR. GEORGE BRUCE HALSTED.

I.

The word Prismoid is a good old mathematical term, and has always had and kept the meaning recognized, for example, by Charles Hutton in his Mathematical Dictionary, the new edition of which was published in London in 1815. There, under the word, you read as follows: "Prismoid . . . Its ends are any dissimilar parallel plane figures of the same number of sides; the upright sides being trapezoids. If the ends of the prismoid be bounded by dissimilar curves, it is sometimes called a cylindroid." This meaning the word maintained down to my own college days at Princeton, where I remember it in the text-books of Loomis, and still maintains, see for example the *Mensuration*, in the latest edition of the Encyclopædia Britannica.

But the formula usually called by the name of this solid, but herein to be called Newton's three-term Prismoidal formula, went far beyond the prismoid in its exact applicability.

Newton (Methodus Differentialis, published 1711; further carried out by Cotes, on Newton's Meth. Dif. in the works collected posthumously, 1722) showed how an area or volume could be evaluated approximately from parallel cross-sections, and especially that from three cross-sections, following at the same distance apart, we get approximately the enclosed segment if we add the outer sections to four times the mid section and multiply the sum by a sixth of the distance between the outer sections.

Maclaurin (1742, Fluxions, No. 848), referring both to Newton and Cotes, made additions which indicate that this special rule of Newton's, the Old Prismoidal Formula, gives the content exactly when every section parallel to the base is a function of its distance from it of a degree not higher than the third,

$$f(x)=n_0+n_1x+n_2x^2+n_3x^3.$$

After a century of applications to areas and volumes, in 1842 Steiner conquered it by elementary geometry, and indicated its applicability to warped or ruled surfaces.

But, in seeming ignorance of all this, American engineers began and continue to give their time to doing over again what had been already done.

In his Field-Book, edition 1854, Henck says: "A prismoid is a solid having two parallel faces, and composed of prisms, wedges, and pyramids, whose common altitude is the perpendicular distance between the parallel faces." This is ambiguous and stupid. It defines nothing. The old prismoid may be cut up into prisms, wedges, and pyramids, but this is not at all its essence, and, to me, does not even definitely suggest the more general solid for which in 1881 I introduced to English readers the word Prismatoid, now adopted by the Encyclopædia Britannica.

The definition appearing in four successive editions of my Mensuration (Ginn & Co.) and four successive editions of my Elements of Geometry (Wiley & Sons), is as follows:

A Prismatoid is a polyhedron whose bases are any two polygons in parallel planes, and whose lateral faces are triangles determined by so joining the vertices of these bases that each lateral edge, with the preceding, forms a triangle with one side of either base.

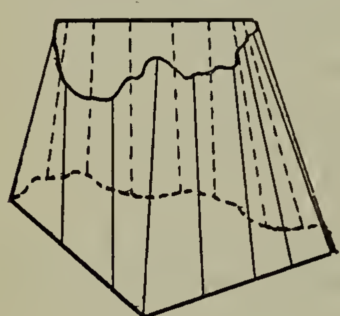

FIG. 1.

The prismatoid is identifiable with the prismoid by considering a triangle as a trapezoid with one null side. The word is due to Wittstein (1860). It is simply the German form of the word prismoid, and now having served its purpose to mark the importance of these triangular trapezoids, it is doubtful if it be worth retaining.

The Newtonian formula, misnamed prismoidal, corresponded in range neither with the prismoid nor the prismatoid, nor their limiting form, the cylindroid. Maclaurin had indicated exactly its applicability. Yet, in 1857, fifteen years after Steiner, Gillespie reaped honor from merely showing that the formula is applicable to the space covered by the hyperbolic-paraboloid.

In 1858 Chauncey Wright in the Mathematical Monthly (Cambridge, Mass.), in a special investigation devoted to the subject, obtained by the Differential Calculus (which was not at all necessary) the cubic equation of applicability, but missed Weddle's beautiful rule.

Prof. E. W. Hyde, in 1876, in an article entitled Limits of the Prismoidal Formula, did not even get as far as his predecessors.

In an extended memoir on the Prismoidal Formula, in Van Nostrand's Magazine, 1879, J. W. Davis, again by the differential calculus, reaches this cubic.

In Halsted's Mensuration (1881) the applicability of the old or three-term prismoidal formula is exhaustively treated and without the calculus. For readers of the calculus the following may be given as a paraphrase of the method in Todhunter Int. Cal., p. 173, of showing that this formula applies exactly to all solids whose cross-sections are cubic functions of the section-height:

$$\text{If}\quad A_x = f(x) = n_0 + n_1 x + n_2 x^2 + n_3 x^3,$$

then $f(o) + 4f(\tfrac{1}{2}a) + f(a) = n_0$

$$+4n_0 + 2an_1 + a^2 n_2 + \tfrac{1}{2}a^3 n_3$$

$$+\ n_0 +\ an_1 + a^2 n_2 +\ a^3 n_3$$

$$= 6n_0 + 3an_1 + 2a^2 n_2 + \tfrac{3}{2}a^3 n_3.$$

Thus $D = \tfrac{1}{6}a[B_1 + 4M + B_2] = \tfrac{1}{6}a[f(o) + 4f(\tfrac{1}{2}a) + f(a)]$

$$= \tfrac{1}{6}a[6n_0 + 3an_1 + 2a^2 n_2 + \tfrac{3}{2}a^3 n_3] = an_0 + \tfrac{1}{2}a^2 n_1 + \tfrac{1}{3}a^3 n_2 + \tfrac{1}{4}a^4 n_3.$$

But by the calculus this is the exact volume of the solid, since it is

$$= \int_0^a f(x).$$

This investigation is faulty, and does not fix the limit of applicability, since it says nothing to show that the conditions are satisfied only by functions which have no fourth or higher powers. This is proved in my Mensuration without the calculus. For readers of the calculus the following method may be of interest:

Measuring x on a line normal to which the sections are made, let $A_x = f(x)$ be the area of the section at the distance x from the origin. Let three sections be made through any solid at the distance $(x-h)$, the distance x, and the distance $(x+h)$ from the origin. Then $f(x-h)$, $f(x)$, $f(x+h)$ will be the areas of these sections, and the old Prismoidal Formula, for the volume between the bases $f(x-h)$ and $f(x+h)$ gives

$$\tfrac{1}{3}h[f(x-h) + 4f(x) + f(x+h)].$$

But the volume is the integral of the differential solid $f(x)dx$ between the limits $x-h$ and $x+h$.

$$\int_{x-h}^{x+h} f(x)dx = \int f(x+h)dx - \int f(x-h)dx.$$

If the function f fulfills the conditions of the Prismoidal Formula, we have, by equating the two expressions for the volume,

$$\int f(x+h)dx - \int f(x-h)dx = \tfrac{1}{3}h[f(x-h) + 4f(x) + f(x+h)].$$

To find what form of f will satisfy the equation, develop both its members by Taylor's Theorem.

The first member becomes (A)

$$\int [f(x) + f'(x)h + f''(x)\frac{h^2}{2} + f'''(x)\frac{h^3}{2\times 3} + \text{etc.}]dx$$

$$-\int [f(x) - f'(x)h + f''(x)\frac{h^2}{2} - f'''(x)\frac{h^3}{2.3} + \text{etc.}]dx$$

$$= \int [2f'(x)hdx + 2f'''(x)\frac{h^3}{2.3}dx + \text{etc.}]$$

$$= 2f(x)h + f''(x)\frac{h^3}{3} + f''''(x)\frac{h^5}{3.4.5} + \text{etc.}$$

The second member becomes (B)

$$\tfrac{1}{3}h[f(x)-f'(x)h+f''(x)\frac{h^2}{2}-\text{etc.}+4f(x)+f(x)+f'(x)h+f''(x)h^2+\text{etc.}]$$

$$=\tfrac{1}{3}h[6f(x)+f''(x)h^2+f''''(x)\frac{h^4}{3.4}+\text{etc.}$$

$$=2f(x)h+f''(x)\frac{h^3}{3}+f''''(x)\frac{h^5}{36}+\text{etc.}$$

Comparing the last members of (A) and (B), we find the equation,

$$2f(x)h+f''(x)\frac{h^3}{3}+f''''(x)\frac{h^5}{60}+\text{etc.}=$$

$$=2f(x)h+f''(x)\frac{h^3}{3}+f''''(x)\frac{h^5}{36}+\text{etc.}$$

Therefore the old Prismoidal Formula applies exactly to *all solids* contained between two parallel planes, of which the area of any section parallel to these planes can be expressed by a rational integral algebraic function, of a degree not higher than the third, of its distance from either of these bounding planes or bases. And in general it applies universally to no other solids.

Thus the cubic

$$A_x=n_0+n_1x+n_2x^2+n_3x^3$$

expresses the law of variation in magnitude of the plane generatrix of old prismoidal spaces.

But our prismatoid needs only a quadratic. This is readily proved. Any prismatoid may be divided into tetrahedra, all of the same altitude

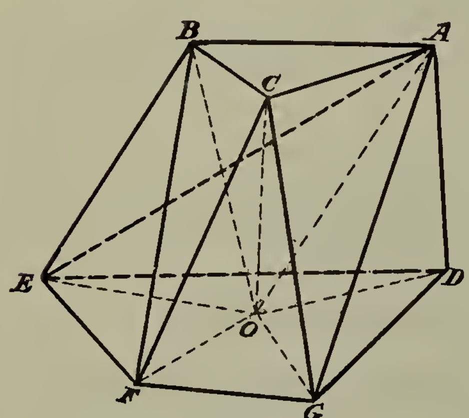

FIG. 2.

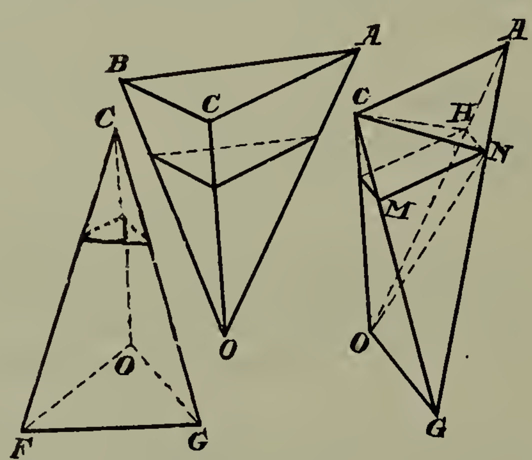

FIG. 3.

as the prismatoid; some having their apex in the upper base of the prismatoid, and for base a portion of its lower base; some having base in the upper, and apex in the lower base of the prismatoid; and others having for a pair of opposite edges a sect in the plane of each base of the prismatoid. A section A_x of a tetrahedron in the first position equals

$$\frac{(a-x)^2B_1}{a^2}.$$

For the second position

$$A_x = \frac{x^2 B_2.}{a^2}$$

For the third position, if the mid section $= \frac{1}{4}\pi a^2$,

$$A_x = \pi(ax - x^2)$$

(see Halsted's Geometry, page 250, whence are taken figures 4 and 5, and where was first given the Theorem: If a sphere be tangent to the parallel planes containing opposite edges of a tetrahedron, and the sections made in the globe and tetrahedron by one plane parallel to these are equivalent, sections made by any parallel plane are equivalent).

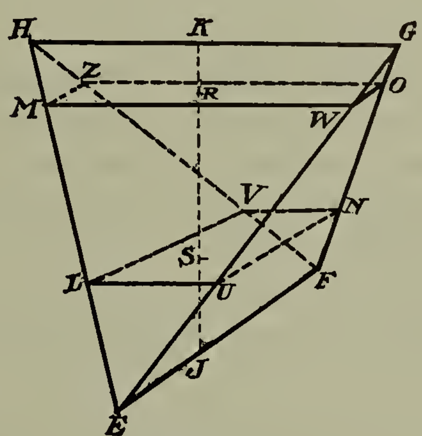

FIG. 4.

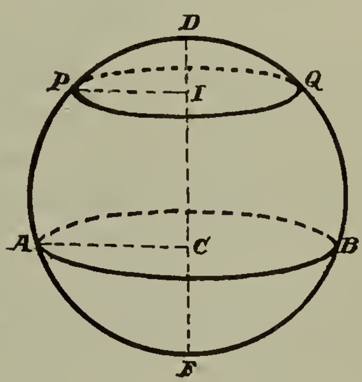

FIG. 5.

But from the mid section $\frac{1}{4}\pi a^2$ of such a tetrahedron we can obtain the mid section of any tetrahedron in this position by three consecutive changes, each of which is equivalent to multiplication by a number. Representing the product of these three numbers by n, the desired mid section $= \frac{1}{4}n\pi a^2$, and any section $A_x = n\pi(ax - x^2)$.

Thus in any prismatoid any cross-section is only a quadratic function of its distance from either base. Therefore in employing for its volume the old three-term formula, we have been using a bear-trap to catch a mouse.

For all solids whose section is a function of degree not higher than the second, or

$$A_x = f(x) = n_0 + n_1 x + n_2 x^2,$$

the volume is $\int_0^a f(x) = n_0 a + \frac{1}{2} n_1 a^2 + \frac{1}{3} n_2 a^3$.

Measuring x from one base B_1, we have

$$A_0 = B_1 = n_0.$$

Then $$A_a = B_2 = B_1 + n_1 a + n_2 a^2.$$

We see at once that any cross-section whatever, if known in addition to the altitude and bases, will give us the volume.

The next advance, the discovery of the most important two-term prismoidal formula, occurs in a paper so little known (I read it for the first time March 7, 1896, in a MS. copy lent me by Prof. T. U. Taylor) that a translation of it is here given:

ON THE THEORY OF THE PRISMOID.

BY HERMANN KINKLIN,

Teacher at the Gewerbschule in Basel.

[Grunert's Archiv, Vol. xxxix, 1862, pp. 181-85.]

Suppose in space any continuous system of straights, the last returning into the first, then these enclose an incompletely bounded space. Cutting this space by two parallel planes, meeting each straight of the system, cuts out of it a solid called a prismoid. The two parallel plane cuts are called bases, and the surface enclosed from the system of straights (a ruled surface returning into itself) is called the lateral surface.

This lateral surface is in general curved, but may in special cases consist of plane pieces.

Inversely, however, it can be said that the lateral surface in general consists of plane pieces, which in special cases may become an infinity and make a curved surface.

Starting from this conception, in whatever follows the bases will be looked upon as any rectilineal polygons with relatively parallel sides [including zero sides], and the lateral surface as consisting of trapezoids side by side [including triangles], which immediately join the parallel sides of the bases. Special forms of the prismoid are, among others, the pyramid and cone, prism and cylinder, the frustum of a pyramid, the hyperboloid of one nappe, the obliquely truncated three-sided prism, the tent, the tetrahedron, etc.

Altogether the prismoid is one of the most general body forms, and is worthy of theoretical and practical interest, the latter all the more as its content can be given by a very simple expression obtainable by most elementary means.

The following properties appear not to have been noticed as yet. They concern size comparison of parallel plane cuts through the prismoid.

Suppose through it three equidistant plane cuts of which the two outer are the bases, and the middle is called the mid section.

Designate the area of these three surfaces respectively as B_1, B_2, M, and the distance between B_1 and B_2, the altitude, by a, so that M is $\frac{1}{2}a$ distant from B_1, as also from B_2

The sides of the mid section are the arithmetic means of the parallel sides of the bases.

The size of M is in general not immediately dependent upon B_1 and B_2, though it may be expressible by means of their sides and angles.

Only in some special cases, as for example the prism, the pyramid and its frustrum, can M be expressed directly by B_1 and B_2.

On the other hand every section S parallel to these three can be made to depend upon B_1, B_2, M, and its distances from these, as will now be shown.

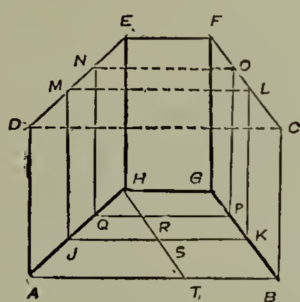

FIG. 1.

Consider first the plane trapezoid ABGH (Fig. 1). Let JK be its medial, that is the sect joining the mid points of the non-parallel sides AH and BG.

Let PQ be any parallel to JK.

The distance of the base lines AB and GH from one another call h, the distance from AB to PQ call h_1, and that from QP to GH call h_2.

Draw the straight HRST parallel to BG. Call the area of ABGH=T; of JKGH=T_1; of GHQP=T_2; of BGHT=P; then KSGH=$\frac{1}{2}$P, and GHRP=Ph_2/h.

From the similarity of the triangles ATH, JSH, QRH follows immediately that $(T-P):(T_2-Ph_2/h)=h_2:h_2^2$, and $(T_1-\frac{1}{2}P):(T-Ph_2/h)=\frac{1}{4}h^2:h_2^2$.

Eliminating P gives an equation from which T_2 is easily determined; thus

$$T_2=Th_2(h_2-h_1)/h^2+T_1 4h_1h_2/h^2 \quad . \quad . \quad . \quad . \quad . \quad (1).$$

In this substituting $h-h_1$ for h_2 gives

$$T_2=T-(3T-4T_1)h_1/h+(2T-4T_1)h_1^2/h^2.$$

Hence T_2, that is the area of the trapezoid GHQP, is a linear function of the trapezoids ABGH and JKGH, and a quadratic function of the distance h_1 of its base QP from AB.

This settled, suppose a prismoid with base B_1 in the plane of the paper, and project it perpendicularly upon this plane; then the projections of all sections parallel to B_1 are equal to the sections themselves. Let ABCDEFGH be such a projection of a four-sided prismoid (Fig. 1) and call the areas ABCD=B_1; EFGH=B_2; JKLM=M; NOPQ=S. Call the distances from B_1 to B_2, from B_1 to S, from B_2 to S respectively a, a_1, a_2.

Then from (1)

$$GHPQ=ABGH(h_2-h_1)h_2/h^2+JKGH\,4h_1h_2/h^2;$$

or since h, h_1, h_2 are respectively proportional to a, a_1, a_2;

$$GHPQ=ABGH(a_2-a_1)a_2/a^2+JKGH\,4a_1a_2/a^2 \quad . \quad . \quad . \quad (2).$$

Similar relations hold for the surfaces BCFG, CDEF, ADEH.

But $S-B_2=GHPQ+QNEH-ONEF+POFG$;
$B_1-B_2=ABGH+ADEH-CDEF+BCFG$;
$M-B_2=JKGH+JMEH-LMEF+KLFG$.

Combining with these the relation (2) and the three corresponding to it gives

$$S-B_2=(B_1-B_2)(a_2-a_1)a_2/a^2+(M-B_2)4a_1a_2/a^2,$$

or, since $a=a_1+a_2$,

$$a^2S=(a_2^2-a_1a_2)B_1+(a_1^2-a_1a_2)B_2+4a_1a_2M \quad . \quad . \quad . \quad (3);$$

or, also,

$$S=B_1-(3B_1+B_2-4M)a_1/a+(2B_1+2B_2-4M)a_1^2/a^2,$$

which determination clearly holds also for every other prismoid.

Therefore in the prismoid the area of a section parallel to the bases is a linear function of the bases and the midsection, and a quadratic function of its distance from a base.

Plotting on a plane the altitudes a_1 as abscissas and the areas S as ordinates in a system of rectangular coördinates, the extremity of the ordinate has for locus a parabola with axis parallel to the axis of ordinates. (Fig. 2.) [Not reproduced in this translation.]

This parabola may meet the axis of abscissas at no point, or touch it at one point or cut it in two points.

The first is the case when no section is null, as, say, in the hyperboloid of one nappe.

The second is the case when only one section is null, as in the pyramid.

Finally the third occurs if two sections are null, as is the case for the tetrahedron when the sections are taken parallel to two opposite edges. In this case the sections lying between the two vanishing sections are positive, if those lying without are taken negative, and inversely. However, such negative surfaces will not be further considered here, as, indeed, they present no difficulties.

The volume of the prismoid between the bases B_1 and B_2 can be found by various methods. It is, for example, also given by the surface covered by the ordinates of the just mentioned parabola which lie between B_1 and B_2.

Very elegant is the deduction by Professor Steiner, who divides the prismoid into pyramids from any point in the mid section.

It can be deduced from the last given value of S by multiplying it by dx and integrating with respect to x between the limits o and a.

This gives easily $V=\frac{1}{6}a(B_1+B_2+4M)$, as is known. To express the volume, instead of by M, by any chosen section S distant a_1, a_2 from B_1, B_2, (3) gives

$$4M=B_1+B_2+2S+(S-B_1)a_2/a_1+(S-B_2)a_1/a_2,$$

which gives for V the expression,

$$V=\tfrac{1}{6}a[2(B_1+B_2+S)+(S-B_1)a_2/a_1+(S-B_2)a_1/a_2 \quad . \quad . \quad (4).$$

With what precedes, many other considerations are connected, of which some will be mentioned, since they lead to remarkable results. Consider first the relation to one another of two sections made at respectively equal distances from the bases.

Let the sections be S_1 and S_2; their distances from the B_1 base a_1 and a_2, then from (3) follows,

$$a^2S_1=(a_2^2-a_1a_2)B_1+(a_1^2-a_1a_2)B_2+4a_1a_2M,$$
$$a^2S_2=(a_1^2-a_1a_2)B_1+(a_2^2-a_1a_2)B_2+4a_1a_2M.$$

Hence follows by subtraction, since $a=a_1+a_2$,

$$S_1-S_2=(B_1-B_2)(a_2-a_1)/a \quad . \quad . \quad . \quad . \quad . \quad (5);$$

that is the difference of two sections at equal distances from the bases is to the difference of the bases as their distance apart is to the whole altitude.

If the two just mentioned sections divide the altitude a of the prismoid into three equal parts, they may be called one-third sections, and if S_1 be the further from B_1, then $a_1=\tfrac{2}{3}a$, and $a_2=\tfrac{1}{3}a$; consequently,

$$S_2-S_1=\tfrac{1}{3}(B_1-B_2);$$

and the formula (4) for volume becomes

$$V=\tfrac{1}{4}a(B_1+3S_1). \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6).$$

This last expression is remarkable for this, that to get by it the volume of the prismoid are necessary only the altitude and two parallel sections, namely, the lower base B_1 and the upper one-third section S_1, or the upper base B_2 and the lower one-third section S_2.

Taking B_1+3S_1 as sum of four magnitudes, the last equation gives: The prismoid is equivalent to a prism of equal height whose base is the arithmetical mean between the lower base and triple the upper one-third section of the prismoid."

While working on this subject, in May, 1895, Prof. T. U. Taylor discovered that in the third edition of "Haupsätze der Elementar-Mathematik," by F. G. Mehler, Berlin, 1864, page 121, after showing (as on page 122 of Halsted's Mensuration) that Newton's rule holds for the volume of solids whose cross-section is a cubic function of its altitude; for which therefore the volume

$$V=ah+\tfrac{1}{2}bh^2+\tfrac{1}{3}ch^3+\tfrac{1}{4}dh^4 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (7),$$

the author adds: "Remark.—For $d=o$ we can put (7) in the form

$$V=\tfrac{1}{4}h[a+3(a+b\,\tfrac{2}{3}h+c(\tfrac{2}{3}h)^2)],$$

consequently if z is the section parallel to a at the distance $\tfrac{2}{3}h$,

$$V=\tfrac{1}{4}h(a+3z)."$$

In 1878, in Schlömilch's Zeitschrift, Becker published what, not having access to the original, I will quote from Halsted's Mensuration, 1881:

"For all solids whose section is a function of degree not higher than the second, or $A_x = q + mx + nx^2$, q, m, n, and consequently A_x for all values of x, are determined if the value of A_x for three values of x is known.

"Measuring x from B_1 we have $A_0 = B_1 = q$.

"Supposing we know the section at $1/z$ the height of the solid above B_1, we have for determining m and n the two equations,

$$B_2 = B_1 + ma + na^2,$$

$$A_{\frac{a}{z}} = B_1 + ma/z + na^2/z^2.$$

"For the volume of the solid we have, by Cor. 2, page 123,

$$V = B_1 a + \tfrac{1}{2} ma^2 + \tfrac{1}{3} na^3,$$

$$\text{or } V = [a/6(z-1)][(2z-3)B_2 - (z-1)(z-3)B_1 + z^2 A_{\frac{a}{z}}].$$

"For $z = 3$, this gives

$$V = \tfrac{1}{4} a (B_2 + 3A_{\frac{a}{3}}).$$

"Again, for $z = 1\tfrac{1}{2}$,

$$V = \tfrac{1}{4} a (B_1 + 3A_{\frac{2}{3}a}).$$

"These give the following theorem: 100. To find the volume of a prismatoid, or of any solid whose section gives a quadratic:

"RULE: *Multiply one-fourth its altitude by the sum of one base and three times a section distant from that base two-thirds the altitude.*"

On the last sheet of the MS. of Kinklin's "Theory of the Prismoid," lent me by Prof. T. U. Taylor, I find the following in continuation of the MS. in the handwriting of the copyist:

"Grunert's Archiv, Vol. LXII, 1879, pp. 440–3.

"NEW EVALUATION OF THE VOLUME OF A PRISMATOID.

"*Th. Sinram.*

"Since long it has been customary in evaluating the Prismatoid, as also the Obelisk, to use both bases, the mid cross-section, and the altitude of the solid, according to the formula

$$\text{Vol.} = \tfrac{1}{6} h [G + g + 4D].$$

"In calculating these bodies the thought was always with me (J. K. Becker has handled this question in his 'Combinatorik'), whether a formula could be deduced geometrically in which should appear either only two cross-sections, or, indeed, only one. Then the general formula would be

$$\text{Vol.} = Dh/a.$$

"I have attained the first, yet not the last, since a will be irrational, whereby" . . .

