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CLARK W. CHAMBERLIN

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CONTENTS OF VOLUME XIII.

January, 1905

September, 1905

June, 1906

September, 1907

SUBJECT AND AUTHOR INDEX

VOLUME XIII

11590

Volume XIII

ARTICLE I.
P. 1—33.

BULLETIN
OF THE
SCIENTIFIC LABORATORIES
OF
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EDITED BY
CLARK W. CHAMBERLAIN,
Permanent Secretary Denison Scientific Association.

CLARENCE LUTHER HERRICK

Granville, Ohio, January, 1905.

CLARENCE LUTHER HERRICK
IN MEMORIAM

BULLETIN OF THE SCIENTIFIC LABORATORIES OF DENISON UNIVERSITY.
Volume XIII. Article I. January. 1905.

C. L. HERRICK AS A MAKER OF SCIENTIFIC MEN.[1]

Ordinarily the closing of a life produces little impression. A limited circle of kinfolk and friends mourn deeply, and the impress of the departed one upon them remains for good or for ill as a character-moulding force. But the circle is small; those outside remember that death is appointed for all men and turn their thought from the unwelcome truth and the new illustration of it as quickly as possible. To be sure the death of a man prominent in public life touches many people, but ordinarily it does not touch them deeply.

A different case presents itself to us tonight; one has passed away whose ideals were so noble and so completely realized in his living, that a deep and abiding influence has passed into the lives of the large circle with which his work of teaching brought him into contact. With many of the earlier members of this Scientific Association these ties have been very close, and it is eminently fitting that we interrupt its ordinary activities tonight to linger for a little while in thought upon the life and services of its departed founder, Clarence Luther Herrick.

Others are to speak tonight of different phases of his personality and work; as a geologist, as a teacher, as a man, as a friend of Denison. I may not be able to avoid encroaching somewhat upon the territory indicated by these sweeping titles, and perhaps it is just as well that I should not. These aspects of his life are so important that it may not be amiss if we look at them from the different angles of several observers. But I desire to emphasize especially tonight his rare power of influencing young men—and that too without seeming to make any effort to do so—to adopt his own point of view on life and devote themselves, wholly or in part, to that quest of truth which was to him the great thing in life. This seems to me to be the most striking and

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[1] An address given at a meeting of the Denison Scientific Association, Sept. 30, 1904, in memory of C. L. Herrick.

thoroughly characteristic thing in Professor Herrick's personality. He was learned, but we have known others learned too; he was devoted to his work, but such devotion though uncommon, we may find elsewhere; he was a rare teacher, but the country has many great teachers; he was a man of strong religious faith and rich Christian life, but that too we may parallel in other lives. But I cannot think of one other man who so powerfully impressed those with whom he came into any sort of contact with a real longing to find out new truth by their own effort and add it to the legacy of knowledge which the present generation has inherited from the past. His own work as an investigator was great; his work as a maker and trainer of investigators was perhaps greater. I have never known an enthusiasm so contagious as his. It is no mere accident that both of his brothers, his wife's brother, his only son and a large proportion of his students have caught the spirit of original research and made important contributions to the fund of new knowledge. Contact with him in classroom, laboratory or household seemed equally efficient for propagating the germ of personal investigation. He might have been a great teacher even without this power, as others have been; with it his success was assured, and eminence certain with favorable conditions.

As a fellow teacher whose work was more closely associated with his through some years than was that of any other member of the Denison faculty, this remarkable power of influencing young men was a matter of great interest to me and I tried to analyze it and find the reason for it, in the hope thereby of acquiring some small measure of such power for myself. I do not know that I can explain it satisfactorily, for any sort of personal magnetism seems almost beyond the power of analysis, but perhaps the attempt will enable us to gain a fuller understanding of his character and work, and incidentally help the considerable number among us who are, or expect to be teachers, to greater efficiency in our chosen work.

What then were some of the reasons for the unquestionable power he possessed of moulding the purposes and lives of his associates? Let us note at least a few of them. One reason for this power was undoubtedly the perfect sincerity of his devotion to science. It was so apparent from even a slight acquaintance with him that he loved it and believed in it as a pursuit worthy not only of his own highest thought and most earnest effort, but deserving as well the supreme attention of any man. He was not given to proselyting; there was no direct appeal to others to interest themselves in those things which he pursued. But, given a noble mind, despising the shams which it already sees constitute so large a part of modern life, longing vaguely to realize its youthful dreams of mental achievement and moral victory, in close daily contact with an enthusiasm so pure and unselfish as that of Professor Herrick, is it any wonder that the ambition to emulate him should be kindled in that mind? We all know the teacher, who seems to teach for "what there is in it" for himself—such small return of money, social position or reputation as seems to be attached to his business; we have seen how he bolsters up his own dead interest in the progress of science by sounding phrases about the dignity of scientific pursuits. No one recognizes the sham more quickly or completely than the students in his class room, and with the recognition his power as a teacher is gone. No one can interest another in an intellectual problem in which he himself is not genuinely interested. Even if he believes himself interested, that is not enough; self-deception cannot save him. His students will feel —vaguely perhaps, but surely—that the interest is not real. On the other hand, the teacher with a genuine zeal for his subject, so simple that it never feels the need of self-assertion, already has his battle two-thirds won. The student unconsciously detects the real article as inevitably as the sham. As it is hopeless to deceive students by the parade of a simulated enthusiasm, so it is unnecessary to proclaim the existence of a real one. Thus Professor Herrick's intellectual honesty and genuine zeal for science found an answering note in the minds and hearts of all those whose lives touched his. We who knew him felt our own ambitions purified and enobled by the contact.

Secondly, his remarkable industry emphasized the effect of his sincere devotion to science. He was not one to tell you how much midnight oil he burned or in any way indicate the intensity of his labors, but both their quality and quantity compelled our attention and we watched and found that he rarely spent an idle minute. Not only were his working hours long, but intensely active. Many of us remember the long, quick stride which carried him so rapidly from task to task; it was an index of the energy of the mental machine within.

A letter recently received from a former student who was for a time a member of his household says: "The tireless energy of the man was inspiring. His light was the last to go out in the home, and on going to breakfast early in the morning it was no unusual thing to meet Professor Herrick returning from the woods or swamp with a supply of material for the day's classes. . . . . If he ever took a rest we never knew of it."

Some who loved him feared the results of this excessive activity and counseled moderation. But he seemed to be driven to work by some necessity of his very being which would not let him rest. Fortunately the long tramps and vigorous outdoor exercise, which his scientific labors demanded, gave some relief from the exhausting effects of the mental application to which he was so inclined, and enabled him to keep up year after year such labors as otherwise would have worn him out. Even those who disapproved of this overwork were forced to admire the unselfish zeal which caused it and felt a new impulse in their own pursuit of truth.

A third reason for Professor Herrick's ability to instill the spirit of research was found in his subordination of most of the common aims which move men to what was evidently the great aim of his life. Most of us attempt so many things that we do none of them very well. We divide our energies between money-getting, reputation-winning, recreation, self-culture and various public interests to such an extent that nothing in our individuality stands out to compel the interest of our fellows. But Professor Herrick, while remarkably faithful to all his duties to others, managed to give such emphasis to his scientific labors that it became but natural to think of him always as a man-of-science.

Another thing that attracted students and led them unconsciously to seek