The sheet of MS. breaks off thus in the midst of a sentence, and this is all I have seen, but is enough to clearly indicate the content of this important paper. Whatever he may have obtained from Becker's "Combinatorik," of which I had never before heard, it is certain that Sinram obtained geometrically a general formula for the prismoid in terms of two cross sections, thus demonstrating by elementary mathematics in 1879 the existence of an unlimited number of such two-term formulae, involving sections of prismoid only.

This result was published fifteen years later by Professor W. H. Echols of the University of Virginia in the Annals of Mathematics, Vol. IX, No. 1, in an article "On the mean-area of the Prismoid." But Sinram had also investigated the mean area and indicated even a one-term prismoidal formula, using a true mean area, only for this as he says, the divisor in the one-term formula would be irrational.

Since Sinram reached all these results geometrically, this part of the subject was exhausted.

II.

Leaving for a moment these innumerable true two-term prismoidal formulas, where the two sections are really cross sections of the prismoid itself, mention may be made of a pseudo two-term prismoidal formula, which uses an extraneous area, that of the so-called "associate-cone"-base, which is not a section of the prismoid.

If a straight passing always through one same point in the plane of one base of a prismoid moves so as to be always parallel to the straight generating the prismoid, it cuts out a cone between the basal planes. This is named the "associate cone." Calling the area of its base B_c, the volume of the prismoid

$$V = a(M + \tfrac{1}{12}B_c).$$

This, in a paper in Scientiae Baccalaureus, Feb., 1891, I correctly attributed to Koppe (Crelle's Journal, Vol. 18, p. 275; afterwards in his "Ein neuer Lehrsatz der Stereometric," by Karl Koppe, 1843, § 5, p. 5.)

But in that paper I deduced it as an immediate corollary from a theorem there proved given in my Mensuration (1881) as follows: Twice the volume of the segment of a ruled surface between parallel planes is equivalent to the sum of the cylinders on its bases, diminished by the cone whose vertex is in one of the parallel planes and base in the other, and whose elements are respectively parallel to the lines of the ruled surface.

This gives for the "mean-area" of the prismoid (that area whose product by the altitude is the volume) the expression

$$A = \tfrac{1}{2}(B_1 + B_2) - \tfrac{1}{6}B_c; \text{ or:}$$

The mean area of a prismoid equals the half-sum of the bases, less one-sixth the base of the associate cone.

This theorem which Professor Taylor has since called "the Associate

Theorem," I also very naturally but incorrectly attributed to Koppe. Professor Taylor having procured a copy of Koppe's book, pointed out that no mention or even hint of the Associate Theorem occurs therein.

Koppe's own demonstration of his theorem is singularly elementary, but utterly different from the one I gave in Scientiae Baccalaureus. His theorem as he states it is as follows:

On page 5 of "Ein neuer Lehrsatz der Stereometrie," by Karl Koppe, 1843, §5. "Theorem:

"Each obelisk is equal to the sum of a prism and a pyramid, both of like altitude with the obelisk, and whose bases correspond in the angles with the bases of the obelisk, while the sides of the base of the prism equal the half sum and the sides of the base of the pyramid the half difference of the like-lying sides of the two bases of the obelisk."

§6, Art. 7, p. 20.—"The application of our theorem extends in general to all bodies with two parallel bases and any curved lateral surface on which straight lines can be drawn, whatever the curve lines be which bound the bases.

"As example may serve a solid whose two bases are ellipses."

§8, p. 25.—"If in a trapezoid the smaller parallel decreases to zero, the trapezoid passes over into a triangle; one may therefore consider the triangle as a special case of the trapezoid, which arises if the smaller parallel vanishes. Our theorem consequently must still hold also for such solids as have parallel bases, and for lateral surfaces partly trapezoids, partly triangles."

Instead of the older and better name prismoid, Koppe used the word Obelisk, suggested by a friend of his, an official in Berlin. There are articles on these Koppe Obelisks in Crelle, Vols. 18, 23, 25, and Grunert's Archiv, Vols. 9 and 11.

What Prof. T. U. Taylor has called the "Associate Theorem" is given with an elementary proof in the well known "Elemente der Mathematik" of Dr. Richard Baltzer, second edition, 1867, where it is thus stated: "The segment of any ruled surface contained between parallel planes can be expressed by two cylinders and a cone. Construct between the parallel planes both the cylinders whose bases are those surfaces of the segment lying on the parallel planes, and also the associate cone of the ruled surface, whose vertex lies on one of the parallel planes, and whose elements in order lie parallel to the straights of the ruled surface. Twice the solid-segment is the sum of the two cylinders, less the associate cone."

$$V = a\tfrac{1}{2}(B_1 + B_2) - a\tfrac{1}{6}B_c.$$

III.

By far the simplest and most valuable of all prismoidal formulas is that due to Kinklin, written in Halsted's Geometry

$$D=\tfrac{1}{4}a\ (B+3T),$$

where D is an abbreviation for prismoid, a its altitude, B one base (either), and T the cross section at $\tfrac{2}{3}a$ from the chosen base B. This two-term formula may be proved by elementary geometry very simply as follows:

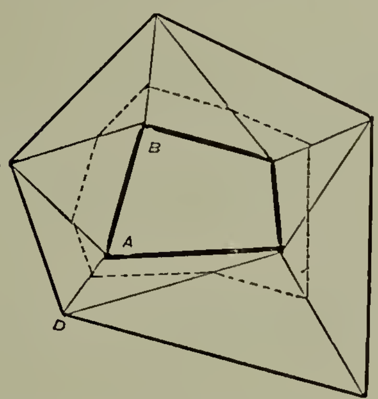

FIG. 6.

By planes through the edges project the prismoid perpendicularly on the lower base B. These planes cut the prismoid into one prism and a series of pyramids, some like ACD (Fig. 6) with three-sided base in B, the others all like ABC with four-sided base in the projecting-plane AB. This latter pyramid equals a prism with base ABC and altitude a, lacking a pyramid with base ABC and altitude a. Therefore, putting B for ABC, its volume is $\tfrac{2}{3}a$B. Its cross section T is

$$(ABC—\tfrac{4}{9}ABC)=\tfrac{5}{9}ABC=\tfrac{5}{9}B.$$

Consequently its volume is $\tfrac{1}{4}a(B+3T)=\tfrac{1}{4}a(B+\tfrac{5}{3}B)=\tfrac{2}{3}a$B. Likewise the volume of the pyramid ACD is given by the formula $\tfrac{1}{4}a(B+3T)$, as is also that of the prism. Therefore the algebraic sum of all these, that is the volume of the whole prismoid, is given by the formula $D=\tfrac{1}{4}a(B+3T)$.

IV.

The *criterion* for two-term prismoid formulas is

$$\tfrac{1}{3}xy=\tfrac{1}{2}x+\tfrac{1}{2}y-1.$$

Proof. In the formula already established by elementary considerations in Section I of this paper for the area of any cross-section,

$$A_x=f(x)=n_0+n_1x+n_2x^2,$$

let x be $1/y$ part of the altitude, then

$$S_{a/y}=n_0+n_1a/y+n_2a^2/y^2. \quad \text{Symmetrically}$$

$$S_{a/x}=n_0+n_2a/x+n_2a^2/x^2.$$

Hence $\quad n_1=[x^2S_{a/x}-(x^2-y^2)n_0-y^2S_{a/y}]/(x-y)a.$

$$n_2=[xy^2S_{a/y}+(x^2y-xy^2)n_0-x^2yS_{a/x}]/(x-y)a^2.$$

Therefore the volume

$$V=an_0+\tfrac{1}{2}a^2n_1+\tfrac{1}{3}a^3n_2, \text{ becomes}$$

$$V=an_0+\tfrac{1}{2}ax^2S_{a/x}/(x-y)-\tfrac{1}{2}an_0(x+y)-\tfrac{1}{2}ay^2S_{a/y}/(x-y)+$$
$$\tfrac{1}{3}axy^2S_{a/y}/(x—y)+\tfrac{1}{3}an_0xy—\tfrac{1}{3}ax^2yS_{a/x}/(x—y).$$

Consequently n_0 is eliminated whenever

$$1-\tfrac{1}{2}(x+y)+\tfrac{1}{3}xy=0.$$

This beautiful *criterion*, graphically an equilateral hyperbola, is in marked contrast to the results given by Prof. W. H. Echols.

Prof. Echols gives as his position-curve an ellipse

$$\frac{x^2}{\frac{1}{2}}+\frac{y^2}{\frac{3}{2}}=1,$$

a form in which of necessity one variable enters differently from the other, and therefore not a true criterion, since in reality the two sections enter indistinguishably.

If for my variables their reciprocals be taken, then $\tfrac{1}{3}xy=\tfrac{1}{2}x+\tfrac{1}{2}y-1$ becomes $2=3x+3y-6xy$, a less desirable form of the equation, though of course the same criterion and the same criterion curve, the equilateral hyperbola. I presented this criterion to the Texas Academy of Science on April 5, 1895. It has never been anticipated.

Assuming the criterion, we have left for the volume

$$V=a(\tfrac{1}{2}x^2-\tfrac{1}{3}x^2y)/(x-y)S_{a/x}-a(\tfrac{1}{2}y^2-\tfrac{1}{3}xy^2)/(x-y)S_{a/y}.$$

This, reduced by use of the criterion, gives at once

$$V=a[\tfrac{1}{2}(3-y)/(x-y)+\tfrac{1}{4}]S_{a/x}+a[\tfrac{1}{2}(3-x)/(y-x)+\tfrac{1}{4}]S_{a/y}.$$

Of this most instructive and self-explanatory two-term prismoidal formula all others are merely special cases.

Writing for x and y their reciprocals, it takes the form

$$V=a[\tfrac{1}{2}(1-2y)/(x-y)]S_{a/x}+a[\tfrac{1}{2}(1-2x)/(y-x)]S_{a/y}.$$

From the criterion

$$\tfrac{1}{3}xy=\tfrac{1}{2}x+\tfrac{1}{2}y-1,$$

and its formula for mean area,

$$A=[\tfrac{1}{2}(3-y)(x-y)+\tfrac{1}{4}]S_{a/x}+[\tfrac{1}{2}(3-x)/(y-x)+\tfrac{1}{4}]S_{a/y},$$

we get for z the coefficient of $S_{a/x}$,

$$z=x^2/(\tfrac{2}{3}x^2-2x+2),$$

and precisely the same form for the coefficient of the other section $S_{a/y}$.

This one relation gives all the coefficients, and is the equation to the coefficient curve.

[*Read before the Texas Academy of Science March 6, 1896.*]

PRISMOIDAL FORMULAE: WITH SPECIAL DERIVATION OF TWO-TERM FORMULAE.

BY THOMAS U. TAYLOR,

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INTRODUCTION.

The well known formula which bears the name of Sir Isaac Newton has so long been called *the* "prismoidal formula" that confusion has arisen in many text-books as to its proper application. It is usually established for the prismoid, and its allied forms—the prismatoid and cylindroid—and its more general application to the volume of any solid whose cross-sections are cubic functions of their distance from one base is entirely omitted, notwithstanding the fact that its application to these higher solids can be established without the use of the calculus. The first real prismoidal formula was established by Karl Koppe in 1838, and it is a two-term formula, as can be seen by referring to these pages. I defer further remarks upon special formula till the next article (2).

Articles 8, 9, 10, 15, and 16 were read before the Texas Academy of Science May 3, 1895; articles 11, 12, 13, and 14 were read before the Cosmos Club of the University of Texas on May 4, 1895. All of articles 8–20 are extracts from my thesis at Cornell on "Prismoidal Formulæ," June, 1895.

THOS. U. TAYLOR.

Austin, Texas, March 6, 1896.

HISTORICAL NOTES.

Reference has already been made to the range of the Newtonian formula, and no allusion will be made to the various proofs of it, except that of Steiner. In 1842 Steiner, by elementary geometry, proved that the Newtonian formula gives the exact contents of a prismoid in its general sense. Four years before, in 1838, Karl Koppe published his celebrated formula in Crelle's Journal. I here call attention to the fact that the formula published is not the one that moderns have ascribed to him (see article 7). In 1843 this "New Theorem in Stereometry" was issued in a small pamphlet of 35 pages.

In the Journal of the Franklin Institute, December, 1857, page 372, W. M. Gillespie showed that the Newtonian formula applies to the volume of earthwork when the upper surface is generated by a straight line moving on two longitudinal straight lines, thus making the upper surface a hyperbolic paraboloid. This proof was based on elementary principles, but it had really been given long before. It can be readily shown that any cross-section is a quadratic function of its distance from either base, and therefore the Newtonian formula applies. Still the method of Gillespie's proof was elegant, and it has been widely copied.* In 1864 Mehler, in his "Elementar Mathematik," page 121, established the two-term formula where the volume is found by multiplying one-fourth of the altitude by the sum of either base and three times a section at two-thirds the altitude from such base. The method of his proof was as follows:

$$\text{If } S_x = a + bx + cx^2 + dx^3,$$

We have by Newton's formula

$$V = \frac{H}{6}(6a + 3bH + 2cH^2 + \tfrac{3}{2}dH^3).$$

If we make $x = \frac{2}{3}H$, we get the section G at two-thirds the altitude.

$$\therefore\ G = a + \tfrac{2}{3}bH + \tfrac{4}{9}cH^2 + \tfrac{8}{27}dH^3.$$

$$\text{But } V = \frac{H}{4}(4a + 2bH + \tfrac{4}{3}cH^2 + dH^3)$$

$$= \frac{H}{4}\left[a + 3\left(a + \tfrac{2}{3}bH + \tfrac{4}{9}cH^2 + \frac{dH^3}{3}\right)\right].$$

If $d = 0$, we have

$$V = \frac{H}{4}(a + 3G).$$

Professor Beman, of Ann Arbor, has called my attention to the fact this two-term formula was published by Hermann Kinklin in 1862, in Grunert's Archiv der Mathematik und Physik, Vol. XXXIX. Acting upon this reference hint, I secured a copy of Kinklin's proof of his two-term formula in May, 1895. Since the reading of this paper before the Texas Academy of Science on March 6, 1896, this MS. copy of Kinklin's work was furnished Dr. Halstead, and he has kindly printed a translation of it in his pamphlet on the criterion for two-term prismoidal formulæ just issued, where those interested can find it.

In 1894 Professor Echols, by the use of Elliot's Extension of Holditch's Theorem (Annals of Mathematics, November, 1894), showed that there is an infinite number of two-term formulæ. The present paper was primarily undertaken to establish this result by elementary mathematics.

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* See Gillespie's "Roads and Railroads."

2. DEFINITIONS.

I here append the following historic definition:

A *prismoid* is a solid whose parallel bases are polygons of the same number of sides, and whose side faces are trapezoids.

The term *prismatoid* was introduced by Wittstein in 1860, in "Das Prismatoid, eine Erweiterung der elementaren Stereometrie." It was defined as a solid with any two parallel polygonal bases, and whose side faces are triangles formed by joining the vertices of the bases so that each line with the preceding forms a triangle with that line and one side of one of the bases.

When the bases are closed curves in parallel planes and the mantle is generated by a straight line whose end points move on the two curves and which finally returns to its initial position, the volume generated has been called a *cylindroid.*

Ein Körper, welcher von zwei parallen Vielecken, als Grundflächen, und von Trapezen, als Seitenflächen, ein geschlossen ist, soll den namen eines Obelisk erhalten. [Koppe's Neuer Lehrsatz der Stereometrie, 1843, page 2.]

If a line passes through a fixed point in the plane of one of the bases of the cylindroid (prismoid) and moves so that it is always parallel to the generating line of the cylindroid, it will cut out between the bases a cone (pyramid) which is called the *associate* cone (pyramid).

The *mean area* (M) of a prismoid is such an area which multiplied by the altitude gives the volume.

It would be sufficient to group all of these solids (prismoid, prismatoid, and cylindroid) under the general name of prismoid. When we use the term "prismoidal formula" it carries with it this general meaning.

3. The mean area of a prismatoid is equal to the half sum of the bases less one-sixth of the base of the associate pyramid.

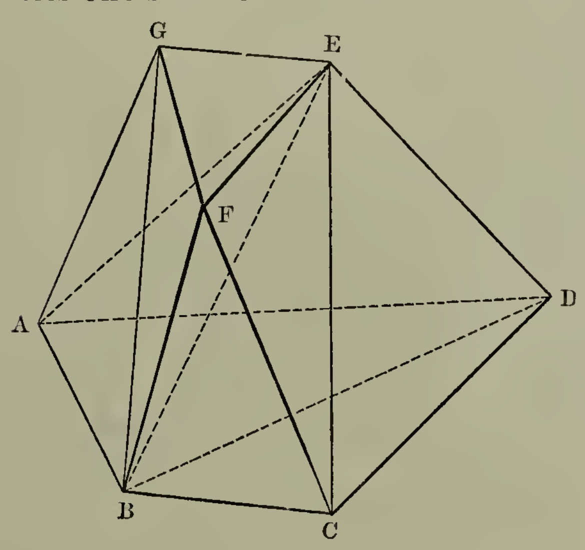

FIG. 1.

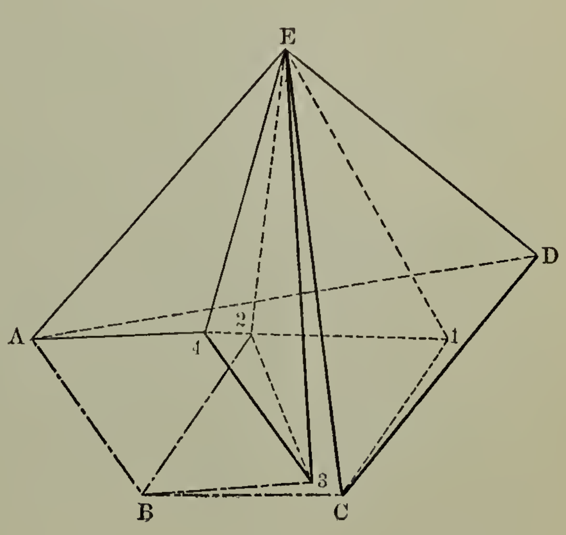

FIG. 2.

Join any vertex, as B, with all of the other vertices of the bases. The prismatoid is composed of pyramid, B—EGF (having base in upper base of prismatoid); the pyramids E—BDC, E—ADB (having their base in the lower base of prismatoid; and the tetrahedra, GE—BC and AB—FE. There are thus three types of solids that make up the prismatoid. We shall first show that Koppe's theorem applies to each class separately.

Given $V=MH=H\left(\frac{B+C}{2}-\frac{1}{6}A\right)$

Where M=mean area of prismatoid.

B=area lower base.

C=area upper base.

A=area base of associate pyramid.

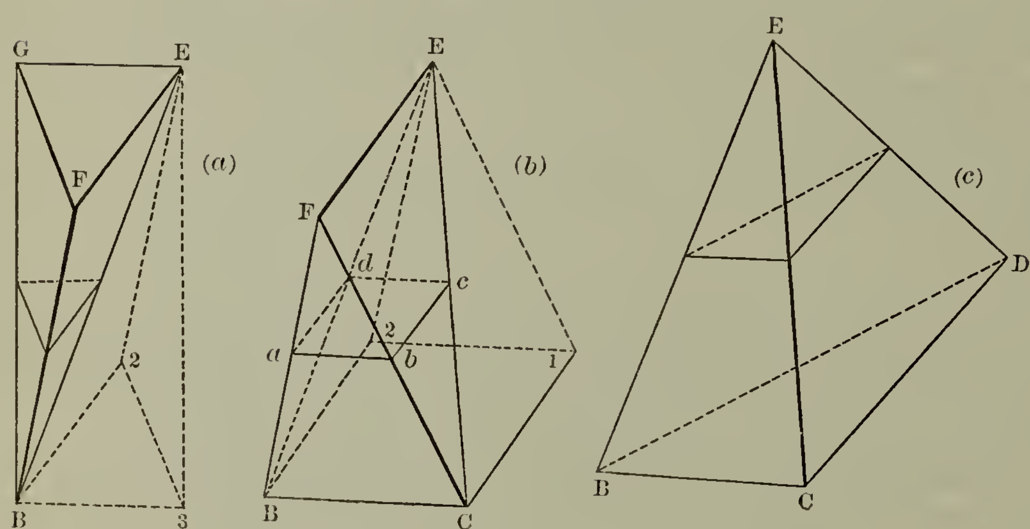

FIG. 3.

(a) In B—EGF we have

$$V=\tfrac{1}{3}HC,$$

But by associate formula,

$$V=H\left[\frac{B+C}{2}-\tfrac{1}{6}A\right]$$

$$=H(0+\frac{C}{2}-\tfrac{1}{6}C)=\tfrac{1}{3}HC.$$

(b) In FE—BC we have

$$V=\frac{H}{6}(B+C+4S_{1/2})=\frac{H}{6}(0+0+4S_{1/2})=\tfrac{4}{6}HS_{1/2},$$

But by associate formula

$$V=H\left(\frac{B+C}{2}-\tfrac{1}{6}A\right)$$

$$=H(0+0+\tfrac{4}{6}S_{1/2})=\tfrac{4}{6}HS_{1/2}.$$

From Fig. 3 (b) we see that

BC12=4(abcd),

Or $A=4S_{1/2}$.

But the areas abcd and BC12 are described clockwise and contra-clockwise, or *vice versa*.

$$\therefore A = -4S_{1/2}.$$

(c) In E—BCD we have

$$V = \tfrac{1}{3}HB,$$

By the associate formula

$$V = H\left(\frac{B+C}{2} - \tfrac{1}{6}A\right)$$

$$= H\left(\frac{B}{2} + 0 - \tfrac{1}{6}B\right) = \tfrac{1}{3}HB.$$

The foregoing investigation is, perhaps, sufficient; but it will be well to follow out the investigation for the prismatoid as a whole. Let us assume that the mid-section of each primary solid of the prismatoid is as indicated in the second column of the following table:

Solid.	Mid-section.	Base of associate pyramid.	Upper base.	Lower base.	Volume.
B—EFG	d	4d	4d	0	$\frac{4}{3}$Hd
E—BCD	e	4e	0	4e	$\frac{4}{3}$He
E—ABD	f	4f	0	4f	$\frac{4}{3}$fH
GE—BC	g	—4g	0	0	$\frac{4}{6}$Hg
FE—AB	k	—4k	0	0	$\frac{4}{6}$Hk

The base of the associate pyramid of the prismatoid is thus equal to the sum of the upper and lower bases of the prismatoid less the bases of associate pyramids of the tetrahedra that have only edges in the bases. It is only necessary to show that the generator of the associate pyramid of the prismatoid graphically sums up these individual bases. Figure 2 shows the associate pyramid to the right of the prismatoid. The lower base is drawn complete for reference. By comparing the prismatoid and the associate pyramid we see that

C1 is equal and parallel to FE,
21 is equal and parallel to BC,
23 is equal and parallel to FG,
34 is equal and parallel to AB, and
4A is equal and parallel to GE.

The parallelograms BC12 and B34A are the bases of associate pyramids of the tetrahedra FE—BC and GE—AB. If we subtract these parallelograms from ABCD and B23, there is left the base of the associate pyramid ADC1234A.

From the last column of the table we have:

$$V = \frac{H}{6}[8d + 8e + 8f + 4g + 4k],$$

$$=\frac{H}{6}[12d+12e+12f—(4g+4e+4f—4g—4k)],$$

$$=\frac{H}{6}[3C+3B—(4d+4e+4f—4g—4k)].$$

But from third column

$$A=4d+4e+4f—4g—4k,$$

$$\therefore V=\frac{H}{6}(3C+3B—A)$$

$$=H\left(\frac{C+B}{2}—\tfrac{1}{6}A\right). \qquad (2)$$

I have called this formula the "associate" formula for lack of a better name. I do not know who first published it. It was published as problem 440 in Halsted's Mensuration in 1881. It was given at the University of Virginia by Prof. Thornton as early as 1880, at least. I have never seen a proof of it, except for the old prismoid.

If in the bases of the cylindroid we inscribe polygons, we can by joining the vertices of the different polygons with each other form a prismatoid. If the number of sides of these polygons be indefinitely increased, the bases of the prismatoids gradually approach the bases of the cylindroid as a limit, and the base of the associate pyramid approaches the base of the associate cone.

If V'=volume of prismatoid,
M'=mean area of prismatoid,
V=volume of cylindroid,
M=mean area of cylindroid,

then the ratio of V' to M' is always constant and equal to H, therefore their limits V and M have the same ratio.

$$\therefore \frac{V'}{M'}=\frac{V}{M}=H.$$

$$\therefore \text{limit of}\left(\frac{B'+C'}{2}—\tfrac{1}{6}A'\right)=\frac{B+C}{2}—\tfrac{1}{6}A.$$

5. KOPPE'S THEOREM.

In 1838 Karl Koppe, Oberlehrer am Gymnasium zu Soest, published in Crelle's Journal the theorem that now bears his name. In 1843 it was republished in his "Ein Neuer Lehrsatz der Stereometrie," a pamphlet that was intended to be a supplement to all text-books on Stereometry. The theorem as enunciated by Koppe was as follows:

"Yeder Obelisk ist gleich der Summe aus einem Prisma und einer Pyramide, welche beide mit dem Obelisken gleiche Höhe haben, und deren Grundflächen in den Winkeln mit den Grundflächen des Obelisken übereinstimmen, während die Seiten der Grundfläche des Prismas den halben Summen und die Seiten der Grundfläche der Pyramide den halben

Differenzen der gleichliegenden Seiten der beiden Grundflächen des Obelisken gleich sind.''

It is thus seen that Koppe's theorem as stated here is confined to the prismoid (obelisk); that is, to solids whose bases are equiangular. This theorem of Koppe was easily established by elementery geometry for the old prismoid. The bases of the prism and pyramid were polygons whose perimeters were respectively the half-sum and the half-difference of the perimeters of the bases, and whose angles were equal to the corresponding angles of the bases.

On page 20 of his ''Neuer Lehrsatz'' Koppe remarks: ''The application of our proposition to bodies that are bounded (enclosed) by curved (or crooked) side faces does not confine itself to the frustrum of a cone, but extends to all bodies which have two parallel bases and curved (or warped) side-faces, that are generated by a straight line which is always on the curved lines that circumscribe the bases.''

6. Koppe's formula can be established for the prismatoid by the same methods we employed for the associate formula. We must bear in mind that the perimeters and areas of sections of the associate pyramid when described contra to those of the bases must be treated negatively.

Refer to Figs. 1, 2, and 3, and table in Art. 3.

(a) B–EFG.

We know that

$$V=\tfrac{1}{3}HC.$$

By Koppe's formula

$$V=H(S_{½}+\tfrac{1}{3}T)=H(d+\tfrac{1}{3}d)=\tfrac{4}{3}Hd=\tfrac{1}{3}HC.$$

(b) BC–EF.

$$V=\tfrac{2}{3}Hg.$$

By Koppe

$$V=H(S_{½}+\tfrac{1}{3}T)=H(g-\tfrac{1}{3}g)=\tfrac{2}{3}Hg.$$

(c) E–BCD,

$$V=\tfrac{1}{3}HB.$$

By Koppe

$$V=H(S_{½}+\tfrac{1}{3}T)=H(f+\tfrac{1}{3}f)=\tfrac{4}{3}Hf=\tfrac{1}{3}HB.$$

The application of the formula can be extended to the prismatoid as a whole.

From the last column of table have

$$V=\frac{H}{6}(8d+8e+8f+4g+4k.$$

$$=\frac{H}{6}[(6d+6e+6f+6g+6k)+(2d+2e+2f-2g-2k)].$$

$$=\frac{H}{6}[(6S_{½}+2T)=H(S_{½}+\tfrac{1}{3}T).$$

Its extension to the cylindroid follows, as in Art. 3.

Prof. Echols in the "Annals of Mathematics" for November, 1894, says:

"The expression for the mean area

$$M=\tfrac{1}{2}(B_1+B_2)-\tfrac{1}{6}A, \qquad (2)$$

wherein A is the area of the base of the associate cone, is, I believe, due to Koppe, and seems to be the first prismoid formula found. This formula, in connection with

$$(1)\ [M=\tfrac{1}{6}(B_1+B_2+4S_{\frac{1}{2}})],$$

easily furnishes the value

$$M=S_{\frac{1}{2}}+\tfrac{1}{12}A. \qquad (3)$$

In this form the mean area has been used by engineers for computing earthwork volumes. The writer's first acquaintance with it thus employed was in the lectures to engineering students at the University of Virginia in 1880. This is a two-term formula, but it involves an extraneous area, that of the director cone, which is not a section of the solid."

Prof. Echols here makes the mistake of ascribing the wrong formula to Koppe. Interchange (2) and (3) and the remarks hold good.

6a. *If* P *(vertex of associate cone whose base is* A*) is in base* C, *then* C *is base of associate cone whose upper base is* A.

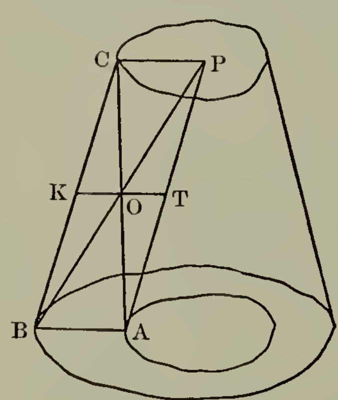

FIG. 4.

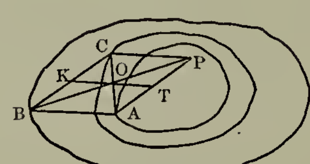

FIG. 5.

In Fig. 4 the upper base (C) is projected orthogonally on lower base B. The generator of the cylindroid is BC, while PA is generator of associate cone whose base is A. As BCPA is a parallelogram, we can conceive another cylindroid generated at same time by BA and its associate cone generated by PC. Then if A is projected orthogonally on upper base, there are two cylindroids generated simultaneously that bear a reciprocal relation to each other.

If M=mean area of cylindroid whose bases are B and C,

and M′=mean area of cylindroid whose bases are B and A,

we have $M=\tfrac{1}{2}(B+C)-\tfrac{1}{6}A$,

$M'=\tfrac{1}{2}(B+A)-\tfrac{1}{6}C$.

$\therefore\ M-M'=\tfrac{2}{3}(C-A)$,

$M+M'=B+\tfrac{1}{3}(C+A)$.

If $S_{1/2}$ and $S'_{1/2}$ are the mid-sections of the cylindroid, we have

$$S_{1/2}=\tfrac{1}{2}(B+C)-\tfrac{1}{4}A,$$
$$S'_{1/2}=\tfrac{1}{2}(B+A)-\tfrac{1}{4}C.$$
$$\therefore\ S_{1/2}+S'_{1/2}=B+\tfrac{1}{4}(C+A),$$
$$S_{1/2}-S'_{1/2}=\tfrac{3}{4}(C-A).$$

The bases (A) and (C) may be regarded as the bases of the cylindroid generated by line CA whose mid-section is generated by point O.

$$\therefore\ \text{Vol. } CA=\tfrac{1}{6}(C+A+4O),$$
$$=\tfrac{1}{6}(C+A+B).$$

The volume generated by the diagonal CA is one-sixth of the three cylinders on B, C, and A.

The volume generated by the parallelogram =

$\frac{H}{2}$ (area generated by line PC+area generated by line BA).

For volume cylindroid

$$=H\left(\frac{B+C}{2}-\tfrac{1}{6}A\right).$$

Volume associate cone

$$=\frac{H}{3}A.$$

$\therefore$ Volume generated by parallelogram

$$=\frac{H}{2}[(B-A)+C].$$

7. If in Figs. 4 and 5, S is any point on the line BC situated so that

$$BS\div BC=m$$
$$\text{and } CS\div BC=n,$$

then from Elliott's Extension of Holditch's theorem we have

$$S=\frac{m}{m+n}C+\frac{n}{m+n}B-\frac{mn}{m+n}A,$$

where S, C, etc., indicate the area traced by the points S, C, etc.

If $m=n=\frac{1}{2}$

$$S=\tfrac{1}{2}C+\tfrac{1}{2}B-\tfrac{1}{4}A=S_{1/2};$$

but from Newton's formula we have

$$M=\tfrac{1}{6}[B+C+4S_{1/2}]. \qquad (3)$$

Eliminating $S_{1/2}$, we have

$$M=\frac{B+C}{2}-\tfrac{1}{6}A.$$

[See Scientiæ Baccalaureus, February, 1891.)

5. *The volume of any prismatoid (cylindroid) is equal to a prism (cylinder) and a pyramid (cone), the altitude of each being equal to the altitude of the prismatoid (cylindroid) and their bases being respectively the mid-sections of the prismatoid (cylindroid) and the associate pyramid (cone).*

From the associate formula we have

$$V=H\left(\frac{B+C}{2}-\tfrac{1}{6}A\right);$$

but by Newton's formula

$$V=\frac{H}{6}(B+C+4S_{1/2}).$$

Eliminating (B+C) we get

$$V=H(S_{1/2}+\tfrac{1}{12}A)=H(S_{1/2}+\tfrac{1}{3}T). \quad (4)$$

For the prismatoid it is readily seen that the perimeter of the mid-section is the half-sum of the perimeters of the bases; and the perimeter of base of the associate pyramid is the algebraic difference of perimeters of the bases. Note that it is necessary to regard all contra-clockwise motion as negative, and all lines thus generated. The perimeter of the mid-section of the associate pyramid is, therefore, half the difference of the perimeters of the bases.

II.

8. *To find an expression for the mean area of a prismoid in terms of the bases and another section.*

It is thought that the following method of deriving such a prismoidal formula is published for the first time.

Let B, C be respectively the lower and upper bases of a prismoid.

Let S be any section parallel to B and C.

H=altitude of prismoid BC.
a=altitude of prismoid BS.
c=altitude of prismoid CS.
A_a=base of associate cone for prismoid BS.
A_c=base of associate cone for prismoid CS.
A=base of associate cone for prismoid BC.
M=mean area of prismoid.
$x=a\div H$.
$z=c\div H$.

$$\text{Vol. BS}=\left(\frac{B+S}{2}-\tfrac{1}{6}A_a\right)a=\left(\frac{B+S}{2}-\frac{a^2}{6H^2}A\right)a \quad (5)$$

$$\text{Vol. CS}=\left(\frac{C+S}{2}=\tfrac{1}{6}A_c\right)c=\left(\frac{C+S}{2}-\frac{c^2}{6H^2}A\right)c. \quad (6)$$

∴ By adding (5) and (6) we get the total volume.

$$\therefore V=\frac{S(a+c)}{2}+\frac{aB}{2}+\frac{cC}{2}-A\frac{a^3+c^3}{6H^2} \quad (7)$$

But V=MH ∴ $M=V\div H$

$$\therefore M=\frac{S}{2}+\frac{xB}{2}+\frac{yC}{2}-A\frac{x^3+z^3}{6} \quad (8)$$

$$\text{But } M=\frac{C+B}{2}-\tfrac{1}{6}A. \quad (9)$$

Substitute the value of A found from (9) in (8) and we get

$$M=\frac{B(x-x^3-z^3)}{2(1-x^3-z^3)}+\frac{S}{2(1-x^3-z^3)}+\frac{C(y-x^3-z^3)}{2(1-x^3-z^3)} \quad (10)$$

Now $x+z=1$ $\therefore$ $x^3+z^3=1-3xz(x+z)=1-3xz$

$$M=\frac{B(3x-1)}{6x}+\frac{S}{6xz}+C\left(\frac{3z-1}{6z}\right) \quad (11)$$

$$=\frac{B(3x-1)}{6x}+\frac{S}{6x(1-x)}+C\left(\frac{2-3x}{6(1-x)}\right) \quad (12)$$

$$=fB+eS+dC, \quad (13)$$

where f, e, d represents the coefficient of B, S, and C, respectively.

$$\therefore\ f=\frac{3x-1}{6x},\ e=\frac{1}{6x(1-x)},\ d=\frac{2-3x}{6(1-dx)}. \quad (14)$$

Transfer the origin for f to (0, $\frac{1}{2}$) and for d to (1, $\frac{1}{2}$) and we get

$$fx=\tfrac{1}{6},\ dx=\tfrac{1}{6}, \quad (15)$$

which are the equations to equilateral hyperbolas referred to asymptotes OB and EF, and PQ and EF.

If for e we transfer origin to ($\frac{1}{2}$, 0) we get

$$e=\frac{2}{3-12x^2}. \quad (16)$$

9. By making x vary from 0 to 1, we can get the following table of coefficients:

x.	f.	e.	d.
0			
.05	—2.833	3.508	.325
.10	—1.167	1.350	.315
.15	— .611	1.307	.304
.20	— .333	1.042	.292
.2114	— .2886	1.00	.2886
.25	— .1666	.888	.277
.30	— .0555	.7936	.262
$\frac{1}{3}$	0	.7500	.250
.35	.00238	.732	.243
.40	.0833	.6946	.2222
.45	.129	.673	.1969
.50	.167	.6666	.1667
.55	.197	.6730	.130
.60	.222	.6946	.083
.667	.250	.7500	00
.70	.262	.7936	.0555

By using x as abscissas and the corresponding coefficients as ordinates, we get the "coefficient" curves as shown in Fig. 6. It is noticed that the "coefficient" of S is symmetrical with reference to the line Kl, and that the curves (f) and (d) are symmetrical, with respect to each other, with reference to the same line.

The (e) curve is asymptotic to lines $x=0$(OB) and $x=1$(PQ). The (f) curve is asymptotic to OB and line $a=\frac{1}{2}$(FE).

It can be seen from equation (16) that the (e) curve is asymptotic to lines $x=\pm\frac{1}{2}$.

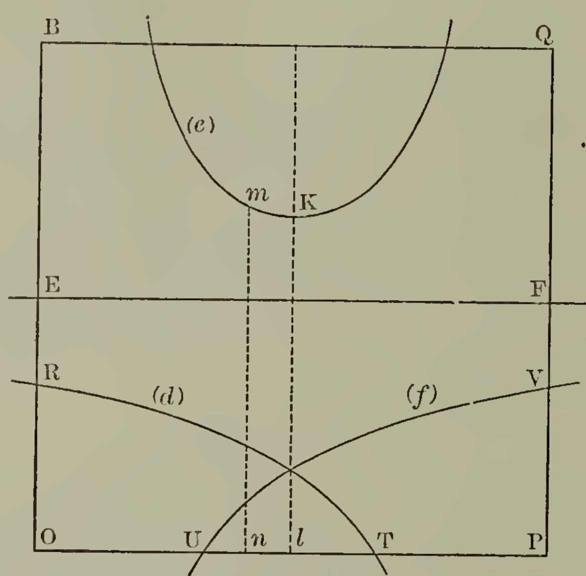

FIG. 6.

10. *Coefficient curves for three-term formulæ.*

From Fig. 6, where $OP=$unity, we readily see that by taking values of x from 0 to 1 the ordinate to (d) curve gives the coefficients of C, the ordinate to (e) curve gives the coefficients of the floating section S, and the ordinate to the (f) curve gives the coefficients of B. When these sections are multiplied by their coefficients and added, a *mean area* is obtained, which, multiplied by the height of the prismoid, will give the true volume.

When $x=\frac{1}{3}$, the coefficient of B disappears, and we get

$$M=\tfrac{1}{4}C+\tfrac{3}{4}S,$$

thus verifying by the three-term formula Kinklin's two-term formula.

When $x=\frac{2}{3}$, we get

$$M=\tfrac{1}{4}B+\tfrac{3}{4}S,$$

another verification of the same formula. This two-term formula can be considered a special case of three-term formula. By inspecting Fig. 6 or the table I, we see that if we wish *positive* coefficients we must take S in the *middle third* of the height, and, as it leaves the *middle third*, it verifies the two-term formula.

The coefficients are symmetrical with reference to cd or the midsection.

When $x=\frac{1}{2}$, we get

$$M=\tfrac{1}{6}(B+C+4S_{1/2}).$$

If $x=\frac{1}{6}(3-\sqrt{3})$, we get

$$M=-.2886B+S_1+.2886C.$$

When $x=\frac{1}{6}(3+\sqrt{3})$,

$$M=+.2886B+S_2-.2886C.$$

By adding we get

$$M=\tfrac{1}{2}(S_1+S_2).$$

This can be readily obtained from the equation to the running section (S) where

$$S=m+nx+tx^2.$$

If $x=\frac{H}{6}(3-\sqrt{3})$, we have

$$S_1=m+\frac{nH}{6}(3-\sqrt{3})+\frac{tH^2}{36}(12-6\sqrt{3}).$$

If $x=\frac{H}{6}(3+\sqrt{3})$, we get

$$S_2=m+\frac{nH}{6}(3+\sqrt{3})+\frac{tH^2}{36}(12+6\sqrt{3}).$$

$$\therefore \tfrac{1}{2}(S_1+S_2)H=H\left(m+\frac{nH}{2}+\frac{tH^2}{3}\right)=V.$$

11. By the use of equations (2) and (12) a two-term prismoidal formula can be derived by elementary geometry as follows:

From (12) we have

$$M=B\frac{3x-1}{6x}+\frac{S_2}{6x(1-x)}+C\frac{2-3x}{6(1-x)};$$

then for any other section (S_1) distant yH from B we have

$$M=B\frac{3y-1}{6y}+\frac{S_1}{6y(1-y)}+C\frac{2-3y}{6(1-y)}. \qquad (17)$$

From (9) $C=2M-B+\frac{A}{3}$.

By substituting this in (12) and (17) and reducing, we get

$$M=B\frac{2x-1}{2x}+\frac{S_2}{2x}+\frac{A(2-3x)}{6} \qquad (18)$$

$$M=B\frac{2y-1}{2y}+\frac{S_1}{2y}+\frac{A(2-3y)}{6}. \qquad (19)$$

Eliminate B;

$$\therefore M=S_2\frac{2y-1}{2(y-x)}+S_1\frac{(1-2x)}{2(y-x)}+\frac{6xy-3y-3x+2}{6}A. \qquad (20)$$

Now if the coefficient of A in (20) disappears, we get a two-term prismoidal formula.

The condition for two-term formulæ is, therefore,

$$6xy-3y-3x+2=0. \qquad (21)$$

By transferring the origin to $(\frac{1}{2}, \frac{1}{2})$, we get

$$xy=-\tfrac{1}{12}. \qquad (22)$$

It is readily seen that this is an equilateral hyperbola referred to its asymptotes.

The coefficients of S_2 and S_1 are

$$p=\frac{2y-1}{2(y-x)}=\frac{1}{4(3x^2-3x+1)},\quad q=\frac{1-2x}{2(y-x)}=\frac{3(1-2x)^2}{4(3x^2-3x+1)}. \quad (23)$$

Transfer the origin to $(\frac{1}{2}, 0)$

$$\therefore\ p=\frac{1}{1+12x^2},\quad q=\frac{12x^2}{1+12x^2}. \quad (24)$$

If OR=OQ=H, say 100, and OA and OC represent the respective axes, the branches of the hyperbola can be plotted, and the ordinates and abscissas to the branch 123 between 7 and 8 and 456 between 4 and 6 will locate all the sections between the bases. (Fig. 7.)

The "coefficient" curve is obtained from equations (23), where for any value of x, the ordinates from OA to the coefficient curve will give the coefficient of S_2 and the ordinates *down* from QD to the same point on the coefficient curve will give the coefficient of S_1.

12. By easy calculation the following values of x, y, p, and q can be found:

x.	y.	Coefficients		h.
		Of S_1. q.	Of S_2. p.	
.00	.666+	.750	.250	.6667
.05	.685	.709	.291	.635
.10	.709	.659	.443	.609
.15	.738	.595	.405	.5880
.20	.778	.519	.481	.5780
.2114	.7886	.500	.500	.5776
.25	.833	.429	.571	.5833
.30	.917	.324	.676	.617
.33⅓	1.000	.250	.750	.6667
.35	1.056	.212	.788	.756
.37½	1.16⅔	.158	.842	.7916
.40	1.333	.108	.892	.9333
.43	1.693	.0556	.9444	1.063
.45	2.167	.029	.971	1.717
.47	3.278	.011	.989	2.808
.48	4.66⅔	.00481	.995	4.186
.49	8.833	.002	.998	8.343
.50	Infinity	0	1.000	Infinity
.60	— .33⅓	.108	.892	
.667	.0	.250	.750	
.70	.083	.324	.676	
.80	.222	.519	.481	
.90	.292	.657	.343	
1.00	.333	.750	.250	
— .10	.639	.812	.188	
— .20	.619	.854	.146	

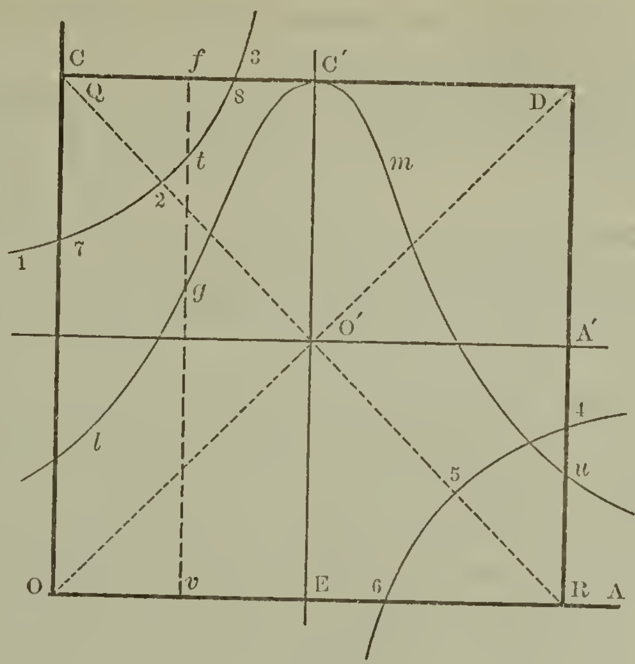

Fig. 7.

13. The coördinates of 7, 8, 6, and 4 locate the sections for Kinklin's two-term formulæ, and the ordinates to the "coefficient" curve give $\frac{3}{4}$ and $\frac{1}{4}$ for S_1 and S_2, and *vice versa*.

The coördinates of 2 and 5 locate the two sections equidistant from the bases where x=.2114 and y=.7886, as given by Prof. Echols, and the "coefficient" curve crosses the asymptote on same ordinate, and gives p=.50 and q=.50. The graphical construction shows that no real section of the prismoid (between bases) can occur for values of x between 8 and 6; *i. e.*, within the middle third. However, good results can be obtained for all values of x from 0 to .45 and from .55 to 100.

No sections can be taken at or very near the center.

Example: For any position, ov=x, vt=y, fg=q, and vg=p.

14. "*Position*" and "*coefficient*" *curves.*

(1) To find the volume of any prismoid measure one section (S_2) at a distance xH=*ov* in Fig. 7, and measure the other section (S_1) at a distance from same base yH=the ordinate to the "position" curve 728=*vt* for the abscissa *vo*. Then multiply the first section by *vg*, and the second section by *fg*, where H=OQ=OR=unity.

(2) The "position" curves are asymptotic to the lines $y=\frac{1}{2}$ and $x=\frac{1}{2}$, or to O^1A^1 and O^1C^1.

(3) The vertices of the "position" curves (hyperbolas) are on the diagonal QR of the square ORDQ.

(4) The point of inflection of the "coefficient" curve is vertically below (above) the points 8 and 6.

(5) The "coefficient" curve crosses asymptote O^1A^1, on an ordinate through vertex of "position" curve.

(6) For the last position, S_2 is at a distance=.2114H from one base and S_1 the same distance from the other base, and the coefficients here are each $\frac{1}{2}$.

(7) When x=0, y=.667, and the coefficients are .250 and .750 respectively, thus again verifying Kinklin's formula.

(8) When x=.333+, y=1, and the coefficients are .750 and .250 respectively.

(9) At the points x=0, .333, .667, or 100, the "position" curve leaves the square, and the branches 728 and 456 give all the sections between the bases.

(10) The diagram and table show very plainly that for any real section (between bases) *no section can occur in the middle third.* The three-term formula for *positive* coefficients requires the section to be taken *in the middle third.*

(11) The "coefficient" curve lgmn is plotted by making QO=unity.

(12) The "position" curve is plotted by making OQ=OR=height of prismoid.

15. In the "Annals of Mathematics" for November, 1894, Prof. Echols has shown that there is an infinite number of two-term formulas that will give the mean area of the prismoid. It is the object of the present note to follow his general method in order to verify the calculations of article 11.

For convenience the two parallel sections will be taken between the bases C and B. The section next to C will be called S_1, and that next to B, S_2. Then, if P be any section,

And the distance from P to section S_2=m

Distance between S_1 and S_2=h

And the distance from P to section S_1=h—m

Distance between section B and S_2=a

Distance between bases B and C=H

Distance between P and base B=z

From Elliott's extension of Holditch's theorem we have

$$P=\frac{m}{h}S_1+\frac{h-m}{h}S_2-\frac{m(h-m)}{h^2}A_h \qquad (25)$$

Where A_h = area of base of "associate cone" between sections S_1 and S_2. It is clear that

$$m=z-a$$

$$\therefore P=\frac{z-a}{h}S_1+\frac{h-z+a}{h}S_2-\frac{(z-a)(h-z+a)}{h^2}A_h \qquad (26)$$

Now we wish to find the mean area of the section P between sections C and B in terms of S_1, S_2 and A_h. Using the well known formula for mean value for y=F (x) between the limits of *a* and *b* for x we have

$$M = \text{mean value} = \frac{1}{a-b}\int_b^a F(x)\,dx \tag{27}$$

From (26) then

$$M = \frac{1}{H-O}\int_0^H \left[\left(\frac{z-a}{h}\right)S_1 + \frac{h-z+a}{h}S_2 - \frac{(z-a)(h-z+a)}{H^2}A\right]dz$$

$$= \frac{H-2a}{2h}S_1 + \frac{2h-H+2a}{2h}S_2 - \frac{3hH-2H^2+6aH-6ah-6a^2}{6H^2}A$$

Now make h=c—a where c=distance S_1 B.

$$\therefore M = \frac{H-2a}{2(c-a)}S_1 + \frac{2c-H}{2(c-a)}S_2 - \frac{3Hc+3aH-6ac-2H_2}{6H^2}A \tag{28}$$

Make a=xH and c=yH.

$$\therefore M = \frac{2y-1}{2(y-x)}S_2 + \frac{1-2x}{2(y-x)}S_1 + \frac{6xy-3x-3y+2}{6}A. \tag{29}$$

Now, as in (20), for a two-term formula, the coefficient of A must disappear:

$$\therefore 6xy-3x-3y+2=0 \tag{30}$$

$$\text{and } xy = -\tfrac{1}{12}. \tag{31}$$

$$p = \frac{1-2x}{2(y-x)},\quad q = \frac{2y-1}{2(y-x)}. \tag{32}$$

15a. Prof. Echols gave as the condition of a two-term formula

$$x'^2+x'y'+y'^2-\tfrac{3}{2}(x'+y')=0.$$

Where x'h=a, and y'h=H—x'h.

If we impose the condition that the sections (for convenience) are between bases, this formula becomes

$$x'^2-x'y'+y'^2-\tfrac{3}{2}(y'-x')=0. \tag{E}$$

But H=h(y'+x')

$$a=x'h=xH$$

$$y'h=H-xH=H(1-x)$$

$$h=yH-xH=H(y-x)=\frac{H}{y'+x'}$$

$$\therefore x'=\frac{x}{y-x}.$$

$$\text{and } y'=\frac{1-x}{y-x}.$$

$$x'+y'=\frac{1}{y-x}.$$

From Equation (21) we have

$$y=\frac{3x-2}{6x-3}.$$

But h=(y-h)H

$$=\frac{6x-6x^2-2}{6x-3}H.$$

The distance (h) apart of the sections S_1 and S_2 is variable. ∴ For maximum and minimum values of *h* we have

$$\frac{dh}{dx}=\frac{36x-36x^2-6}{(6x-3)^2}=0.$$

For maximum value of h, $x=\frac{1}{2}$.

For minimum value $x=\frac{1}{6}(3\pm\sqrt{3})$.

For maximum value $x=$ infinity.

For minimum value $h=\frac{1}{\sqrt{3}}=.5776$.

For real sections of the prismoid h varies from .5776 to .6666. The coördinates of the vertices of the equilateral hyperbolas give the sections that are nearest together. The height (h) is the ordinate between line OD and curve 123 in Fig. 7.

Substituting the values of x^1, y^1 in (E) and reducing, we get

$$6xy-3x-3y+2=0.$$

If we make $x=\frac{1}{u}$ and $y=\frac{1}{v}$ we get

$$\tfrac{1}{3}uv=\tfrac{1}{2}(v+u)-1. \qquad \text{(K)}$$

This is the form of the condition that Dr. Halsted presented to the Texas Academy of Scienee (April 5, 1895), and which he christened the *criterion* formula.

16. From (25) we have

$$S=xC+yB-xyA.$$

Combine this with (9) by eliminating (A), and we get

$$M=B\left(\frac{3x-1}{6x}\right)+\frac{S}{6x(1-x)}+C\left(\frac{2-3x}{6(1-x)}\right) \qquad (33)$$

[This proof was given by Mr. E. P. Schoch, an engineering student in the University of Texas, in May, 1895. Afterwards the writer found it in an article published by Prof. Echols in 1895.]

17. Dr. Halsted in his Mensuration, p. 129, by using the equation to the running section S, where

$$S=ax^2+bx+c \qquad (34)$$

has derived the following formula:

$$V=MH=H\left[\frac{2z-3}{6(z-1)}C+\frac{6(z-1)}{S_2z^2}+\frac{3-z}{6}B\right] \qquad (35)$$

where the section S_2 is $\frac{1}{z}$ the height from B. Make $x=\frac{1}{z}$ and substitute in 35.

$$\therefore M=\frac{3x-1}{6(1-x)}B+\frac{S}{6x(1-x}+\frac{2-3x}{6b}C. \qquad (36)$$

Then at any other section S_1 at a distance yH from B, we have

$$M=\frac{3y-1}{6(1-y)}B+\frac{6x(1-x)}{S^1}+\frac{2-3y}{6y}C. \qquad (37)$$

But $M=\frac{1}{2}(C+B)-\frac{1}{6}A$. (38)

Substitute the value of C obtained from (38) in (36) and (37), and then eliminate B, and we get

$$M=\frac{2y-1}{2(y-x)}S_2+\frac{1-2x}{2(y-x)}+\frac{6xy-3x-3y+2}{6}A. \qquad (39)$$

The same conditions and results follow as in article 11, etc.

18. *To find an expression for the mean area of the prismoid in terms of the mid-section and two sections S_1 and S_2 equidistant from the mid-section.*

From (12) we have

$$M=B\frac{3x-1}{6x}+\frac{S_2}{6x(1-x)}+C\frac{2-3x}{6(1-x)}.$$

Then again

$$M=B\frac{2-3x}{6(1-x)}+\frac{S_2}{6x(1-x)}+C\frac{3x-1}{6x}.$$

But $C=6M-B-4S_{1/2}$.

Substitute this value of C in the preceding equations, and then eliminate B, and we have

$$M=\frac{S^1+S^2}{6(4x^2-4x+1)}+\frac{6(4x^2-4x+1)}{6(4x^2-4x+1)}S_{1/2}. \qquad (40)$$

$$=K(S_1+S_2)+jS_{1/2}.$$

The following table of coefficients is readily calculated:

x.	k.	j.
0.000	.166	.666
.100	.260	.479
.1456	.333	.333
.2000	.463	.019
.2114	.500	.000
.2500	.667	— .333
.2959	1.000	—1.000
.3333	1.509	—1.333
.5000	∞	—∞
.6670	1.500	—1.333
.7041	1.000	—1.000
.7500	.667	— .333
.7886	.500	0.000
.8564	.333	.333
1.0000	.167	.667

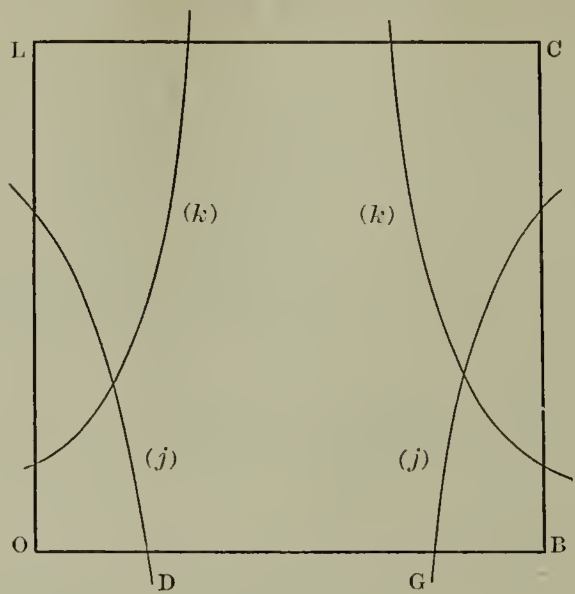

FIG. 8.

Let OB=altitude of prismoid=1. Then the two coefficient curves (k) and (j) can be plotted as in the figure.

If x=0 or 1 we get

$$M=\frac{1}{6}(B+C+4S_{\frac{1}{2}}).$$

If $x=\frac{2\pm\sqrt{2}}{4}=.1464$ or $.8536$ we get

$$M=\frac{1}{3}(S_1+S_2+S_{\frac{1}{2}}) \qquad (41)$$

If $x=\frac{3\pm\sqrt{3}}{6}=OD$ or OG we get Echol's formula

$$M=\frac{1}{2}(S_1+S_2).$$

19. If in formula (20) we make $x=\frac{1}{2}+z$, and $x=\frac{1}{2}-z$, the two sections S_1 and S are equidistant from the mid-section.

$$\therefore\ M=\frac{1}{2}(S_1+S_2)+(\tfrac{1}{12}-z^2)A. \qquad (42)$$

If z=0 we get Koppe's formula where

$$M=S_{\frac{1}{2}}+\tfrac{1}{12}A=S_{\frac{1}{2}}+\tfrac{1}{3}T.$$

If $z=\pm\frac{1}{2}$, we get the associate formula where

$$M=\frac{1}{2}(B+C-\tfrac{1}{6}A).$$

If $z=\pm\frac{1}{6}\sqrt{3}$, we get Echol's formula where

$$M=\frac{1}{2}(S_1+S_2).$$

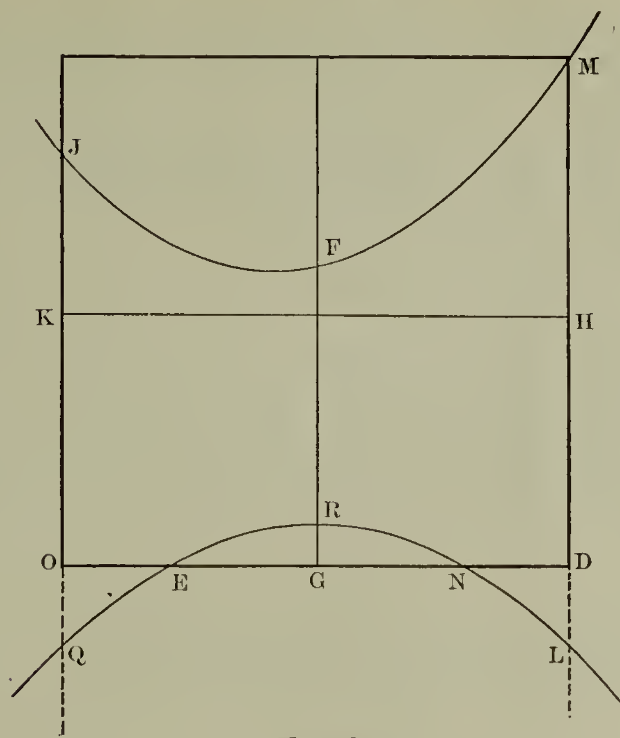

FIG. 9.

We thus see that the Koppe, associate, and Echols formulæ all belong to one group or family.

The parabola QRL is the coefficient curve for A, where $OD=1$, $RG=\frac{1}{12}$, $Q0=DL=-\frac{1}{6}$, and $OE=DN=\frac{1}{6}(3-\sqrt{3})$. The line KH is the coefficient curve for (S_1+S_2) where $OC=DH=\frac{1}{2}$.

If $z=\pm\frac{1}{6}\sqrt{21}$, we get another neat formula where

$$M=\tfrac{1}{2}(S_1+S_2-A). \qquad (43)$$

If $z=\pm\frac{1}{12}\sqrt{30}$, we get

$$M=\tfrac{1}{2}(S_1+S_2-T). \qquad (44)$$

20. *To find any section graphically.*

By equating equation (12) with that of Newton and simplifying, we get

$$S_x=B-x(3B+C-4S_{\frac{1}{2}})+x^2(2B+2C-4S_{\frac{1}{2}}) \qquad (45)$$

This equation represents a parabola, and any section can be found graphically.

When $x=0$, $S=B$.

$x=.50$, $S=S_{\frac{1}{2}}$.

$x=1$, $S=C$.

In Fig. 9 lay off $OJ=B$, $FG=S_{\frac{1}{2}}$, and $DM=C$; then describe a parabola through these points. Any section at distance xH from the base can thus be found by measuring the proper ordinate.

For another proof of this, see Grunert's Archiv, Vol. XXXIX.

(The two parabolas in Fig. 9 have no connection whatever.)

The area of ODMFJ where $OD=H$ gives the volume of the prismoid.

If in (42) we make $S_x = M = \frac{1}{6}(B + C + 4S_{\frac{1}{2}})$ we get the value of x where the sections are equal to the mean area. It is thus possible to get a one-term formula.

If $Q = 3B + C - 4S_{\frac{1}{2}}$, and $R = 2B + 2C - 4S_{\frac{1}{2}}$, we have

$$S_x = M = \tfrac{1}{6}(B + C + 4S_{\frac{1}{2}}) = B - Ox + Rx^2,$$

$$\text{or } Rx^2 - Rx = \tfrac{1}{6}(C + 4S_{\frac{1}{2}} - 5B).$$

By solving this and substituting the roots x_1 and x_2 in (42) we get M.

$\therefore V = MH.$

If in (32a) we make $S_x = M = \frac{1}{2}(B + C) - \frac{1}{6}A$ and make $z = 1 - x$ we get

$$S_x = \tfrac{1}{2}(B + C) - \tfrac{1}{6}A = B + x(C - B - A) + Ax^2.$$

This equation will also give the values of x where the section $S_x = M$. In the same way we can get a one-term formula from this associate as we did from (42).

I find

$$x = \frac{1}{2A}(A + B - C) \pm \left[\frac{3(B-C)^2 + A^2}{12A^2}\right]^{\frac{1}{2}}.$$

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TEXAS ACADEMY OF SCIENCE.

ADDRESS BY THE PRESIDENT, DR. GEORGE BRUCE HALSTED.

THE CULTURE GIVEN BY SCIENCE.

To be a man of broadest culture is a high ideal.

Fortunately the idea and the associations conveyed by this word "culture" are still of the finest, the noblest.

But when scanned in the new light of the present, has not the flower of culture, like everything else of the best, gained a living heart of science, taken on the pure, high, unfading colors of science, the benign empress of our modern world?

And with this change has not culture developed a firmer moral fibre from the inexorable, inevitable insistance of science on a moral courage in her votaries which would sacrifice all unflinchingly in the pure cult of truth?

Before the age of science the man of the then culture was as his fellows in fear of being known to have been wrong.

Said Lowell: "There are three short and simple words, the hardest of all to pronounce in any language (and I suspect they were no easier before the confusion of tongues), but which no man or nation that can not utter can claim to have arrived at manhood. These three words are, *I was wrong.*"

Even Goethe, the very highest type of culture not based on a core of science, even Goethe, with his calm and coldness as of the immortals, with his magnificent appetite and digestion, even Goethe mouths and sulks and rants like a stupidly obstinate boy when even his friends declare that in the explanation of colors he is wrong and the man of science, Newton, is right.

He snarls and spits to the very last, and like his countryman, Hegel, makes himself disgusting by reviling Newton. Says J. H. Stirling, Hegel's devoted apologist: "One thing, however, he will not think excusable even in a Hegel: this latter's unsparing bitterness of tone to him —Newton—whom as a productive thinker mankind have so much reason sincerely to thank and supremely to honor." Says Helmholtz: "To give some idea of the passionate way in which Goethe, usually so temperate and even courtier-like, attacks Newton, I quote from a few pages of the controversial part of his work the following expressions, which he applies to the propositions of this consummate thinker in physical and astronomical science—'incredibly impudent;' 'mere twaddle;' 'ludicrous explanation;' 'but I see nothing will do but lying, and plenty of it.' "

Nothing could more exactly illustrate the change of heart which culture has undergone. Could any one imagine Justus von Liebig berating Pasteur for overthrowing utterly Liebig's theory of fermentation?

The friends of Darwin bemoaned the inestimably valuable time which he habitually gave to considering the weakest objections of the feeblest objectors, and even to setting forth and clothing all objections with his own strength. The culture given by science is strikingly characterized by equipoise of mind, impartiality of view, freedom from obscurations due to selfishness, a taking of self objectively.

This comes in part from the fact that high scientific instruction or attainment can not be divorced from scientific investigation. Thus in Germany, the leader in modern culture, "a university professor is both a teacher and a scientific investigator, and the latter is considered the more important." "Again, when a professor is mentioned the question is asked: What has he written? what are his scientific achievements?"

The culture given by science relegates to the moribund institutions of tradition the old hypothesis that truth is given and fixed, and needs only to be transmitted unchanged We have seen in our own generation changes accepted and made part of regular university instruction which are so deep-reaching as to under-cut the knowledge thought for twenty centuries to be fixed. Witness the non-Euclidean geometry, and evolution. The watchword of modern scientific culture is independence of thought and investigation. "Whatsoever is, may be wrong!" Its most cherished palladium is freedom to think, freedom of research, freedom in teaching.

To break a bond restricting liberty to search and say the truth may be more important than killing a definite positive error.

The culture given by science can tolerate no distinct dogmatic brand.

A pertinent illustration is found in the attitude of the highest culture now toward language and language teaching. It is found that language, like the expression of numbers by symbols, has attained a higher state by taking aid from space concepts, by making definitely fixed use of position as significant. The inflectional languages, such as Latin and Greek, correspond to their own writing of numbers. There is a hint at some use of position. Witness IV and VI, or the difference of emphasis given by position in the Latin sentence. But this is like confining the use of steam to the blowing of whistles. Compare 10 and .01, or a few English sentences with their Latin translations.

Like the Hindoo discovery of the zero and consequent modern arithmetic is the organic use of position in language as typified by English.

Again, the number-system of every child is at first *one*, *two*, *many*. The third number, the indefinite, takes different forms, "some," "a few," "a lot," etc. But the mental step from knowing *two* up to knowing three, recognizing a class or aggregate as just exactly possessing the distinctive quality *three*, as being triple or a triplet, is a slow and long and difficult step.

In the high-bred, smart American child this step represents roughly a whole year's development, which can not be much hastened.

Now just this child stage with the enormously undue importance which it attaches to the number two is represented by the whole Greek language and grammar.

This speech has an entire system of grammatical forms, called duals, whose creation rests wholly on the baby-mistake, the child-misconception about *two*. To babies and to Greek grammar *two* is still a god in a trinity. A modern writer speaks slightingly of "the apeing and prolonged caw called grammar, the cackling of the human hen over the egg of language;" but may not the laborious puerilities which have so long passed current as Latin and Greek grammar be of interest to the scientist in comparative child study?

"A single scientific idea may germinate into a hundred arts."

[*Presented to the Texas Academy of Science May 1, 1896.*]

THE ESSENCE OF NUMBER.

BY DR. GEORGE BRUCE HALSTED.

Number is primarily a quality of an artificial individual. By artificial is meant "of human make." The characteristic of these artificial individuals is that each, though made an individual, is conceived as consisting of other individuals. In language the designations for artificial individuals so characterized usually contain other connotation. Examples are a flock, a herd, a bevy, a covey, a throw, a flight, a swarm, a school, a pack, a bunch, a cluster, a drove, a company, a brood, a group, etc. To any such artificial individual pertains an important quality, its "Anzahl," which may agree or differ among such artificial individuals, as may their color. But something like color is made and recognized by insects and animals, so that color is not so highly artificial as number, but will serve for an illustration. Just as the color of a bunch of grapes might be identified by use of a card of standard colors, and so a particular descriptive color name attached to the bunch, in the same way by a well-known process of identification its "Anzahl" may be determined and the proper descriptive name attached. This particular process of identification is called counting, and used originally the standard set of artificial individuals makable from the fingers.

The creation of artificial individuals having this numeric quality, "Anzahl," the creation of number of necessity preceded counting, which is only a subsequent process for identification, for finding the "Anzahl" where it is already known to be.

Number is so peculiarly human a creation that it might be used as an argument for the unity of mankind. Man has found it advantageous to perceive in nature distinct things, the primitive individuals. Each distinct thing is a whole by itself, a unit. The primitive individual thing is the only whole or distinct object in nature. But the human mind takes primitive individuals together and makes of them a single whole, an artificial individual, and names it. These are artificial units, discrete magnitudes. The unity is wholly in the concept, not in nature. It is of human make.

From the contemplation of the primitive individual in relation to the artificial individual spring the related ideas "one" and "many." A unit thought of in contrast to "many" as not-many gives us the idea *one* or "a one." A "many" composed of "a one" and another "one" is characterized as "two." A many composed of "a one" and the special many "a two" is characterized as "three." And so on, at first absolutely without counting, in fact before the invention of that patent process of identification now called counting. For a considerable period of its early life every child uses a number system consisting of only three terms, *one*, *two*, *many*, and no counting. The undue importance given in this system to the number two is fossilized in the *duals* of Greek grammar, and indicated by the unnecessary richness of languages in such terms as a pair, a couple, a yoke, a span, a brace, etc.

The "Anzahl" of a group is wholly abstract, in that it represents all at once the primitive individuals or elements of the group or artificial individual, and nothing more. There never was and never will be a concrete number or anything concrete about number.

The number in the sense of "Anzahl" of a group is a selective photograph of the group, a numeric picture which takes or represents only one quality of the group, but takes that all at once. This picture process only applies primarily to those particular artificial wholes which may be called discrete aggregates. But these are of inestimable importance for human life.

This overwhelming importance of the number-picture after centuries led to a human invention as clearly a device of man for himself as is the telephone. This was a device for making a primitive individual thinkable as a recognizable and recoverable artificial individual of the kind having the numeric quality. This is the recondite device called measurement.

Measurement is an artifice for making a primitive individual conceivable as an artificial individual of the group kind, and so having an "Anzahl," a number picture.

It may be likened to dyeing cotton with analine dyes. This will give the cotton a color which may then be identified by comparison with the set of standard colors.

The height of a horse, by use of the artificial unit, a "hand," is thinkable as a discrete aggregate and so has a number-picture identifiable by comparison with the standard set of pictures, that is by counting, as say 16. But to argue from this the implicit presence of the measurement idea in every number is the analogue of maintaining the implicit presence of the process-of-dyeing idea in every color.

Remark on the preceding by Dr. Edmund Montgomery: "I think you are right in conceiving the 'essence of number' to consist in the fact that mind-made 'artificial individuals' are found in reality to be composed of physically originated 'primitive individuals.'

"The intuitive apperception and synthesis of a manifold has evidently preceeded in us its conscious analysis.

"Erst der geistige Inbegriff, dann die ueberlegte Zerlegung seines objectiven Inhaltes.

"And to how many false philosophies has this mental priority of the One over the Many given rise!

"Formal logic with its ready made premises and purely deductive reasoning has almost exclusively governed our interpretation of nature until lately; until by means of the scientific method we are making sure of the objective correctness of the premises.

"Conceptual Realism has enticed thinkers from Heraclitus, the Eleatics and Plato on, throughout the middle ages in the contest raging between Realists and Nominalists, up to our present Neo-Hegelians.

"Thus have mere conceptual Unities been regarded as supreme reality, as something not of human make, but of independent existence, and constitutive of all nature.

"You are (like myself) convinced that the world we consciously perceive is out and out a mental phenomenon.

"But (also like myself) you seem to insist that such conceptual Unities as constitute 'artificial individuals' are 'of human make' and not 'in nature'; that on the other hand the 'primitive individuals' forming part of them are subsisting somehow 'in nature' as well as in conscious perception.

"This is perhaps the most weighty philosophical conclusion one can arrive at."

[*Read before the Texas Academy of Science, June 15, 1896.*]

ARE WE CONSCIOUS AUTOMATA?

BY DR. EDMUND MONTGOMERY.

It is a remarkable fact, and one not to be gainsaid, that with all the accumulated experience of ages at our disposal, with all the searching aid philosophy has afforded us, with all the keen light shed by science on the phenomena of mind and matter, that with the help of all these fruitful means of knowledge, the verdict of the competent is still wavering—wavering whether we proud lords of creation have to be regarded out and out as mere automatic creatures, as mere puppets in the supernal drama of existence, or whether, to some extent at least, we are self-determined beings.

It seems natural, and is certainly self-gratifying to most of us, to nurture the fond belief that we are able to act as we choose; that we can regulate our life in accordance with a self-determined plan. The immediate inference of consciousness would appear to warrant such a belief. We feel as if we were volitionally conducting our doings toward self-appointed ends.

On close examination, however, serious doubts arise as to this power of volitional self-determination.

The clay-dauber, for instance, might believe that it is building its cells, depositing its eggs, setting out in search of spiders, thrusting its paralyzing sting into their nerve-ganglia, filling the cells brim full with their succulent bodies—it might believe that it was performing these sundry acts of its life-history by self-determined effort. Yet, not only is every one of them strictly preconcerted, but their final aim remains to the last wholly hidden from the consciousness of the performer. It is thus evidently only an automaton, fulfilling a task for which it itself, with all its faculties, is instrumentally, fatefully pre-destined.

It is the same with all animals. From beginning to end, from birth to death, they move—urged by some pre-potent instigation—through their range of pre-appointed activities, wholly unaware of the efficiencies that are here steadfastly at work beyond their own conscious realization. Whatever amount of conscious awareness may accompany these aimfully automatic actions, whether dim or lucid, it would seem to enter only as an inefficient by-play, as a mere passive spectator.

For, without a modicum of it, the plant sinks its eager roots into the fruitful soil, lifts its slender stem into the luminous air, spreads wide and wider its verdant foliage to the chemic influx that elaborates life's all-nourishing pabulum, and finally bursts into the gorgeous, sweet-scented splendor of insect-luring bloom—solemnizing thus, arrayed in delicate beauty, the hymeneal rites of creation.

And all this rich fulfillment of far-reaching purpose without a trace of conscious participation.

Now, is it not likely that man, sharing with his humbler brethren the vicissitudes of existence, with all its fateful round of doings from the hour of birth to that of death—is it not likely that his consciousness, not less than theirs, however intently concerned in the shifting scenes of life, is witnessing them also as a mere unparticipating spectator?

This, indeed, however surprising the conclusion, is the deeply considered verdict, not only of extreme predestinarian theologians and determinist philosophers, but of the foremost scientists of the present time.

Huxley, for example, emphatically declares that the conscious-automaton theory "holds equally good for man," that "all states of consciousness in us are immediately caused by molecular changes in the brain-substance;" that "there is no proof that any state of consciousness is the cause of change in the motion of the matter of the organism;" and that, consequently, "our mental conditions are simply the symbols in consciousness of the changes which take place automatically in the organism."

This, surely, is a plain-spoken, unmistakable statement.

Tyndall arrives at the same conclusion. He says: "If we are true to the canon of science, we must deny to subjective phenomena all influence on physical process."

These illustrious scientists, intimate friends and admirers of such confirmed transcendentalists as Carlyle and Emerson, and likewise given to idealistic views, find themselves, nevertheless, irresistibly caught in the meshes of the conscious-automaton theory.

In fact, hardly a single leading scientist of our time has escaped the same fate.

Du Bois Reymond paints a vivid picture of a mind capable of grasping, with mathematical precision, the mechanical world-formula. Such a mind, realizing the exact relative positions and velocities of all ultimate material particles of the universe, would thus be enabled to foretell, with the same accuracy astronomical occurrences are at present foretold, all future events, inclusive of the minutest actions of all men; nay, would be able to calculate backward every change that had ever taken place in the past.

Such prospective and retrospective omniscience would, of course, depend on the absolute validity of the doctrine that everything happening in the material universe is in all verity the result of atomic mechanics.

This abstruse mechanical and necessitarian doctrine, so strangely at variance with what our individual feelings and intuitions seem to teach, has, nevertheless, come to be the canon adopted by modern science, for guidance in its marvelously successful investigation and technical use of natural phenomena.

Descartes already maintained, and so also Gassendi, that "all variation of matter, or all diversity of its forms, depends on motion." Hobbes reduced, likewise, all natural occurrences to modes of motion. And it can not be denied that the so-called laws of motion, experientially ascertained and mathematically formulated by Galileo, Huygens, Newton, and their followers, when applied to natural phenomena, have, by furnishing us with definitely verifiable knowledge, proved themselves most efficient deliverers from the phantasmagorical superstitions of the dark ages.

It is undeniably clear that all perceptible changes in nature are modes of motion of that which is seen moving. Consequently, the general laws governing the motions being ascertained, they need only be applied to special cases in order to scientifically determine them. And this, in fact, is what atomic mechanics is seeking to accomplish. It assumes that what we see moving are material particles, and that these move in rigorous keeping with mechanical laws.

This view in mind, Newton and Boyle looked upon all changes in the material universe as mechanically effected. Leibnitz declared, likewise, that "everything in nature is effected mechanically," and "that a body is never moved naturally, except by another body, which presses in touching it." Huygens expresses himself to the same effect by asserting that "in true philosophy the causes of all natural effects are to be conceived mechanically." And, coming down again to our own time, Helmholtz tells us that "the object of the natural sciences is to resolve themselves into mechanics." Kirchhoff, the discoverer with Bunsen of spectrum analysis, reiterates the same scientific conviction when he says: "The highest object at which the natural sciences are constrained to aim is the reduction of all phenomena of nature to mechanics." In the same strain other physicists and biologists, and among them most emphatically Haeckel and Wundt. In fact, it has been the strenuous effort, not only of physics, but also of chemistry and physiology, to seek an explanation of their respective phenomena by expressing them in terms of atomic mechanics, or simply in time and space determinations of that which is moving.

All this, no doubt, sounds like rank materialism, and is as such abhorrent to the pious ears of our present sectarians. It would be a great mistake, however, to confound this mechanical view of the material universe, as is often done, with Atheism, or, indeed, with impiety of any sort. Quite the contrary. Eminently pious believers, such as Gassendi, Descartes, Boyle, Newton, Leibnitz, Priestly, and ever so many others, have firmly held the mechanical doctrine. Nay, it may even be confidently asserted that this materialistic doctrine involves the conception of an omnipotent deity more stringently than any other view of physical nature. For, in the very first cast of the world-constituting atoms, all subsequent occurrences in the universe were thereby, of necessity, preordained in their minutest details. A mechanically ordered cosmos would thus, in all verity, afford the most positive proof of the existence of an all-mighty prime mover and designer.

Now, it is quite evident that in a world where all occurrences are effected under the undeviating sway of atomic mechanics, where every succeeding change is rigorously determined by the exact state preceding it, that in presence of such an unbroken chain of mechanical causation, there is no room whatever for the intervention of consciousness.

Such mechanical view being at present the generally adopted canon of science, it will, I hope, be granted that the question I have proposed today, the question whether we are, indeed, conscious automata, can not be deemed as altogether idle, and the time bestowed upon its elucidation as utterly wasted.

To relinquish the firm and fruitful hold on natural phenomena which science actually gives us, in order to luxuriate in the facile realm of imagination, is a dangerous procedure. To appreciate rightly the incalculable debt of gratitude due to the results attained through strict adherence to the science of physical causation, we have not only to consult the numerous memorable chapters in the warfare of science against theological superstitions, but also the cabalistic and magic beliefs universally current in the pre-scientific era — incredibly fantastic beliefs, propounded with systematic seriousness by such naturalistic wizards and medicine-men as Aggrippa and Paracelsus.

The black art, with its incantations and conjurations, pretending to produce extra-natural effects by invoking the assistance of spirits; alchemy, with its universal, all-converting, all-healing nostrum and panacea; astrology, with its supposed prediction of natural events—these, and other utterly useless and misleading necromantic arts, supplied in those benighted times the place of science.

And let me whisper politely, out of hearing of our present sectarians, theosophists and spiritualists, that strict adherence to the methods of science affords us still the only safeguard against a precipitous relapse into the occult practices that have filled with fiendish tortures and death-agonies the mediaeval, goblin-haunted darkness. As late as the middle of the 16th century, in protestant Geneva, there were tortured and put to death, on account of witchcraft and heresy, in the space of three months only, 500 persons. And all this pious holocaust of fellow-men was religiously and conscientiously offered up to please a vengeful demon, created by the cruel fancy of barbarous ancestors.

It can, therefore, not be deemed devoid of interest to let pass in rapid survey the principal steps by which the chaos of capricious influences once believed to have constituted and controlled nature, was eventually converted into the conception of an ordered cosmos, whose occurences, without exception, follow unswervingly the rules of natural causation.

True, this wholesome transfiguration was effected under the penalty of being ourselves scientifically reduced to a state of conscious automatism. But, perhaps, a more comprehensive, though no less verifiable, view of nature may enable our thought consistently to remove the impediment which mechanical causation seems to oppose to our volitional exertions. At all events, such an attempt shall here finally be made.

The modern scientific era was initiated not, as is often asserted, by Lord Chancellor Bacon, who remained to the last steeped in mediaeval superstition, though at times he dabbled in natural experimenting, and insisted upon inductive, instead of deductive, methods of knowledge; it was, in truth, initiated by Gassendi's revival of Greek atomism. The defense by this pious prelate of the atomic physics of Epicurus, published in 1647, was the momentous event which set rolling the irresistible, all-involving scientific avalanche.

Descartes, Boyle, Newton, Leibnitz, and their followers, in rapid succession, succeeded in applying the mechanical laws of corpuscular, or atomic, motion to divers phenomena of nature, physical, chemical and physiological. In the year 1660 the Royal Society of London for Improving Natural Knowledge was founded. In 1661 Boyle published his "Chemista Scepticus," by which alchemy was laid to rest for evermore. Newton entered the Royal Society in 1681. His "Principia" were composed during the years 1685 and 1686.

The heliocentric view of our planetary system, enunciated as a hypothesis by Copernicus, and proved to be a fact by Galileo's astronomical discoveries, inspired the ardent spirit of Giordano Bruno to arise to the sublime conception of a boundless universe, boundlessly peopled with harmoniously moving worlds. At that time, when our own tiny globe was universally believed to be the only existing world upon which all divine solicitude was exclusively centered, this minimizing of our mundane importance was considered a dangerous, all-subverting heresy. Despite of it, in opposition to the rigorously canonized geocentric tenet, the ineffable magnificence and infinite vastness of the new world-conception fired with unconquerable conviction the vivid imagination of this courageous Dominican monk.

Deep down in an inquisitorial dungeon, secreted from all the world and its notice, himself all-forsaken, he endured, for the sake of this glorious belief, year after year, the infliction of untold tortures. Without wavering or weakening, this intensely sensitive child of the South bore it all with steadfast fortitude, unencouraged, unloved, unadmired, by his fellowmen, in awful solitude, unfalteringly loyal to his divine enlightenment. And when his last hour arrived, the transcendent revelation nerved him to ascend with undaunted spirit, amid the execrations of the Roman mob, the blazing pile that was forever to quench his eloquent voice—but signally failed to fulfill the expectation of his torturers by silencing, also, the undying truth he so heroically proclaimed.

Only 85 years later, Newton, by force of the now established physical theory wielded by him with consummate mathematical genius, disclosed irrefragably the exact mechanical law which, to the utmost depths of illimitable space, is undeviatingly followed by innumerable systems of speeding, circling, whirling worlds in their solemn, tireless, spheric dance toward creative fulfillment.

An essential impetus to the mechanical interpretation of nature was also given by Harvey's discovery of the mechanical circulation of the blood, published in 1628. It induced Descartes to formulate an out-and-out mechanical view of the organism and its vital functions. In his answer to Morus, he says: "It appears to me a very remarkable circumstance that no movement can take place, either in the bodies of beasts, or even in our own, if these bodies have not in themselves all the organs and instruments by means of which the very same movements would be accomplished in a machine." And in his "Traité de l'Homme" he specializes the purely automatic interpretation of all vital functions, an interpretation which led him to deny to animals even conscious sensibility, while, to be sure, he allowed to men the super-position of a thinking substance, somehow miraculously connected with the automatic organism. "I desire," he says, "that you should consider that the functions of the bodily machine naturally proceed from the mere arrangement of its organs, neither more nor less than the movements of a clock or other automaton from that of its weights and wheels."

We have to confess that, despite the strenuous philosophic and scientific efforts of the last two centuries, no logically valid escape from the conscious-automaton theory has yet been found.

When, in the light of the extensive additional experience, carefully gathered during these 200 years, we contemplate how vital processes of the most complex nature may, without the assistance of consciousness, attain aimfully preconcerted ends; and, on the other hand, how absolutely dependent on definite organic structure special modes of consciousness are proved to be, we shall be forced to conclude that it is no easy matter to ascribe to consciousness its right place in the economy of life.

Persons not familiarly conversant with natural science, and more especially with biology, are slow to realize how its votaries are irresistibly compelled to submit their traditional ideas and intuitions to the stern correction of well-ascertained and verifiable facts of nature. Such unscientific persons, however cultured otherwise, can hardly be expected to understand the strength and insistence of scientific convictions, though they seem flagrantly to contradict currently accepted notions. To people who habitually move without scientific restraint in the frictionless expanse of intuitive thought the conscious-automaton theory will naturally appear a monstrous fallacy.

Yet, when nightly to sleep they give their conscious powers away, withdrawing from the garish scenes of the sense-obtruding world to those mysterious depths where all creative work is wrought; there, out of all self-control, away from all conscious participation, nature's automatic travail, with unremitting toil, is keeping not only intact and whole their entire being, but is restoring to full efficiency its mental and other vital energies, maimed in the heated struggle of its waking hours.

And mothers, when they receive with tearful joy and tenderest solicitude their new-born babes, full-fashioned out of the creative depths of unconscious being, are they not holding to their loving breasts the mystic consignment of all times, the embodied result of all vital travail, their ownest own, and yet the fruit of ages upon ages, bearing our world's ripest hope?

Surely, when such supreme creative marvels are wrought beyond conscious awareness and participation, it is, after all, no wonder that the conscious-automaton theory has forced itself from various standpoints upon investigators of nature.

And just as certain as functionary organic structures become elaborated without conscious interference, just as certain do all modes of consciousness, all sensations, perceptions, emotions, thoughts and volitions depend in the strictest manner on specific organic structure in efficient activity.

Careful experiments by Hitzig, Ferrier and others, frequently verified since, have proved that by stimulating definite parts of the brain, movements are automatically produced by contraction of definite sets of muscles, which, otherwise, are only effected by so-called volitional action. The cortex of the brain has thus been mapped out, not by any means into complex mental faculties, as pretended by the pseudo-science of phrenology, but into definite motor and sensory regions. Thus the structure whence the organs of speech receive their innervation is definitely located in the lower frontal convolution of the left side. Injuries affecting this special organ give invariably rise to what is called aphasia, which means speechlessness.

As Erxner remarks, many different efficiencies conspire to enable us to use language, and the brain-centers where these are located have to be all intact for the purposes of speech. To give a proper answer to a question, for example:

First. The words have to be heard.

Second. They have to be understood.

Third. The process set going in the receiving organism by the words has to elaborate there a proper result.

Fourth. The result has to be expressed in words.

Fifth. Appropriate innervation has to set the articulating muscles in motion.

Sixth. The innervation must reach the muscles of articulation in proper order and intensity.

All these divers organic efficiencies, located in definite nerve-centers, have to be set harmoniously going in order to give a proper answer to the simplest question.

Now, as we are not even in the least conscious of having any brain-centers, much less of their definite location, how can our consciousness possibly perform on an organ whose keys and stops are utterly unknown to it? It must, evidently, be some agency vastly more potent than conscious awareness which extracts from that marvelously intricate central organ of ours, in harmonious sequence, whole strains of speech and all manner of purposive movements.

A hypnotized person, carrying out consciously-unremembered suggestions; a somnambulist, writing an elaborate essay unbeknown to his waking self; a dreamer, constituted, beyond his own volitional determination, actor and spectator in thrilling dramas; in all these faithful imitations of what is believed to be otherwise consciously effected, there surely must be some agency at work of an entirely different order, something performing of itself, automatically, what we in our waking state are wont to attribute to the doings of our consciousness.

Nevertheless, who can in truth believe that pleasure and pain, hope and fear, love and hate; that ideal purposes firmly set, and unflinching faithfulness to their execution in actual life; who can believe that all this impassioned consciousness is of no slightest avail, that it is utterly powerless to influence the irreversibly fated drift of human existence?

Notwithstanding, the question remains still unsolved how mental states can possibly influence bodily actions. Ever since the mechanical interpretation of physical nature gained sway, leading necessarily to the bi-section of our unitary being into the two seemingly incommensurable entities, called respectively body and mind, their mode of intercommunication became the central puzzle of philosophy.

Under this dualistic aspect, we find, outside of consciousness, nothing but a world of mechanically actuated matter; inside consciousness, a world replete with ideal feelings and thoughts, and, strange to say, no rationally conceivable interaction between the two.

To bridge this provoking chasm, the Cartesians assumed a "concursus divinus," a divine concurrence each time body is seemingly acting on mind, or mind on body. Spinoza sought to escape from the perplexing dilemma by postulating an absolute substance, of which the two incommensurable substances in question were conceived as attributes, asserting, then, simply that the order and connection of thought is, by force of eternal concordance, ever the same as the order and connection of things. Leibnitz advanced, in explanation of the same riddle, his celebrated two-clock arrangement, by means of a divinely pre-established harmony; Kant believed that free causation in a surmised intelligible world appeared as necessitated causation in the sensible world; and so on in endless variations have futile attempts been made to overcome this estrangement between mental awareness and bodily actions.

To all these eminent thinkers man remained, therefore, in verity, but a conscious automaton, whose physically ineffective mind is miraculously brought into harmony with his mechanically executed actions.

But, quite irrespective of atomic mechanics, with its ultimate "adamantine" material particles, knocked from outside by transient modes of motion or energy into the grouped arrangements which constitute the things of the perceptible world, quite irrespective of mechanically necessitated causation, does not biological evolution, in its sundry expressions, teach the same fatalistic doctrine of pure automatism? Here it is either through fortuitous variations, selected in the struggle for existence, that organic development is held to be effected; or, as others will have it, through pre-destined developmental tendencies, inherent from the beginning in the primordial germ of life; or, again, ideally expressed, through a power, not ourselves, making for progress and righteousness.

Is it not strange that man, in verity the most self-willed being in creation, so readily abdicates in theory his power of self-determination? Whenever he sets out to give a reasoned account of the impelling causes of his conduct, he almost invariably comes to the conclusion that he is acting under the spell of some overwhelming fatality. He exults in pronouncing himself the impotent plaything of external conditions. First, all sorts of evil or good spirits are held to foil or foster his course. Then, though highly civilized otherwise, he will not move without propitiating his household gods, or consulting the soothsayers. Then he makes himself believe that some pre-potent stress, or the eternal stars, are swaying his destiny. In his scientific moods he delights in the idea that a fortuitous or a pre-destined concourse of atoms is bringing everything about, or that the elementary lives of his constituent cells are the true agents that blindly perform the functions of his being. Or, again, to disclaim his own responsibility in his actions, the plea of insanity is advanced; or, more sweeping still, the plea of irremediable heredity. And next it is evolution, either mechanically or divinely ordained, that is believed, by dint of purely physical processes, to achieve all results. Yet, regardless of all his fatalistic theories, the inconsistent creature will thrill with rapturous admiration at the account of noble deeds, and with all his might, and at all risks, he will battle in defense of his honor and of his beloved ones, and for fulfillment of his ideals.

Naturalistic thinkers, when they contemplate the central dilemma of body and mind, find themselves generally confronted by the following two-fold perplexity: First, how can so material an occurrence as molecular brain-motion be possibly converted into so completely immaterial a phenomenon as a conscious state? And, vice versa, how can an immaterial something, which a mental state evidently is, how can it possibly impart motion to matter?

Sundry modes of vibration impinge from outside on our recipient sensory organs. A definite molecular stir is thereby set up in their respective nerves and propagated along their course to the brain-substance. And here it is where we are brought face to face with the all-important hyper-mechanical problem. For the metamorphosis of a material motion into consciousness, the metamorphosis of a definite molecular stir into a definite conscious state, this out-and-out incommensurate transmutation is, to our mind, utterly incomprehensible.

Most scientists have, in fact, openly declared this distracting psychophysical riddle to be insoluble, to be a final inexplicability in nature.

And no less unthinkable is the imparting of motion to matter by a mental state, by something wholly devoid of momentum, and, therefore, of moving power. Consequently, it is out of the question that it can be any kind of mental state in us, call it "motive," or by any other name, which is initiating and directing our so-called voluntary movements.

Do we, then, here really stand before an impenetrable mystery? Is our thought really doomed to stay forever still before this seeming deadlock?

Recently a number of scientists, and among them Huxley and Tyndall, have pretended to circumvent the awkwardly pointed horns of this great dilemma by coolly declaring that, irrespective of their scientifically adopted mechanical canon and conviction, they have found intellectual rest in pure idealism.

This desperate salto mortale, this unqualified flopping round to the diametrically opposed idealistic side, when their scientific thought had to halt, baffled by the central enigma, seems to me a lame subterfuge, which I, for one, refuse to have recourse to.

There can be no doubt that, by following the idealistic bent of the dilemma. surprisingly luminous conclusions are reached. After Locke had elaborated the sensorial side of Descarte's mental philosophy, colors, sounds, odors and tastes were recognized to be purely individual sensations, and, therefore, phenomena of consciousness, instead of properties of external things. After Berkeley had furthermore enlarged the domain of consciousness by despoiling physical nature of all perceived qualities whatever, proving that everything which is realized as perception is of necessity a mental phenomenon, and by no means a physical existent, this at first astounding conclusion has since been considered flawless. And after Kant had finally demonstrated that time and space, as consciously realized by us, are likewise mental phenomena, a royal road was opened for idealistic revelling. For, after such complete draining into the sphere of consciousness of everything which seemed to make up physical nature, it became doubtful to philosophically trained minds whether there exists, in truth, anything in the world save consciousness itself. To perceive is to be, so enunciated the Berkelians. Thought and Being are identical, so proclaimed the Transcendental Idealists.

It would take vastly more time than is here at my disposal to enter into a detailed discussion of this weighty question. This I have attempted on former occasions. I will now directly appeal to this audience to corroborate my principal contention against pure idealism. This consists in the simple assertion that to you all I am a visible, audible, palpable presence; that you all perceive what is called my body, together with its sundry sense-affecting activities.

However idealistically inclined anyone among you may be, I hardly think he will venture to deny the truth of this simple assertion.

Now, it is just as true and certain that my mental states, my sensations, perceptions, emotions, thoughts and volitions are, as such, altogether imperceptible to you, that they have no power whatever to affect your senses. If you were to look into every nook and crevice of my brain, or I into yours, no inkling of anything of mental consistency could be detected there—nothing but molecular commotion, no trace of any conscious state.

It is quite clear and incontestable, then, that what you perceive as my body must be something of a nature entirely differing from my consciousness, from my feelings and thoughts, which you can not perceive, and which I have to convey to you symbolically by means of bodily signs.

When I move my arm, it is obviously nothing forming part of my consciousness, nothing of mental consistency, which affects your senses and arouses in you the perception of a bodily arm in motion. Now, what we desire to know is, whether this bodily arm is mechanically, automatically moved, or whether I, myself, volitionally move it by dint of free self-determination?

This is the decisive question.

The ancient Roman eulogist of the atomic materialism of Epicurus, the illustrious poet Lucretius, was already fully aware of the inexorable fatalism involved in the purely mechanical conception. He says: "If all motion is connected and dependent, a new movement perpetually arising from a former one in definite order, the primordial elements never deviating from the straight path to give rise to fresh springs of action, potent to subvert the laws of fate and break the rigid chain of cause on cause in infinite succession, whence comes the freedom of will to all animals in the world; whence, I say, the liberty of action wrested from the Fates, by means of which we go wheresoever inclination leads each of us, moving not at any fixed time, nor in any fixed part of space, but just as our mind prompts us?"

The problem before us, after the lapse of 2000 years, could hardly be more forcibly expressed.

If my body is really a machine, that is a peculiarly collocated congeries of parts, acting mechanically upon one another, and set in motion by heat derived from the combustion of food-particles, then never anything but purely mechanical effects can be expected from the performance of such a contrivance; and the link between its motions and its conscious states remains as inscrutable as it was to Descartes and his followers.

Julius Robert Mayer, the first promulgator of the doctrine of the correlation and transmutation of forces, enunciated, also, the heat-engine doctrine of our vital activities. According to it, vital structure, the muscle for example, is, in Mayer's own words, "only a machine through whose instrumentality is brought about the transformation of force." "The muscle is not, itself, the material by means of whose chemical metamorphosis the mechanical effect is produced."

This modern prevalent notion of the organism being a machine, set going by extraneous, non-vital force, is, despite its scientific aspect, just as preposterous as the ancient mystic notion of vital spirits. It is an out-and-out unphysiological and altogether mistaken conception. My own studies of motility in protoplasmic individuals, and in muscular fibers in particular, published in Pfleuger's Archiv, have visibly demonstrated that the force by which vital movements are effected is not derived from any combustion whatever, but that these movements are in every one of their stages the mass-manifestation of a definite cycle of chemical activity, occurring in the very substance which exhibits the motions.

Indeed, muscular action, as well as all other vital function, is a display of specific energies, strictly inherent in the wondrous complexity of the slowly elaborated molecular structure which performs the function. This molecular complexity is the phylogenetic result of the vital interaction of countless generations of living individuals with their surrounding medium. Vital energy is thus in no instance the mere transfer of some other energy furnished from external sources. It is, on the contrary, the display of most peculiar spontaneous powers, inwrought, and persistently maintaining themselves, in the living structures. Or, more correctly, vital energy is the display of the very forces which constitute the living structures. For these structures are themselves but the visible manifestation of such vital forces.

How, then, can a vital force-manifestation, issuing from the astounding hereditary wealth of such a minutely organized and livingly sustained structure ever yield to any mechanical explanation? Vital activity, in every one of its manifestations, is wholly an emanation from within. Any influence believed to be actuating from outside the organism and its life, whether brought to bear in the shape of miraculous intervention, or of an animal soul, or of vital spirits, or heat, of electrical fluids or combustion of food-particles, whatever the name of such surmised extrinsic causative agency, it has to be utterly eliminated from biology before we can hope to gain an understanding of the transcendent wealth and import of individual existence.

It is as an indiscerptible organic being that I am endowed with the power of volitionally moving the organs which bring me into relation with the outside world. I can move them in definite individual ways, or may refrain from moving them. When, in my right mind, I hold a pistol in my hand, I can, irrespective of any ever so potent instigation, either pull the trigger, or abstain from pulling it. And this freedom of choice as regards my so-called volitional movements is exactly what constitutes me a responsible being.

If you ask me how I manage to perform this executive or inhibitory feat I may, perhaps, be able to tell when we know how a gas-molecule manages, by force of its so-called elastic endowment, to impart resilient motion to other molecules; how the efficiencies that underlie the phenomena of gravitation, cohesion, chemical affinity, magnetism and electricity manage to produce their perceptible effects.

Meanwhile, the difference between voluntary and conscious, as well as unconscious, automatic activity, can be distinctly realized by watching, for instance, our breathing movements. These are generally carried on automatically and unconsciously. By directing our attention to them, we can, however, become consciously aware of their automatic activity. This is a genuine instance of conscious automatism, for there is no effective intercommunication between the movements and the awareness of them. But we are able to assume, moreover, voluntary control of the movements. We can, at will, breathe quicker or slower, deeper or less deep, or entirely inhibit the movements for a time. The consciousness of this voluntary performance, compared with the consciousness of the mere automatic action, will clearly indicate the difference between volitionally spontaneous and mere automatic activity. Here the two activities have entered into effective intercommunication. The activity which underlies the movements has become dependent on the activity which underlies the conscious volition.

Few people, when absorbed in their routine rush through existence, get to realize how wonderfully and fearfully they are made.

From out the inscrutable depths of nature myriads of dark effluences strike with subtle touch the attuned chords of our responsive being, and lo! the perceptible world, and we therein, stand revealed in the conscious medium of vivid sensations and perceptions. A still more exquisitely refined play of intrinsic agitation, and our moment of awareness is filled with those intellectualized emotions and volitions that constitute our imperceivable self-consciousness.

Yet, we do not, in reality, consist of these mere conscious states, nor are we merely lumps of material elements moulded into the shape of a mammalian biped.

Time-originated beings, livingly moulded in the fiery clash of battling forces, do not consist of such flimsy stuff as dreams are made of; nor do they consist of so intrinsically inert a material as a mechanically agitated aggregate of particles is held to be.

As Goethe says:

> "Und keine Zeit, und keine Macht zerstückelt
> Gepraegte Form die lebend sich entwickelt."

The life we bear, so singularly gifted with transcendent proficiencies, how strikingly different from lifeless nature! What contrast between the toilsomely sustained complexity of our life-quickened organization and the facile and uniform maintenance or random mutation of inanimate things! With the intuition of its world-wide bearings and sympathies inwoven in its all-harmonizing constitution, our living being awakens aimfully to confront, amid these immemorial memories, an otherwise senseless, impercipient world, which buries from instant to instant all its casual happenings in perpetual forgetfulness.

The firmest rock, towering in majestic grandeur, cleaves, falls and crumbles insentiently into scattering dust. But the frail body of man, by dint of those living bequeathments, victoriously resists the shattering influences, gathering mindfully new strength in its clashing encounters, and leaving its heightened existence in rejuvenated form to meet with new ardor the brunt of oncoming times.

And here chimes in the true import of consciousness. Consciousness consists of the inner awareness by means of mental symbols of our own being, with its memorized faculties, and of the things and happenings of the world at large. Though its states are, as such, themselves forceless, and, therefore, incapable of being the cause of bodily motion, they compose our only source of information, through which we are guided in the execution of our voluntary movements.

Whenever we are conscious, this our moment of present awareness forms a marvelously complex microcosm, into which come crowding, besides perceptual arousings from without and multifarious individual reminiscences, the immemorial memories of our race. All this resuscitated, ghost-like assemblage of outer and inner experience falls into more or less systematic order, and is partly governable, for intentional purposes, by means of attentive focusing and fixation through linguistic contrivances.

We find thus before us, at our immediate disposal, unchecked by time and space-limitations, and rationalized by social usage and linguistic thought, the cumulated result of all ingathered experience, emotional and perceptual. And as our executive organs, those, namely, which bring us into direct communion with the outside world, are subject to our volitional control, we become thus responsible for the practical use to which we put the vast deliberate information yielded by our microcosmic consciousness.

Far, then, from being mere conscious automata, we are, if true to our evolutional mission, consciously-informed volitional agents in the realization of human progress; nay, in the evolutional realization of the evolving universe.

Drawing with mystic roots our life-blood from the endless reach of time-withdrawn ages, we contemporaneous, sole-surviving scions of the perennial tree of life, are now here faithfully to uphold the painfully acquired worth of human existence, offering it in sympathetic interchange and gladsome sacrifice to the fructifying light of the progressive day.

Is it not a sacred and exultant mission to be thus personally intrusted with the cumulated achievements of all bygone ages, to be constitutionally representing the crowning embodiment of all secured results of life's sore travail?

Hallowed by the passing away into eternal silence of generation after generation of striving, feeling beings, whose offspring we are, we, heirs of all that has been, stand now here, this present moment, in awe-inspiring isolation, alone alive on this earth, in the immensity of star-lit space, in the infinity of lapsing time—sole sentient links between what was ever done here before and what shall ever be done hereafter. On fidelity to our vital, to our human, trust, the past has built with never-flagging zeal—and with hopeful confidence the future is depending on it for further fulfillment.

[*Read before the Texas Academy of Science, November 6, 1896.*]

ECONOMY OF GOOD ROADS.

BY THOMAS U. TAYLOR.

The advantages to be obtained from a system of good roads are very little appreciated. To the farmer, they are directly beneficial. By the most accurate experiments of eminent road engineers (MacNeill, Morin, etc.), it has been found that on a good broken-stone road a horse can draw three to four times as much as he can on a common dirt road. This supposes that both roads are in fair condition. In rainy seasons, the relative capacity of the horse is greatly increased, for on the metal road his pulling or tractive effect remains about the same in wet and dry weather, provided the road is in such condition that he can get a good foothold; but on the dirt road his effective tractive power varies from one-third to nothing. We thus see that under the most favorable circumstances the amount of team to do a certain amount of work on the road can be decreased two-thirds after the road is macadamized.

Many experiments have been made to find how much tractive force (pulling force) in pounds would haul a ton on a level on the various kinds of lines of communication, i. e., steel rails, iron rails, stone rails, plank roads, macadam, telford, gravel and dirt roads. The results generally accepted among road engineers are those of Morin, made in 1838. His results were as follows:

On iron rails, 10 pounds would pull a ton of 2240 pounds.
On Telford road, 46 pounds would pull a ton of 2240 pounds.
On Macadam road, 65 pounds would pull a ton of 2240 pounds.
On gravel road, 88 pounds would pull a ton of 2240 pounds.
On dirt (loose) road, 200 pounds would pull a ton of 2240 pounds.
On dirt (hard and dry), 89 pounds would pull a ton of 2240 pounds.

Before proceeding to conclusions, we must say that on the best steel rails, in our best railway practice, the co-efficient of traction is about eight pounds. The co-efficient of traction of 200 pounds for dirt roads is not an estimate for our black land roads in dry weather. When the surface is not rough, and when the road is thoroughly hardened by travel, the dirt road, for the time being, becomes almost as good as a macadamized road. Its co-efficient would be nearer 46 or 65 pounds than 200. However, this is true for only a small fraction of the year, and during this fraction the country does not need the roads for working its crops.

Several attempts have been made to either verify or correct Morin's results, as given above, but these results are still taken as a standard. In 1893 the Studebaker Bros., of the great wagon industry, made a series of experiments with their wagons of different widths of tires. These tires were $1\frac{3}{4}$, 3 and 4 inches wide, respectively. The result of their tests was that on a hard surface the width of tire had very little effect, if any; that on a soft surface they found the expected result that the advantage was with the wide tire. On a stone block pavement, the traction force varied with the vehicle, and varies from 30 to 65 pounds; from 60 to 100 for a gravel road, and from 240 to 325 pounds per ton on a muddy road. These results were obtained after the wagon had been started, and it was found that it required an extra expenditure of 125 to 200 pounds per ton to start the wagon.

The United States government recently carried on a series of experiments at the Atlanta exposition for the purpose of finding the co-efficients for various surfaces. These results are published in Bulletin No. 20, under the title of "Traction Tests." They were made under S. T. Neely, the assistant engineer of the road engineering department. The following deductions were made from this series of tests: (1) the force of traction varies *universally* as the diameter of the wheel; (2) the force of traction increases with the speed upon hard roads, but not in proportion to the velocity. It is probable that the word "universally" is a misprint for the word "inversely;" otherwise, the statement is contrary to the facts established by former experimenters.

The power of a horse, or the force a horse can exert continuously, in pulling a load on a level has been the subject of many investigations. If the horse is equivalent to the theoretical horse, as defined by James Watt when he introduced the term "horsepower," he can exert a horizontal force of 150 pounds at the rate of $2\frac{1}{2}$ miles an hour. It is highly probably that 100 pounds would be a liberal estimate for our Texas work horses. It is even questionable whether they exert this much tractive force.

The advantages to a city obtained by improving the roads that feed it are easily seen. If the town is the market for wheat, cotton, etc., and its feeding roads are so improved that the same wheat and cotton can be hauled two or three times as far without further expense, it is manifest that the trade of said town can be increased four to nine times. Again, when one town knows that on account of bad roads it will be impossible for the farmer to take his produce elsewhere, it is probable that that town will offer the lowest price of the market; but the moment another town is brought into competition by the introduction of good roads the highest market price is sure to be offered.

* See Jenks' Road Legislation for American States.

Some years ago it was estimated in Berlin, Germany, that $25 would be saved per horse annually by improving their pavements. In other words, the people were paying that much per annum for not improving their streets. Prof. Ely, of Johns Hopkins University, thinks that a conservative estimate for Maryland and the adjoining States would be $15. This means that the farmer is paying each year $15 per horse for the privilege of using bad roads. This is the toll road in every sense of the word. Every bad road in the country is a toll road that exacts more tax than the annual gate fees would amount to on a turnpike. The State of Texas has no provision in her laws for toll roads, but here they are, without any legislation on the subject. How long will the farmers of Texas pay this toll? Let us take the estimate of Prof. Ely and see what it means for us here in Texas. We will confine our calculations to the more populous counties of the State. It is a fact that many of our horses in our oldest counties are range horses, and it is another fact that his estimate of $15 was not made for a black waxy region. To be within the safest of bounds, let us say $5. The following table, in which the headings will sufficiently explain themselves, will give us an idea (although a rough one) of how much our poor roads are costing us. The data are taken from Commissioner Rose's Texas agricultural and statistical report for 1894:

County	No. of Horses.	Wealth.
Grayson	25,614	$17,118,025
Collin	27,000	10,910,400
Fannin	24,331	10,120,000
Hunt	21,109	8,822,725

These four counties have a total valuation of property of $46,971,650. There are 98,000 horses. A county official of Hunt county says, in a letter to the writer, that there are 9000 farm horses in that county. In this group there would be, then, according to this, 42,000 farm horses, giving a cost annually of $210,000, about 45 cents on the $100.

Every time a farmer repairs his wagon, his harness, his buggy, etc., he is paying that much tax in labor and money to bad roads, for which they return nothing to him, but are continually calling for more. Every time he buys these, he is paying part of the price for the privilege of driving over bad roads. Our farmers may complain that they can't stand the tax to make and maintain good roads. Let me say here that the introduction of good roads would not increase, but decrease, the resultant taxation. Every farmer in Texas pays annually more taxes to bad roads than would pay his annual fees over the most excellent system of turnpikes ever constructed.

We complain of our farmer boys leaving the farm and rushing to the city, and the complaint is just. Why do they leave? Is it because farm life, or, better, country life, does not offer as many attractions? Why is it that the country life in the older States is so desirable? The reason will be found in the better equipment of the country in all respects. One of the greatest agencies in this work is our schools. Thanks to good management, they are now on rising ground, and it will soon be so that no farmer will be compelled to send his children to town to reach schools. A greater agent still in this work of social reform is the introduction of first-class roads. When our counties become belted and checkered by fine macadamized roads, the stampede from the country to the town will cease, and we shall see the tide turn the other way. It needs no statement here to convince anyone that the social life in the country would be improved, and that instead of our country boys selling their patrimonies and joining in the strife for wealth in the teeming cities, we shall see them settle down to the sturdy life of the yeoman citizen.

The labor tax, or labor levy system (known by us as the overseer system) is so universally adopted that it needs more than a passing notice. As usually carried out in practice, it is very defective. In theory, the same objection can be urged against it that are urged against the poll tax. It is in reality a poll tax in labor. The work is under the control of an overseer, who generally knows little about the principles of road making except what he has learned by discharging his few (five) days' assessment from year to year. As everyone knows, in the majority of cases the day is fooled away in discussing politics, or retailing the latest gossip of the country. As effective work, the day's labor does not amount to three hours' honest work. The overseer can not *make* the hands work. Every man, of course, should do something for his roads, but this something should be left to some competent road man. The work of a raw hand, however willing and industrious, is not as effective as a regular road worker. It would be better if all road work could be done by hands regularly employed on the roads. The only way to do this is to abolish the overseer system and place all roads under the supervision of experienced men, and, instead of a labor levy of five days, make every man over 21 years of age pay a road poll tax of $1 to $3. Personally, I should prefer $2.50. Some of the special road laws permit a person to pay $3 and escape the road levy. I can not say how many avail themselves of this privilege. Statistics on this subject would be interesting.

First of all, there should be a county commissioner of roads, a man well skilled in the science of road and bridge making. It seems to me that this system would be preferable to the law making county commissioners ex officio road commissioners, as in the special road laws of Fannin (1895) and of Collin, Grayson, etc. (1893).

However, if the county commissioners are made road commissioners also, they certainly should receive more pay than they receive now. The office of commissioner is one of the highest importance and should be filled by men of intelligence and men of affairs. The per diem is poor compensation for a man who is expected to devote a large part of his time to studying the interests of his district and county. As it is, he gets pay only for the time that court is in session. He can not study the needs of his constituents while court is in session, and if he is not paid for it, we can not expect him to devote any more time to it. If the overseer system is abolished, the commissioners will have to devote more attention to the roads, or employ someone to do so for them.

COUNTY.	Miles of road.	Population, 1890.	Taxable Wealth, 1894.	Road levy in cents per $100.	Annual expenditure on roads.	Inhabitants per mile.	County Road Equipment. (Partial.) Mules or horses.	Graders.	Scrapers.	Road Rollers.	Regular hands.	Foremen.	Mules worked to grader.	Are convicts worked on roads?	How many in all?	How many in a squad?	How kept at night?	Is convict work satisfactory?	Do convicts do as much as ordinary hands?	Best width of county road.	Best width of ditches.	Height center above ditch.	Is it advisable to have a State Com'r or Road Supt?	Amount road each grader can make per day?	Special road law?	Are you in favor of retaining the overseer system or of raising the road levy and working by regular hands?
																				ft	ft	in.				
Bell	1800 to 2000	33,387	$12,462,380	9	$11,000	17	*40	4	200	...	...	...	*10	Very little	6 or 8	...	Guards	No ...	No ...	30	5	12 to 15	Yes	¼ to 1 mile	Yes, 1893	Present one defective but not in favor of radical change.
Grayson	2100	53,211	17,118,025	15	25,000	26	60	5	20	...	12	4	10	Yes	21	21	Cages	Yes ..	Yes ..	40	...	...	No ..	...	Yes, 1893	Change from 5 days' work to a poll tax of two dollars.
Hill	1500 to 2000	27,583	10,447,150	15	20,000	13	57	4	...	...	...	...	8	Yes	28	6	Chains	Yes ..	More	40	6 to 10	...	No ..	¾ mile	Yes, 1895	Yes.
Navarro	...	26,373	10,840,017	...	15,000	13	...	4	100	...	...	...	6	Not much	...	...	Poor farm.	...	Yes ..	60	8	30	No ..	...	No ..	Prefer a new system.
Tarrant	...	41,142	20,339,960	25	40,000	...	60	2	20	2	10 to 15	...	4 to 6	Yes	50	20 to 30	Guards	Yes ..	No ...	60	...	...	No ..	...	No ..	We have no trouble with overseers.
Travis	1500	36,332	15,864,390	15	22,000	18	40	3	...	1	23	...	6	Yes	12 to 15	12 to 15	Guards	Yes ..	Yes ..	60	...	...	No ..	...	Yes, 1891	Should be revised and a poll tax of one dollar levied.
Dallas	1275	67,042	33,326,100	15	40,000	53	...	4	...	...	...	...	8	Yes	75	15 to 20	Guards	Yes ..	Yes ..	40	8	...	No ..	...	Yes, 1895	Road overseers are a nuisance.
Fannin	1400	38,709	10,120,180	15	20,000	28	25	2	400	...	10	...	8	Yes	15	15	Guards	Yes ..	Yes ..	40	...	...	Yes	...	Yes, 1895	...
Collin	1500	36,736	10,910,400	...	...	25	51	18	800	...	28	...	12	Yes	10	...	Cages	Yes ..	Yes ..	40	4	18	No ..	½ mile	Yes, 1891	Properly managed, overseers are O. K.
Hunt	1250	81,885	8,822,725	15	15,000	24	...	4	300	...	...	...	6	No	...	...	...	...	...	60	...	...	No ..	...	Yes, 1895	Yes.
Ellis	1200	31,774	14,268,933	10	21,000	27	40	4	...	...	...	...	8	Yes	30	30	Guards	Yes ..	More	40	...	30	No ..	¾ mile	Yes.	Raise tax levy.

* Bell county works oxen instead of mules, but the commissioners court has decided to sell the oxen and buy mules.

ROADS IN THE BLACK LAND COUNTIES.

With a view of ascertaining the condition of the roads in the different black land counties, inquiries were sent out in October and November, 1896, to all the counties mentioned in the table, and to several others, from which no reports have been received. Attention is called to this table, especially to the road equipment of the different counties. Many valuable suggestions that can not appear in the table were made in these reports. Some of them are submitted:

Judge Furman, of Bell: The overseer system is defective, but I am not in favor of a radical change at this time. The overseers co-operate with the county force in Bell.

We have been working oxen to our graders, but shall abandon this method and buy mules, as oxen are too slow.

The advice of an expert (as State superintendent of roads) would be invaluable.

Judge Hall, of Cooke: To levy an additional tax and work altogether by taxation would be more profitable and much more satisfactory.

I am of the opinion that with the right man (as State superintendent of roads), much good might be accomplished.

Judge M. L. Shelton, of Navarro: The proposition to increase our road levy was submitted to the people, and was lost by a large majority. We have no regular hands. County convicts work (when they do work) at 50 cents per day. I think a new system for working the roads is sooner or later inevitable. We should levy a special tax and work the county convicts more extensively.

A State superintendent of roads would be an unnecessary expense.

We in this county have no facilites for keeping the convicts over night away from the county poor farm (at which place we, of course, have a prison), and, therefore, we only work convict labor near the farm, but we do not work convicts over two months per annum. Most of our road work is done by the overseer and his hands. We have four graders and work three hands and six mules with each grader.

Mr. J. W. Vaughan, of Hill: Hill county has been using one grader for about eight years, but, owing to the demand for grading, we bought three more last April. We keep two graders and one plow in each squad, and work eight mules to each grader, and from four to six to a plow. An extra squad, with drag scrapers, is maintained to fill in where the grader can not be used. Each squad makes about three-fourths of a mile of road per day—about $18 per mile. This includes all expenses of county farm, except clothing paupers.

The grader is undoubtedly the road maker for the black land of Texas. The depth of ditches and height of center depend upon local conditions. Forty feet is ordinarily wide enough.

I think a special law should apply to the group of black land counties. Our special law is not altogether satisfactory, but it is so much better than the old law we are satisfied till we can do better, although the pay for the superintendent is not enough. The business occupies our entire time, and we ought to receive $3 per day for our road services. The forty-five days allowed per quarter is, I think, enough. The office of commissioner is the most important office in the county, and pays less. When we get a law that will elevate the commissioners' court to the place it should occupy, intelligent men will be placed in that office, who will study the interests of their respective counties. There is only one way by which this can be done, and that is by paying the commissioners for their time. If they are allowed $3 per day for the 45 days allowed per quarter, they could afford to do their full duty.

The overseer system is not satisfactory, but in making a law to work by taxation it will be difficult to keep down fraud and rascality. I prefer the present law to the one under the E. J. Davis administration.

B. R. Long, of Grayson: Eight years ago last March, Grayson county began the solving of two questions, i. e.: (1) the improvement of the public roads by direct taxation, and (2) the making of this improvement by convict labor. We have solved both problems to the satisfaction of our taxpaying population. We commenced in March, 1889, with six mules. In twelve months we had fourteen mules; in July, 1891, we bought 24 mules, and started three eight-mule outfits. We have continued to add to the force until now we have the following outfits: (1) convict gang, which consists of superintendent, two guards, 24 mules, two iron cages, two American road machines, three plows, four wheel scrapers, three wagons and all necessary smaller tools, and (2) three other outfits, each having 12 mules, one grader, two wagons, two plows, smaller tools, etc. The latter outfits employ four hired men: Boss man, $45 per month, and three others at $35 per month.

We have graded 1200 miles of road, 400 miles second time, built 1900 bridges and culverts (span 3 feet to 75 feet). In addition to this, our county has 56 iron bridges (spans 50 to 150 feet) and we have no road and bridge bonded indebtedness.

If the present force is kept until 1898, we will have all our roads of much importance graded, bridged and sewered, and then the time will have arrived to abolish the old, abominable system of road working that has heretofore prevailed, and which has proven such a splendid failure. Instead of working five days, we should assess a poll tax on all men subject to road service, not to exceed $2, and before they are allowed to deposit their ballots require them to show their receipt for their last taxes due.

Our experience has demonstrated to us some needed changes in our present law. Convicts are allowed now 50 cents per day, clothing and board. We would give them 75 cents per day, charge them for all clothing and board while sick. They would have better health and their clothes would last longer. Quite a per cent of our convicts have been in our county only a few days. When we turn them loose, penniless and among strangers, they are necessarily tramps of the most pronounced type. We should allow them, after working out their time, to work five days longer at 50 cents per day cash.

We believe a State superintendent of roads would prove a failure, but a county superintendent is a necessity, unless all counties, like Grayson, working a road outfit in each commissioners' district, should raise the commissioner's salary to $75 or $100 per month, and let him devote his whole time to his road and bridge work when not engaged in attending to his other duties.

William Walton, of Ellis: The superintendent of the poor farm has charge of farm and road gang. Each commissioner is entitled to 25 miles of road work wherever he wants it, each commissioner taking his turn. We work our men in gangs, each scraper gang having six convicts, four teams, four scrapers and one guard. Our plow gang consists of eight mules, three convicts and one guard. We use the road machine (grader) for shaping up the road. We can throw up more road with machine than with scrapers, but can not get them high enough; besides, the machine work is too hard for teams. We grade on an average one-half to three-fourths of a mile per day with 20 teams.

I think the present road law needs changing. Let everyone subject to road duty pay a poll tax, with property tax in connection.

The overseer system is an expense to the county.

Judge Chenoweth, of Fannin: I am inclined to think that we have approached the time for a system of general road laws executed under the direction of a State superintendent, such as existed many years ago in Kentucky. I think it would be advisable to have a State road superintendent, if we could have a good general system of laws.

We are not willing to entirely dispense with the overseer system, but in addition advocate a supplement thereto a general tax levy. The overseer system is a great deal of trouble, and we get very little satisfaction out of it.

We are working at the present time 31 convicts, 16 on the roads and 15 on the poor farm. Our work with convicts has been in the main satisfactory.

Our county commissioners are ex-officio road commissioners (acts 1895, pp. . .)

Hon. J. S. Sherrill, of Hunt: We have no general system of working convicts in my county. We have no material. Neither have we a regularly organized county road force.

The work on roads is done mostly by the overseers. To these are furnished scrapers, etc., and, when demanded, the grading machines. While the overseer system is not very satisfactory, I think we are not prepared to work the roads by a general system of taxation. For the present, we must, of necessity, retain the overseer system.

Each commissioner puts in about 45 days per quarter looking after his precinct. Our special law (1895) allows them $2 per day, provided their pay does not exceed $90 per quarter.

Many men subject to road duty pay the $3 and are thus exempt. This money is used in hiring road hands.

Mack Smith, of Collin: Collin county works its convicts with the hired help in four different outfits. We have about ten convicts on an average, and our work with them has been satisfactory.

We need only three hands to run a grader. Of course, we use more in digging stumps and getting road ready for grader. Where the county force does the plowing, we grade about a half mile of road per day; but on a section of road that has a good lot of teams, and a good overseer, the plowing is done by the overseer, and we can then grade one mile of road per day. The overseers are generally assigned to sections of road from three to six miles in length.

I think it is not advisable to have a State superintendent of roads. We have no use for him.

MACADAMIZED ROADS IN THE BLACK WAXY COUNTIES.

The term *macadamized,* as used in this paper, is applied indiscriminately to all roads whose surfaces are improved by the application of broken stone or gravel. Technically speaking, a macadamized road is one formed of broken stones, every fragment of which can pass through a small ring of 2½ inches in diameter. This was John MacAdam's test on the Bristol road. However, I shall use the word in its popular sense.

About five years ago a good roads association was organized in Travis county, and to it is due the credit of having inaugurated a movement that has given Travis county an impulse in the direction of better highways. The officers of the association were for the most part citizens of Austin, and they proposed to raise by subscription one-third of the amount spent in making a road, provided the county would pay the other two-thirds. Although this association was short-lived, it succeeded in settling many doubtful points to the satisfaction of the business man of the town and the farmer in the country. The two main points settled were: (1) that a good road could be obtained at moderate cost, and (2) that a good road could be obtained in black soil. The first road constructed under the auspices of the association was about one mile in length and cost about $1 per linear yard. It was constructed of limestone rock that was crushed in place after having been hauled from the quarry. The metal or stone was obtained from the black sticky soil of the State lunatic asylum land. At first glance, the country at this point would offer no evidence of building or constructing material, but a space was uncovered and the underlying limestone afforded material in abundance. This material was transported in carts and crushed by hammers, as stated above.

Several other pieces of road were constructed, and, while they were excellent in their way, still their greatest utility consisted in being an object lesson to the farmers. The road association was a pioneer organization, and proved that good roads were within the reach of the progressive people. Shortly after these pieces of road were constructed, under the administration of Judge Von Rosenberg, a new method of the division of the cost of construction was introduced. Instead of raising a subscription in cash in the city, a subscription in labor was raised along the line of the road, and this method proved very successful. The road was constructed mostly of gravel and the chief labor consisted in hauling the material. The farmers that lived on the line of the road manifested a disposition to help by furnishing teams and laborers to supplement the county force. The roadbed was first graded and heaped in the center to afford good drainage, and the gravel was dumped thereon and spread. Over 75 miles of such road has been constructed. The cost of this road to the county averaged $1000 to $1500 per mile.

Travis county has three road outfits. Two of these are worked by hired hands and one by convicts. The foremen (superintendents) are paid $60 per month. The convict force is used mostly in macadamizing.

Cooke county has about 20 miles of macadamized roads. These were constructed almost entirely of gravel and cost the county $1000 to $1500 per mile.

In Tarrant county, the convicts grade and gravel the roads, while the overseers simply keep the road in repair. These roads (gravel) cost about $850 under the new law and about $1000 per mile under the old law. The county has two superintendents of roads, one for each camp, and the commissioner in whose precinct they work has control of the outfit. Tarrant has about 100 miles of macadamized roads.

Dallas county has about 40 miles of macadamized roads. The material used for metal was white rock (limestone) or gravel. The gravel is spread 18 feet wide and six or eight inches deep. These roads cost about $1500 per mile.

Some of the counties (as Cooke, Hill, etc.) have a few sandy roads. These are improved by grading up and coating with clay or gravel. This is the old-established treatment for such roads. (See special road law for Dallas, p. . .)

ROAD LAWS — GENERAL AND SPECIAL.

The Legislature in 1891 passed a law (see acts pp. 149-151) authorizing the appointment of road superintendents for the county, or for a superintendent for each commissioner's precinct, at the discretion of the commissioners' court. The duties of the superintendent were defined, but it is sufficient to say that he was given general control of the road-working system, subject to the orders and direction of the commissioners' court. His salary in counties that have 15,000 inhabitants can not exceed $1000 per annum, and in counties that have over 15,000 inhabitants it can not exceed $1200 per annum. Similar instructions were applied to precinct superintendents, the salary being $300 and $400 respectively. The counties of Grayson, Travis, Dallas, Limestone, Lamar, Hill, McLennan, Tarrant et al. were exempted from the provisions of this act. Dallas and Collin had the option of adopting this law in lieu of the special acts for these counties.

In 1891 (acts 1891, pp. 69-73) the Legislature passed a special road law for the counties of Grayson, Dallas, Fannin, Travis, Hunt, Hill et al. This law empowered the said counties to employ a road commissioner, whose duties were similar to those of the superintendent mentioned above. His salary was not to exceed $100 per month. It also provided for working convicts on public roads, but made no allowance for the payment of officers' cost in the case of said convicts.

In 1893 (acts 1893, pp. 106-109) a special road law was passed for the counties of Collin, Grayson, Williamson, Lamar and Bell. This law makes the county commissioners of these counties ex officio road commissioners, whose duties as road commissioners were similar to those of the superintendent defined in the general law of 1891. Each commissioner had the power to appoint, with the advice and consent of the commissioners' court, a deputy, who was to act as road commissioner for his precinct. This law required county convicts to be worked at the usual allowance of 50 cents per day and made provisions for paying the county officers costs within certain limits. It also provided that any citizen could, by paying on or before the first day of January of any year, the sum of $3, be exempt from road duty for that year. Road commissioners were allowed $2 per day, provided they should not receive more than $45 per quarter.

In 1895 (acts 1895, pp. 203-207) a road law was passed for the counties of Fannin, Kaufman and Robertson. The provisions of this law were similar as to county commissioners being ex officio road commissioners and as to their duties as such to the provisions of the law for Collin, Grayson, etc., passed in 1893. It made provisions for working convicts on roads, for payment of officers' costs and payment of road commissioners, but allowed no more than $90 to be received by a road commissioner per quarter. It made provision for exemption from annual road duty by the payment of $3 on or before the 1st day of January; or by the payment of $1 to the road overseer before the day set for work, an exemption was obtained for that day. This is also the law for Hill, Cooke, Hunt et al.

In 1895 (acts 1895, pp. 213-217) a special road law was passed for the counties of Dallas, Lamar and Medina. This law contained the same provisions as to county commissioners being road commissioners, the exemption from road service by the payment of $3 and the working of convicts as the Fannin law of the same year. The road commissioners receive $2.50 per day, provided they receive no more than $75 per quarter. The law specifies that all convicts in Dallas county shall be kept at work all the time upon four first-class roads, beginning at the city limits of Dallas and extending as nearly as practicable north, south, east and west to the county lines, except in cases of emergency, when they may be transferred; that when these roads are finished, others as nearly as practicable centrally between them should be constructed; that the roads built by convict labor be macadamized, except in black waxy neighborhoods.

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Byrne's Highway Construction 5.00
Gillespie's Roads and Railroads 2.50
Herschel & North's Road Maintenance .... .50
Gen. Roy Stone's New Roads and Road Laws 1.50

Codrington's Macadamized Roads $3.00
Road Essays in Engineering Record ....
Spalding's Text-Book on Roads 1.50
Judson's City Roads and Pavements 1.00
A Move for Better Roads 2.00
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Also the following articles in magazines and pamphlets:

Harper's Weekly, August 10, 1889.
Scribner's Magazine, October, 1889.
Traction Tests, Bulletin No. 20, U. S. Agr. Dept.
New York Independent, February 6, 1896.
County Roads, by T. U. Taylor, Bulletin University of Texas, 1890.

CONSTITUTION.

Article I.—Name.

Section 1. This Association shall be called "The Texas Academy of Science."

Article II.—Objects.

Section 1. The objects of the Academy are: To advance the natural and exact sciences both by research and discussion; to promote intercourse between those who are cultivating science in different parts of the State; and especially to investigate and report on any subject of science or industrial art, when called upon by any department of the State government.

Article III.—Membership.

Section 1. The Academy shall consist of Members, Fellows, and Patrons.

Sec. 2. In order to become a Member, the applicant must be recommended in writing by two Members or Fellows, approved by the Council, and elected by ballot of the Society. In order to be elected, two-thirds of the ballots must be affirmative.

Sec. 3. Fellows shall be elected by the Council from such of the Members as are professionally engaged in science, or have in any way advanced or promoted science.

Sec. 4. Anyone who contributes to the funds of the Academy the sum of five hundred dollars shall be classed as a Patron.

Article IV.—Officers.

Section 1. The officers of the Academy shall consist of a President, a Vice-President, an Honorary Secretary, and a Treasurer. They shall be elected from the Fellows by ballot of the Academy at the June meeting of each year.

Sec. 2. The officers of the Academy, together with three Fellows to be elected by the Academy at the June session in each year, shall constitute a Council for the transaction of such business as may be assigned to them by the Constitution and By-Laws of the Academy.

Sec. 3. The President of the Academy, or in case of his absence the Vice-President, shall preside at the meetings of the Academy and of the

Council; shall nominate all committees except such as are otherwise specially provided for; shall refer investigations required by the State government to members especially conversant with the subject, and report to the Academy at its next formal meeting; and with the Council shall direct the general business of the Academy.

SEC. 4. The Honorary Secretary shall conduct the correspondence, advise with the President and Council in cases of doubt, and make a report at the formal meeting in June of each year.

It shall be the duty of the Secretary to give notice to the members of the place and time of all meetings, of all nominations for membership, and of all proposed amendments to the Constitution.

The minutes of each meeting shall be duly engrossed before the next meeting, under the direction of the Secretary.

SEC. 5. The Treasurer shall attend to all receipts and disbursements of the Academy, giving such bond and furnishing such vouchers as the Council may require. He shall collect all dues from the members, and keep a set of books showing a full account of receipts and disbursements. He shall present a general report at the June session of each year.

ARTICLE V.—MEETINGS.

SECTION 1. There shall be two formal meetings of the Academy each year, one of which shall be held in June at Austin, and the other within Christmas week at any place selected by the Council at the previous June meeting.

SEC. 2. The ordinary meetings of the Academy shall be at Austin on the first Friday of October, November, December, February, March, April, and May.

Meetings of a more informal character may also be held on the third Saturday of these months.

ARTICLE VI.—PAPERS.

SECTION 1. Intimation of the business of each meeting shall be given to each member by means of a printed card.

SEC. 2. No title of a paper can appear on the card before the paper itself, or an abstract of it, has been approved by the Council or the Secretary.

SEC. 3. The Academy may provide for the publication, under the direction of the Council, of proceedings, memoirs, and reports.

SEC. 4. The advice of the Academy shall be at all times at the disposal of the State government upon any matter of science or art within its scope.

ARTICLE VII.—ASSESSMENTS.

SECTION 1. The admission fee for a Member shall be two dollars, and the admission fee for a Fellow five dollars, or an additional three dollars on promotion to Fellowship.

SEC. 2. The annual assessment shall be one dollar.

ARTICLE VIII.—ALTERATION OF THE CONSTITUTION.

SECTION 1. No part of this Constitution shall be amended or annulled, except after notice given at a formal meeting, and approval by two-thirds of those voting at the succeeding formal meeting.

BY-LAWS.

CHAPTER 1.—MEMBERSHIP.

1. No person shall be accepted as a Member or Fellow unless he pays his initiation fee and the dues for the year within three months after notification of his election.

2. An arrearage in payment of annual dues shall deprive a Member or Fellow of taking part in the management of the Society and of receiving the publications of the Society. An arrearage for one year shall be construed as a notification of withdrawal.

CHAPTER 2.—ELECTION OF MEMBERS.

1. Nominations for membership may be made at any time in due form to the Honorary Secretary.

2. The form of the nomination of Members shall be as follows:

In accordance with his desire, we respectfully nominate for membership in the Texas Academy of Science—

Full name: ....
Address: ....
Degrees, if any: ....
Occupation: ....
Branch of science engaged in, work already done, and publications, if any ....

Signed by two Members, or Fellows.

The Honorary Secretary will bring the nominations before the Council at its first meeting thereafter, and the Council will signify its approval or disapproval of each nomination.

The Honorary Secretary shall have lists or cards printed and sent to each Member, giving name of each nominee and such information as may be necessary for intelligent voting.

The Members and Fellows receiving the list will signify their approval or disapproval of each nominee, and return list to the Honorary Secretary.

At the next meeting of the Council, the Honorary Secretary will present the lists and the Council will canvass the returns and declare the results at the next succeeding meeting of the Academy.

Chapter 3.—Committee on Publication.

The Council shall appoint a Committee of Publication, consisting of three members, of which the Honorary Secretary shall be chairman ex officio, who shall decide upon the value of articles submitted to them for publication, and in case of doubt be authorized to call upon any member of the Society who is specially familiar with the branch of science treated of for assistance in such determination.

If the paper is accepted, the author must deposit with the Honorary Secretary a sufficient sum to defray publication charges, at a rate not exceeding $2.00 per octavo page, and pay for all cuts or illustrations.

(At present the Academy bears the expenses of publication).

Chapter 4.—Order of Business.

1. Call to order by Presiding Officer.
2. Statements by President.
3. Report of Council.
4. Report of Treasurer.
5. Election of Officers.
6. Declaration of results of election of Officers.
7. Reports of Committees.
8. Announcements.
9. Unfinished Business.
10. New Business.

At the monthly meetings the order of business shall be:

1. Call to order by the President.
2. Statements by the President.
3. Presentation of memoirs, and discussion.
4. Report of Council.
5. Announcements.

Chapter 5.—Election of Officers and Other Members of the Council.

(Added April 12, 1895.)

The Honorary Secretary shall send to each member a circular letter including a list of the Fellows, with a request to send in a ballot nominating each officer and other members of the Council. The ballot must be received by the Honorary Secretary by May 15. The Council will select two from the three nominees receiving the highest number of nominations for each position, and prepare a ballot to be sent to each member of the Academy in time to permit his vote being received previous to the June meeting, at which time the votes will be counted.

Chapter 6.—Permanent Members.

(Added January 11, 1896.)

Any Member of the Academy may become a "permanent member" on payment of fifty dollars; all "permanent members" to be free from all subsequent assessment.

The money received from this source shall be invested as a permanent fund, the interest of which may be used towards paying for the printing of the transactions of the Academy or for such other purposes as the Council may determine.

LIST OF PATRONS, FELLOWS AND MEMBERS.

PATRONS.

George W. Brackenridge, San Antonio.
Mrs. G. B. Halsted, Austin.

FELLOWS.

George W. Brackenridge, San Antonio.
I. H. Bryant, High School, Fort Smith, Ark.
David Cerna, M. D., Ph. D., Demonstrator of Physiology and Lecturer on the History of Medicine, University of Texas, Galveston.
W. F. Cummins, Dallas.
George W. Curtis, Washington State Bank, Washington, La.
E. T. Dumble, State Geologist, Austin.
Major Clarence E. Dutton, U. S. A., San Antonio.
R. B. Halley, Professor of Natural Science, Sam Houston Normal, Huntsville.
George Bruce Halsted, Ph. D., Professor of Mathematics in the University of Texas, Austin.
Henry Winston Harper, M. D., Professor of Chemistry in the University of Texas, Austin.
H. H. Harrington, M. S., Professor of Chemistry and Mineralogy in the Agricultural and Mechanical College, College Station.
Ferdinand Herff, M. D., San Antonio.
Robert T. Hill, B. S., U. S. Geological Survey, Washington, D. C.
William R. Howard, M. D., Professor of Histology, Pathology and Bacteriology, Medical Department Fort Worth University, Fort Worth.
R. S. Hyer, A. M., Professor of Chemistry and Physics in the Southwestern University, Georgetown.
A. J. James, B. Sc., Dallas.
William Keiller, M. D., F. R. C. S. Edinburgh, Professor of Anatomy in the University of Texas, Galveston.
Alexander Macfarlane, D. Sc., LL. D., Professor of Electrical Engineering, Lehigh University, South Bethlehem, Pa.
Charles F. Maxwell, B. Sc., Temple.
A. C. McDaniel, M. D., San Antonio.
Austin Lee McRae, D. Sc., Electrical Engineer, 306 Oriel Building, St. Louis, Mo.

Sidney E. Mezes, Ph. D., Professor of Philosophy in the University of Texas, Austin.

Edmund Montgomery, Ph. D., M. D., Hempstead.

James C. Nagle, M. A., M. C. E., Professor of Civil Engineering and Physics in the Agricultural and Mechanical College, College Station.

Wesley W. Norman, M. A., Professor of Biology, University of Texas, Austin.

J. F. Y. Paine, M. D., Dean of the Medical Department, University of Texas, Galveston.

Charles Puryear, M. A., C. E., Professor of Mathematics in the Agricultural and Mechanical College, College Station.

Frederic W. Simonds, Ph. D., Professor of Geology in the University of Texas, Austin.

Allen J. Smith, M. D., Professor of Pathology in the University of Texas, Galveston.

John T. Smith, Civil Engineer, Austin.

Prof. W. H. von Steeruwitz, C. E., M. E., Mining Engineer, Austin.

Thomas U. Taylor, M. C. E., Professor of Applied Mathematics in the University of Texas, Austin.

James E. Thompson, M. D., F. R. C. S. Eng., Professor of Surgery in the University of Texas, Galveston.

C. H. Tyler Townsend, member of staff of U. S. Department of Agriculture, Las Cruces, New Mexico.

MEMBERS

Sol M. Acree, B. Sc., Austin.

Duncan Adriance, M. S., Bryan.

H. G. Askew, Conchologist, Clerk of Railroad Commission, Austin.

James R. Bailey, B. A., Tutor in Chemistry in the University of Texas, Austin.

Aubrey L. Banks, B. S., Adjunct Professor of Mathematics in the Agricultural and Mechanical College, College Station.

William James Battle, Ph. D., Professor of Greek in the University of Texas, Austin.

Joseph Baldwin, A. M., LL. D., Austin.

Adolph E. Böcking, M. D., Fredericksburg.

Sidney J. Brooks, B. L., Attorney-at-Law, San Antonio.

Ban Sylvester Brown, B. A., Tutor in Biology, University of Texas, Austin.

R. L. Brown, Attorney-at-Law, Austin.

W. H. Bruce, Ph. D., Superintendent of Schools, Athens.

C. E. Burgoon, B. M. E., Assistant Professor of Mechanical Engineering at the Agricultural and Mechanical College, College Station.

O. C. Charleton, Professor of the Natural Sciences, Baylor University, Waco.

Ira Carlton Chase, B. A., Professor of Chemistry and Physics, Fort Worth University, Fort Worth.

I. M. Cline, M. D., U. S. Weather Bureau, Galveston.

J. L. Cline, Galveston.

R. R. D. Cline, Ph. G., Professor of Pharmacy, Medical Department, University of Texas, Galveston.

A. G. Clopton, M. D., Professor of Physiology, Medical Department, University of Texas, Galveston.

J. H. Connell, M. Sc., Professor of Agriculture and Director of Experiment Station, A. & M. College, College Station.

Henry P. Cooke, M. D., Galveston.

Charles Corner, C. E., Engineer for the Railroad Commission, Austin.

William Corner, San Antonio.

Walter L. Crawford, B. A., Law Student, Austin.

W. T. Davidson, M. D., Temple.

L. E. Dickson, Ph. D., Student in Leipzig.

Malone Duggan, M. D., Eagle Pass.

A. Butler Duncan, M. A., Albany, Shackleford County, Texas.

U. S. Ellingson, C. E., Austin.

George A. Endress, Architectural Draughtsman, Monterey, Mexico.

R. B. Ewing, Childress.

Thomas Fitz-Hugh, A. M., Professor of Latin, University of Texas, Austin.

Thomas Flavin, M. D., Demonstrator of Anatomy, Medical Department, University of Texas, Galveston.

Mark Francis, D. V. M., Professor of Veterinary Science, A. & M. College, College Station.

F. E. Giesecke, M. E., Professor of Drawing, A. & M. College, College Station.

John Lee Gammon, B. L., Attorney-at-Law, Waxahachie.

Tom L. Greer, student at Cornell, Ithaca, N. Y.

James B. Hawley, B. Sc., Civil Engineer, Fort Worth.

Yale Hicks, Attorney-at-Law, San Antonio.

H. L. Hilgartner, M. D., Austin.

L. E. Hill, Editor of "The Alcalde," Austin.

Alexander Hogg, M. A., Fort Worth.

J. W. Hopkins, Ball High School, Galveston.

David F. Houston, A. M., Professor of Political Science, University of Texas, Austin.

Charles H. Huberich, Law Student, University of Texas, Austin.

W. H. P. Hunnicutt, Civil Engineer, Waco.

W. Goodrich Jones, B. Sc., Banker, Temple.

William A. James, B. Sc., M. A., Science Teacher, Ball High School, Galveston.

T. L. Kennedy, M. D., Galveston.

W. Kennedy, Geologist and Civil Engineer, Austin.

E. W. Kerr, B. Sc., Assistant Professor of Mechanical Engineering, A. & M. College, College Station.

G. W. Kidd, Secretary of the Cotton Exchange, Houston.

George H. Lee, M. D., Lecturer on Diseases of the Skin, Medical Department, University of Texas, Galveston.

Arthur Lefevre, C. E., Instructor in Pure Mathematics, University of Texas, Austin.

James Bruce Lewright, B. A., Attorney-at-Law, Newark, N. J.

C. Lombardi, Houston.

John Avery Lomax, Austin.

F. W. Malley, M. Sc., Hulen, Galveston County, Texas.

C. K. McDonald, Austin.

J. W. McLaughlin, M. D., Austin.

B. Mackensen, B. Sc., Science Teacher in the High School, San Antonio.

Louis E. Magnenat, M. D., Demonstrator of Chemistry, Medical Department, University of Texas, Galveston.

J. D. Mitchell, Victoria.

John T. Moore, M. D., Demonstrator of Anatomy, Medical Department, University of Texas, Galveston.

T. V. Munson, Horticulturist, Denison.

H. Ness, B. S., Assistant Professor of Botany, A. & M. College, College Station.

Charles Fishback Norton, B. Sc., Student in Medical Department, University of Texas, Galveston.

Edwin F. Northrup, Ph. D., Professor of Physics, University of Texas, Austin.

James Edwin Pearce, M. A., Principal of High School, Austin.

George W. Pierce, M. A., Science Teacher, High School, Dallas.

B. C. Pittuck, B. S. A., Assistant Professor of Agriculture, A. & M. College, College Station.

Constance Pessels, Ph. D., Instructor in English, University of Texas, Austin.

W. C. Poston, M. A., Professor in Weatherford College, Weatherford.

Sylvester Primer, Ph. D., Professor of the Teutonic Languages, University of Texas, Austin.

C. W. Raines, Historian, Austin.

John H. Reagan, Railroad Commissioner, Austin.
Fritz Reichman, C. E., Fellow in Physics, University of Texas.
C. D. Rice, A. M., Principal of High School, Belton.
J. S. Riley, Principal of High School, Gainesville.
J. W. Sammonds, Palestine.
E. F. Schmidt, Houston.
W. B. Seeley, Teacher, San Antonio.
Q. C. Smith, M. D., Austin.
A. C. Snead, Edgemoor Bridge Works, Wilmington, Del.
D. W. Spence, B. Sc., C. E., Assistant Professor of Physics and Drawing, A. & M. College, College Station.
S. W. Stanfield, B. Sc., Professor in Coronal Institute, San Marcos.
Wilfred D. Stearns, Rosenberg School, Galveston.
E. H. Sauvignet, B. S. A., Student of Medicine, City of Mexico.
E. P. Schoch, A. M., Teacher, High School, San Antonio.
William Schoch, M. A., Principal of High School, San Antonio.
J. E. Smith, Superintendent of Schools, San Antonio.
M. M. Smith, M. D., Austin.
Noyes D. Smith, C. E., Civil Engineer, Eagle Pass.
G. M. Sublette, Minneapolis, Minn.
P. H. Swearingen, B. L., Lawyer, San Antonio.
J. A. Taff, B. Sc., United States Geological Survey, Washington, D. C.
Robert A. Thompson, M. A., Civil Engineer, Lake Charles, La.
P. S. Tilson, M. S., Associate Professor of Chemistry, A. & M. College, College Station.
George W. Townsend, Photographer, Austin.
P. H. Underwood, Teacher in Ball High School, Galveston.
Clarence Warfield, M. D., Galveston.
Lawrence S. Williams, Post-graduate Student, University of Texas, Austin.
R. Lee Wilson, B. Sc., M. A., Student in Medical Department, University of Texas, Galveston.
George T. Winston, A. M., LL. D., President of the University of Texas, Austin.
Joe S. Wooten, M. D., Austin.
S. O. Young, M. D., Galveston.
G. B. M. Zerr, Ph. D., Texarkana.

PATRONS.

On March 6, 1896, the Secretary received notice from the Treasurer that George W. Brackenridge and Mrs. G. B. Halsted of Austin had each paid to the Academy five hundred dollars, and had thereby become Patrons.

COUNCIL.

From January 9 *to June* 14, 1892.

President, Edgar Everhart.
Vice President, E. T. Dumble.
Honorary Secretary, Alexander Macfarlane.
Treasurer, J. C. Nagle.
Other members of the Council: George Bruce Halsted, W. H. von Streeruwitz, Frederic W. Simonds.

From June 14, 1892, *to June* 19, 1893.

President, Edgar Everhart.
Vice President, E. T. Dumble.
Honorary Secretary, Alexander Macfarlane.
Treasurer, J. C. Nagle.
Other members of the Council: George Bruce Halsted, W. H. von Streeruwitz, Frederic W. Simonds.

From June 19, 1893, *to June* 19, 1894.

President, E. T. Dumble.
Vice President, A. J. Smith.
Honorary Secretary, A. Macfarlane.
Treasurer, J. C. Nagle.
Other members of the Council: G. B. Halsted, E. Everhart, F. W. Simonds.

From June 19, 1894, *to June* 17, 1895.

President, Dr. George Bruce Halsted.
Vice President, Dr. Allen J. Smith.
Honorary Secretary, I. H. Bryant.
Treasurer, E. T. Dumble.
Other members of the Council: J. C. Nagle, Dr. David Cerna, W. H. von Streeruwitz.

From June 17, 1895, *to June* 15, 1896.

President, Dr. George Bruce Halsted.
Vice President, Dr. David Cerna.

Treasurer, State Geologist E. T. Dumble.

Honorary Secretary, W. W. Norman.

Other members of the Council: W. H. von Streeruwitz, R. B. Halley, Dr. H. W. Harper.

From June 15, 1896, *to June* —, 1897.

President, Dr. George Bruce Halsted.

Vice President, Dr. David Cerna.

Treasurer, State Geologist E. T. Dumble.

Honorary Secretary, W. W. Norman.

Other members of the Council: W. H. von Streeruwitz, Dr. H. W. Harper, T. U. Taylor.

TITLES OF PAPERS READ BEFORE THE ACADEMY.

(Papers indicated with a star (*) are published in full in the Transactions.)

Austin, February 6, 1892.

* Introductory Address by the President, Dr. Edgar Everhart.

* On the Precious and Other Valuable Metals of Texas; W. H. von Streeruwitz.

* On Scientific Analysis as the Basis of Language; Alexander Macfarlane.

* On Spherics; M. B. Porter.

Austin, March 5, 1892.

Linkage, a New Development in Kinematics; Dr. George Bruce Halsted.

* The Sources of the Texas Drift; E. T. Dumble, State Geologist.

Extension of the Method of Topographic Surveying with Transit and Stadia; James C. Nagle.

Analysis of a Hydrocarbon from Mexico; James R. Bailey.

Austin, April 2, 1892.

On the Discovery and Occurrence of Mica in North Carolina; Dr. Frederic W. Simonds. (For Abstract, see page 114.)

* The Texas Meteorites; W. F. Cummins, member of Texas Geological Survey.

The Fundamental Theorem in Trigonometry; Dr. A. Macfarlane.

Austin, May 7, 1892.

The Present Idea of the Molecule; Dr. Edgar Everhart.

An Account of the Potable Waters in Austin; Dr. Joe S. Wooten.

The Square Root of Minus One; Dr. A. Macfarlane.

The Lower Carboniferous Rocks of Arkansas; Dr. Frederic W. Simonds. (For Abstract, see page 114.)

Austin, June 14, 1892.

Address by the President, Dr. Edgar Everhart.

Some of the Problems of Biology; Dr. Charles L. Edwards.

* The Development of the American Trotter: A Study in Animal Physics; Prof. George W. Curtis.

* The Occurrence of Volcanic Dust in Texas; E. T. Dumble.

A New Theorem in the Integral Calculus; H. Y. Benedict.

The Theorem of Limits; I. H. Bryant.

Austin, October 1, 1892.

Modern Theory of Multiplication; Dr. George Bruce Halsted.

Paper by Prof. Cragin, member of the Geological Survey.

The Rochester Meeting of the American Association for the Advancement of Science; A. Macfarlane.

Austin, November 5, 1892.

The Geology of Benton County, Arkansas; Dr. Frederic W. Simonds. (For Abstract, see page 115.)

A Texas Mylodon Specimen, and Record of Previous Observation; E. T. Dumble.

The Fundamental Geometrical Concepts; I. H. Bryant.

Austin, December 3, 1892.

On a Logical Problem in Physics; A. Macfarlane.

A New Method of Forming the Conic Sections; L. E. Dickson.

The Rain-Making Experiments at San Antonio; A. Macfarlane.

Galveston, December 31, 1892.

* Maternal Impressions and Transmissions of Mutilations; Dr. James E. Thompson.

* The Non-Metallic Mineral Resources of the State of Texas; W. H. von Streeruwitz.

Potable Water from the Chemical Standpoint; Dr. Edgar Everhart.

* Rain-making; Dr. A. Macfarlane.

School Ventilation; Dr. C. L. Gwyn.

Note on the Occurrence of Jet in Texas; E. T. Dumble, State Geologist.

Austin, February 4, 1893.

On a Marine Biological Station for the University of Texas; Charles L. Edwards.

Uniform vs. Concentrated Loads in Bridge Designing; Thomas U. Taylor.

On the Definitions of the Trigonometrical Functions; A. Macfarlane.

Austin, March 4, 1893.

* How the New Mathematics Interprets the Old; Dr. George Bruce Halsted.

The Age of the Llano Estacado; E. T. Dumble.

Austin, May 6, 1893.

On the Electric Strength of Paraffin and Beeswax; Dr. A. Macfarlane and G. W. Pierce.

On the Theory of Inscription of Regular Polygons; L. E. Dickson.

Austin, June 19, 1893.

* The Pilgrimage and Civilization of the Toltecs; Dr. David Cerna.

Austin, October 7, 1893.

The Season's Work of the Geological Survey; E. T. Dumble.

The International Electrical Congress at Chicago; Dr. A. Macfarlane.

Austin, November 4, 1893.

The Mathematical Congress at Chicago; Dr. George Bruce Halsted.

Pollex of a Chicken's Wing Provided with an Ancestral Claw; Dr. C. L. Edwards.

College Station, December 16, 1893.

Address by the President, E. T. Dumble.

Animal Fats as Influenced by Feeding Cottonseed Meal; H. H. Harrington and D. Adriance.

Points in which Disease Gives Evidence of the Truth of the Idea of Evolution; Dr. Allen J. Smith.

On a Saurian from the Eagle Ford Shales; E. T. Dumble.

The Fundamental Principles of Exact Analysis; Dr. A. Macfarlane.

* A Contribution to the Study of the Physiological Actions of Sparteine. Dr. David Cerna.

* Irrigation; W. H. von Streeruwitz.

On the Electric Strength of Paraffin; Dr. A. Macfarlane and G. W. Pierce.

The Age of the Iron Ores of East Texas; W. Kennedy.

Austin, February 3, 1894.

On the Lowest Integers Representing the Sides of a Right Triangle; L. E. Dickson.

On the Scientific Aspect of Volapuck; B. Mackensen.

Austin, March 3, 1894.

Education and Fatigue; Dr. Joseph Baldwin.

The Cretaceous Formations of West Texas; E. T. Dumble.

Hyperboloidal Trigonometry; Dr. A. Macfarlane.

Austin, April 7, 1894.

The Recent Advance in Projective Geometry; Dr. George Bruce Halsted.

A Visit to the Weather Bureau; Dr. A. Macfarlane.

On the Irreducibility of the Equations upon which Depends the Inscription of Regular Polygons; L. E. Dickson.

Austin, May 5, 1894.

On Comparative Psychology; Dr. C. L. Edwards.

On the Electric Strength of Paraffin; G. W. Pierce.

Address by the President, E. T. Dumble.

Songs and Stories of Bahama Negroes: A Contribution to Folk-Lore; Dr. C. L. Edwards.

Austin, June 19, 1894.

The Tertiary Geology of Texas; E. T. Dumble.

The Number of the Inscriptible Regular Polygons; L. E. Dickson.

The Fayetteville Test-Well; Dr. Frederic W. Simonds. (For Abstract, see page 115.)

Austin, October 12, 1894.

* Original Research and Creative Authorship the Essence of University Teaching; Dr. George Bruce Halsted.

Austin, November 16, 1894.

* Some Morphological Relationships of the Cactaceae; C. F. Maxwell.

Symposium: Mexico as a Field for Scientific Work.

Galveston, December 31, 1894.

Address by Dr. James E. Thompson.

* The Phonetic Arithmetic of the Ancient Mexicans; Dr. David Cerna.

Descriptive Anatomy of the Heart; Dr. William Keiller.

Developmental Anatomy and Pathology of the Kidneys; Dr. Thomas Flavin.

* Present Need of Engineering Education in the South; T. U. Taylor.

* The Storm-Water Storage System of Irrigation; Robert A. Thompson.

Austin, March 8, 1895.

* An Address: The Relation of Science to Modern Civilization; Major Clarence E. Dutton.

Austin, April 5, 1895.

* The Criterion for Two-Term Prismoidal Formulas; Dr. George Bruce Halsted.

Cometary Orbits as Related to the Solar System; Charles K. McDonald.

Demonstration of the Germs of Malarial Fever; permanent mounts, prepared by Dr. Allen J. Smith.

Austin, May 3, 1895.

Developments and Practical Applications of Two-Term Prismoidal Formulas; Thomas U. Taylor.

The Segmentation of the Nucleus without Segmentation of the Protoplasm; W. W. Norman. (Paper published in Archiv fuer Entwickelungs-mechanik der Organismen, III Band, 1 Heft.)

Facts and Hypotheses of Modern Chemistry; E. P. Schoch.

Austin, June 17, 1895.

* The Law of Hypnotism; R. S. Hyer.
* County Roads; Charles Corner.
* The Soils of Texas; E. T. Dumble.
* Genesis of Certain Ore Veins, with Experimental Verifications; W. H. von Streeruwitz.

Austin, October 4, 1895.

* Address by the President, Dr. George Bruce Halsted; subject: The Culture given by Science.

Austin, November 3, 1895.

Mental Therapy; Dr. M. M. Smith.
* Genesis of Certain Ore Veins in Siliceous Gangues, with Experimental Verifications; W. H. von Streeruwitz.
Report on the International Congress of Americanists; Dr. George Bruce Halsted, delegate, member of the Commission sent by the Congress to President Diaz.

Austin, December 6, 1895.

An Address: The Character, Personality, and Teachings of Herbert Spencer; Parker H. Sercombe.
Floating Sand: An Unusual Mode of River Transportation. (For Abstract, see page 115.)

Galveston, December 27, 1895.

* An Address: The Molecular Theories of Organic Reproduction; Dr. Edmund Montgomery.
A Study of the Anatomy and Pathology of the Lower End of the Rectum; Dr. James E. Thompson.
Glycerine in the Preparation of Anatomical Museum Specimens; Dr. William Keiller.
Weather Forecasts and Their Improvement; Dr. I. M. Cline.

Austin, February 7, 1896.

An Address: Science and Original Research in the University of Chicago; L. E. Dickson.

Austin, March 6, 1896.

The Basis of Insanity; Dr. Joe S. Wooten.

* Prismoidal Formulae; T. U. Taylor.

Brief Announcement by the President, Dr. George Bruce Halsted, of his New and Simple Method of Defining and Treating Poles and Polars by Duality alone.

Austin, April 3, 1896.

An Address: Beads—A Study in Anthropology; William Corner.

Austin, May 1, 1896.

On the Poison of Centipedes; W. W. Norman. (For abstract, see page 118.)

* The Essence of Number; Dr. George Bruce Halsted.

Austin, June 15, 1896.

* Are we Conscious Automata? Dr. Edmund Montgomery.

On the Number of Codots in a Polystim; U. S. Ellingson.

A Preliminary Report on the Awareness of Objects on the part of the Blind; Dr. S. E. Mezes and Dr. Hilgartner. [To be printed in next number.]

Notes on the New Cave Salamander of San Marcos, Texas; John T. Smith.

Austin, October 2, 1896.

The Annual Address of the President, Dr. George Bruce Halsted; subject: Life and Science in Russia.

Austin, November 6, 1896.

* Economy of Good Roads; T. U. Taylor.

Prof. Ch. Fred. Hartt—A Tribute; Dr. Frederic W. Simonds. (For Abstract, see page 116.)

The Constitutional Formulae of the Ferro- and Ferricyanides; a Contribution to the Chemistry of the Nitrogen Ring. Preliminary Announcement; Dr. H. W. Harper.

San Antonio, December 31, 1896.

Vertical Curves for Railways; J. C. Nagle.

Hydrazine Derivatives of Propionic Acid; James R. Bailey. (By title.)

Notes on Indian Corn (Zea mais), and some of its uses among the ancient and modern Mexicans; Dr. David Cerna.

Notes on the Physiology of the Central Nervous System of Some of the Lower Animals; W. W. Norman.

Cystiglyphus Trichogenetos (Boecking), a human parasite; Dr. A. E. Boecking. (By title.)

The Evolution of Culture; Thomas Fitz-Hugh.

A New Suggestion concerning the Transmutation of Matter; Dr. H. W. Harper. (By title.)

The Cervanka Gas Well; E. T. Dumble. (By title.)

Address—The Economics of Concentrated Capital; Major C. E. Dutton.

The Greatest Foundling House in the World: A Personal Study in Russian Sociology; Dr. George Bruce Halsted.

ABSTRACT OF PAPERS.

BY FREDERIC W. SIMONDS.

On the Discovery and Occurrence of Mica in North Carolina. (Read April 2, 1892.)

In this paper the author gives some of the results of his investigations in the Blue Ridge regions of North Carolina. The occurrence of mica in Mitchell, Yancey and Macon counties is discusssed, and the story of its discovery told. (See "Commercial Mica in North Carolina: The Story of its Discovery," Science, N. S., Vol. IV, No. 89, September 11, 1896.)

The Lower Carboniferous Rocks of Northwest Arkansas. (Read May 7, 1892.)

This paper is an abstract of a part of a report on the geology of Washington county, Arkansas, recently completed by the author. (See "Geology of Washington County," in Annual Report of the Geological Survey of Arkansas for 1888, Vol. IV, Little Rock, 1891, pp. 1-148.) It deals largely with a complete section of the Lower Carboniferous rocks from the Silurian to the Coal Measures (the Devonian being doubtfully represented by the Eureka Shale), and in it are set forth the difficulties of preparing an accurate geological map in a region composed of practically horizontal strata very much denuded.

The Geology of Benton County, Arkansas. (Read November 5, 1892.)

This paper is an abstract of the author's portion of a somewhat lengthy report having the same title published under the joint authorship of T. C. Hopkins and himself in Vol. II, Annual Report of the Geological Survey of Arkansas, for 1891. Little Rock, February, 1893; pp. 1-75.

In it are briefly considered: (1) The Topography of the region—the northwest county of the State. (2) The Hydrography, including the river drainage, springs, many of which are large and strong, and wells. (3) The Rocks, which represent the following formations: (i) Silurian, limestones and sandstones. (ii) Devonian(?), a bed of black shale, never exceeding 40 to 50 feet in thickness, known as the Eureka Shale. (iii) Lower Carboniferous: the Boone Chert and Limestone, the Wyman Sandstone, the Fayetteville Shale, and the Batesville Sandstone. The position of each, their mode of occurrence, and many local details are explained.

The Fayetteville, Arkansas, Test Well. (Read June 19, 1894.)

An abstract of the author's investigation of the record and samples of a well 1480 feet deep sunk at Fayetteville, Ark., in 1891, with the hope of finding natural gas or oil. This enterprise was undertaken contrary to expert advice, after a thorough understanding of the order of stratification was possible from the work of the State Geological Survey. The result illustrates the fact that oftentimes the soundest geological conclusions may be reached in an indirect way, for neither gas nor oil were found, and water even failed to reach the surface. (See "Oil and Gas—The Deep Well at Fayetteville." Annual Report of the Geological Survey of Arkansas for 1891. Vol. II. Little Rock, 1894; pp. 66-69.)

Floating Sand: An Unusual Mode of River Transportation. (Announced December 6, 1895. This paper is published in full in the American Geologist, Vol. XVII, January, 1896, pp. 29-37. Reprinted, without table, in Scientific American Supplement, Vol. XLI, No. 1048, February 1, 1896, pp. 16745-16746.)

Abstract: Sand, mainly quartzose, was seen by the author floating on the surface of the Llano river at Bessemer, Texas, about 94 miles from Austin, on the morning of August 8, 1895. His interest being awakened, he immediately began an investigation of the phenomenon. Its occurrence elsewhere was ascertained and experiments undertaken to determine how sand may be floated, what sand will float, and why sand will float. The experiments, which were carefully performed, are minutely described, and the behavior of no less than fourteen different kinds of sand from widely separated localities tabulated. The conclusions reached are:

1. That sand grains will float in perfectly still water for an indefinite time.

2. That the grains which float are not necessarily siliceous. That flakes of mica, fragments of marble, bituminous shale, etc., also float, and that some of them, the marble and the bituminous shale, for example, are unusually buoyant.

3. That the property of floating is not confined to the sand of any particular locality, but depends to a considerable extent upon the angularity, i. e., the shape, of the grains.

4. That whether sand will float or not depends, also, upon the mode of launching. Whether it be by ripple waves, as stated by Mr. Graham, or by undermining, it must be gently done, for should the grains be plunged into the water with sufficient force to completely immerse them they will immediately sink.

5. That the natural conditions necessary to the floating of sand in rivers are somewhat unusual, depending, in the case of the Llano, upon a flood without local rains, and, in that of the Connecticut (where a similar phenomenon had been observed), upon the manner in which certain waves strike a sandbar. It is quite possible, however, that floating sand is much more common than is ordinarily supposed.

6. That the physical explanation of the problem is complex rather than simple, and at best unsatisfactory in several important particulars, and that with the advance of molecular physics we may hope for a better understanding of what we now, for convenience, term "superficial viscosity" and "capillary attraction."

The author's researches enabled him to confirm the following observations of Mr. James C. Graham:

1. They show that coarse sand can be floated on a current of far less velocity than 0.4545 miles per hour. (Note conclusion 1, above.)

2. They indicate a possible explanation of the coarse particles of sand found in otherwise very fine deposits.

(See Amer. Jour. Sci., III, Vol. XL, p. 476.)

Professor Ch. Fred. Hartt, M. A.—A Tribute. (Read Nov. 6, 1896.)

Abstract: This paper, originally prepared for The American Geologist, is a tribute to the first professor of geology in Cornell University, by one of his students.

Professor Hartt was a man of marked personality and unbounded influence with young men. In this contribution the author presents him in a two-fold aspect: 1, as the teacher; 2, as the man of science. His career at Cornell was comparatively brief (1868-1878 nominally, but really much less), yet he left a deep and lasting impression upon the institution.

The lesson of his life is wholesome and encouraging to those who would aspire to either a professional or a scientific career. The key-note of his influence is expressed in this paragraph: But the greatest source of our inspiration lay in the fact that our teacher carried on his private work in our presence. His industry, patience, and devotion served us as an example; his enthusiasm aroused us—we seemed to share his labor. Research, investigation, they had for us a different meaning now—had we not seen the Truth-seeker as he unraveled Nature's secrets? Manuscripts, drawings, publications, conversations in the brief intervals of rest—all kept the youthful mind in a glow of healthful excitement. And soon, under his fostering care, some of the advanced and special students began the preparation of original papers.

Hartt's scientific career began in Nova Scotia and New Brunswick. His discovery of insect-remains in the Devonian shales, "Fern Ledges," near St. John, at the time the oldest fossils of the kind known, gave him widespread fame. Upon the invitation of Professor Louis Agassiz he went to Cambridge (1863) to study, and later accompanied his distinguished teacher to Brazil as one of the geologists of the Thayer expedition (1865). Becoming interested in the empire, it was thereafter the field of his scientific labor. In 1867 he returned for further investigations and study, and in 1870 and 1871 he conducted the first and second Morgan expeditions. On the first of these he was accompanied by a large party of his Cornell students, which added not a little to his care and responsibility. "If," he wrote, "to discover a new carboniferous fauna will repay a journey to Brazil, of how much greater importance is the discovery of a new naturalist! Had the expedition produced no other result than to have added four new men to science, I should have considered time and money amply well spent."

Hartt's final trip to Brazil was made in the autumn of 1874, and the following spring he was made chief of the Imperial Geological Commission. The succeeding years of his life were full of activity and responsibility. Doubtless, at times, he suffered from the severe nervous strain attendant upon the management of such an enterprise. The end came suddenly. In the spring of 1878 he fell ill, dying rather unexpectedly on the 18th of March—a victim, it was supposed, of yellow fever—at the comparatively early age of thirty-seven years and seven months.

Of his many investigations, mention may be made of his work upon the structure of the valley of the Amazon; his explorations of the coast and reefs north of Rio to the mouth of the great river; and his researches relative to the prehistoric and native races of the country. Moreover, he placed scientific work in Brazil upon a high plane, and gave an impetus to honest, thorough investigation, which is even yet felt.

Professor Hartt's publications number over forty titles, many being in the Portuguese language.

BY W. W. NORMAN.

The Poison of Centipedes (Scolopendra morsitans).

During the spring of 1896 four large centipedes, varying in size from six to seven and one-half inches in length, were brought into the laboratory.

As these animals are much dreaded by the people, it was the desire of the writer to determine by experiment the effectiveness of the bite.

Experiments:

1. An adult mouse was put into a glass cylinder with the centipede, and the two animals brought together by slightly inclining the jar. During the fifteen minutes in which they were together the mouse was caught a few times by the hindmost pair of legs. (The last pair of legs are decidedly curved, and serve very well as forceps for holding the victim.) Once the mouse was held fast and bitten by means of the fangs (which are the modified first pair of appendages of the trunk). The mouse was then put into its cage. This was at 10 o'clock in the morning. It remained active during the day, but toward night it became quiet, assuming a humped position. Next morning it was dead.

2. A mouse one-half to two-thirds grown was bitten twice, the second bite following the first within a few seconds. The mouse began at once to die; humped itself, trembled, gasped for breath, and fell over dead.

3. An adult mouse was held into the jar containing the centipede by means of a string fastened to its tail. The mouse died the following night from the effects of the bite.

4. Two ground-snakes, each about seven inches long, were bitten by the same centipede that was used for the above experiments. The bite was prolonged, and the fangs inserted anew several times. The snakes continued to live for several days without suffering any apparent evil effects. Their death may have been due to want of proper care.

5. An adult mouse was bitten by a second centipede, but it escaped at the first touch of the fangs. It was doubtful whether any poison entered the mouse. It did not suffer any from the bite.

6. This experiment was similar to No. 2. The mouse used was about two-thirds grown. It was bitten in the flank region and on the back in the lumbar region. It attempted to walk, but the poison had taken effect, and the animal appeared paralyzed in its right hind leg. It moved a few inches, but was dead within a few seconds.

7. An adult mouse was caught by a third centipede (the largest of the four). The centipede crawled along its back, and held it with several pairs of appendages. It then caught the mouse with its fangs on the under side and continued biting for about 30 seconds. The mouse ran off when released. It died four days afterward.

8. An adult mouse was bitten twice, but each time only for an instant. The mouse continued to live as lively as ever. Three days afterward it had an unusual appearance, as it had lost its tail. As there was another mouse in the cage, the tail might have been gnawed off. One of the bites of the centipede, however, was at the base of the tail; the chances are the loss was the result of the bite.

Attempts were made to get the centipedes to bite toads, but without success.

It is the popular belief that the tips of all the legs are poisonous and inflict severe wounds merely by the animal crawling over the naked skin, especially if the claws are pressed into the skin; there is, of course, no evidence for the belief.

TREASURER'S STATEMENT FOR YEAR ENDING JUNE 3, 1892.

Membership fees		$43 00
To Clarke & Courts, printing	2 95	
Express charges on same	30	
To cash for postage stamps	2 00	
To Myers & Haswell, one record book	80	
To Dr. Macfarlane, Honorary Secretary, cash for printing	20 00	
To membership fees paid to Honorary Secretary	3 00	
Express on package to Honorary Secretary	25	
		$29 30
Balance in treasury		$13 70

J. C. Nagle, Treasurer.

TREASURER'S STATEMENT FOR YEAR ENDING JUNE 21, 1893.

Debit.

Balance in treasury	$13 70	
Received of Secretary	3 15	
Fellowship fees	6 00	
Membership fees	18 00	
Annual dues	43 00	
		$83 85

Credit.

By amount paid for postage for Secretary and Treasurer	$11 89	
By amount paid for telegram concerning Galveston meeting	55	
By amount paid to Ben C. Jones & Co., printing	13 75	
By amount paid to the Secretary, for money paid out	3 35	
		$29 54
Balance in treasury		$54 31

J. C. Nagle, Treasurer.

TREASURER'S STATEMENT FOR YEAR ENDING JUNE 9, 1894.

Debit.

Balance in treasury	$54 31	
Thirteen membership fees	26 00	
Two fellowship fees	6 00	
Dues	48 00	
One copy proceedings	1 00	
		$135 31

Credit.

By amount paid to J. C. Nagle, express charges	$0 30	
By amount paid for postage	5 50	
By amount paid to A. Macfarlane, postage and telegraphing	6 55	
By amount paid for printing	69 10	
		$81 45
Balance in treasury		$53 86

J. C. Nagle, Treasurer.

TREASURER'S STATEMENT FOR YEAR ENDING JUNE 18, 1895.

E. T. Dumble, Treasurer, in account with the Texas Academy of Science.

Debit.

To amount received from J. C. Nagle, Treasurer	$53 86	
To forty membership fees	80 00	
To five fellowship fees	15 00	
To dues	95 00	
Total receipts to date		$243 86

Credit.

By amount paid Dr. Macfarlane, Secretary	$11 32	
By amount paid Ben C. Jones & Co	29 00	
By amount paid Ben C. Jones & Co	150 00	
By amount paid E. T. Dumble	3 50	
Total expenditures		193 82
Balance in treasury		$50 04

TREASURER'S STATEMENT FOR YEAR ENDING JUNE 15, 1896.

E. T. Dumble, Treasurer, in account with the Texas Academy of Science.

Debit.

To twenty-eight membership fees	$50 04	
Cash in treasury	56 00	
To five fellowship fees	15 00	
To annual dues	106 00	
To two Patron fees	1,000 00	
Total receipts		$1,227 04

Credit.

By amount paid to—		
W. W. Norman, Secretary	$10 00	
Ben C. Jones & Co., printing	80 00	
Ben C. Jones & Co., printing	65 00	
Ben C. Jones & Co., printing	201 40	
T. U. Taylor, for engraving	10 22	
E. T. Dumble, Treasurer, for postage	7 00	
Total expenditures		$373 62
Balance in treasury		$853 42

LIST OF INSTITUTIONS WHICH EXCHANGE WITH THE TEXAS ACADEMY OF SCIENCE.

The Royal Society of Queensland, Brisbane, Australia.

The Royal Society of Victoria, Melbourne, Australia.

Kaiserliche Akademie der Wissenschaften, Wien, Austria.

L'Académie Royale des Sciences, des Letters et des Beaux-Arts de Belgique, Bruxelles, Belgium.

La Société Royale des Sciences de Liege, Belgium.

Die Koenigl. boehmische Gesellschaft der Wissenschaften, Prag, Bohemia.

Museu Nacional do Rio de Janeiro, Brazil.

Natural History Society, Montreal, Canada.

The Canadian Institute, Toronto, Canada.

Cambridge Philosophical Society, Cambridge, England.

The Royal Geographical Society, London, England.

The Royal Society, London, England.

The Manchester Literary and Philosophical Society, Manchester, England.

La Faculté des Sciences de Marseille, Marseille, France.

L'Académie des Sciences, Inscriptions et Belles-Letters de Toulouse, France.

Die Berline Gesellschaft für Anthropologie, Ethnologie und Urgeschichte, Berlin, Germany.

La Société Hollandaise des Sciences à Harlem, Holland.

Magyar Tudományos Akadémia, Budapest, Hungary.

L'Académie Hongraise des Sciences, Budapest, Hungary.

Natural History and Philosophical Society, Belfast, Ireland.

Royal Dublin Society, Dublin, Ireland.

R. Accademia delle Scienze, Bologna, Italy.

Circolo Matematico di Palermo, Italy.

R. Accademia delle Scienze, Torino, Italy.

Societa Toscana di Scienze Naturali, Pisa, Italy.

Revue de Mathematiques, Torino, Italy.

Instituto Geológico de México, Mexico.

Observatorio Astronómico Nacional de Tacubaya, México.

Sociedad Cientifica "Antonio Alzate," City of Mexico, Mexico.

Nova Scotia Institute of Science, Halifax, Nova Scotia.

Real Observatorio Astronomico de Lisboa, Portugal (Tapada).

Finska Vetenskaps-Societeten, Helsingfors, Finland, Russia.
Société Physico-Mathématique de Kasan, Kazan, Russia.
The Royal Society of Edinburgh, Edinburgh, Scotland.
The Philosophical Society of Glasgow, Glasgow, Scotland.
The South African Philosophical Society, Cape Town, South Africa.
Kongl. Vetenskaps Akademiens, Stockholm, Sweden.
The Geological Institution of Upsala, Sweden.
Naturforschende Gesellschaft, Zurich, Switzerland.
The University of California, Berkeley, Cal.
The California Academy of Sciences, San Francisco, Cal.
The Lick Observatory, San Francisco, Cal.
The Colorado College Scientific Society, Colorado Springs, Col.
The Colorado Scientific Society, Denver, Col.
The Meridian Scientific Association, Meridian, Conn.
The Department of Agriculture, Washington, D. C.
The Bureau of Education, Washington, D. C.
The Smithsonian Institute, Washington, D. C.
The Southern History Association, Washington, D. C.
The Weather Bureau, Washington, D. C.
The Field Columbian Museum, Chicago, Ill.
The Indiana Academy of Science, Indianapolis, Ind.
The Davenport Academy of Science, Davenport, Iowa.
The Iowa Academy of Science, Des Moines, Iowa.
The Kansas University Quarterly, Lawrence, Kan.
The Kansas Academy of Science, Topeka, Kan.
The American Academy of Arts and Sciences, Boston, Mass.
The Boston Society of Natural History, Berkley street, Boston, Mass.
The Geological and Natural History Survey of Minnesota, Minneapolis, Minn.
The Minnesota Academy of Natural Sciences, Minneapolis, Minn.
The Missouri State Geological Survey, Jefferson City, Mo.
The American Mathematical Monthly, Springfield, Mo.
The St. Louis Academy of Science, St. Louis, Mo.
Columbia University, New York, N. Y.
The New York Academy of Sciences, New York, N. Y.
The Rochester Academy of Science, Rochester, N. Y.
The Mitchell Scientific Society, University of North Carolina, Chapel Hill, N. C.
The Case School of Applied Science, Cleveland, O.
Oberlin University, Oberlin, Ohio.
The Academy of Natural Sciences, Philadelphia, Pa.
The American Philosophical Society, Philadelphia, Pa.
The Franklin Institute, Philadelphia, Pa.

The University of Pennsylvania, Philadelphia, Pa.
The Wisconsin Academy of Sciences, Arts and Letters, Madison, Wis.
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The University of Virginia, Charlottesville, Va.
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The Proceedings of the Academy from its beginning, January, 1892, to January, 1897.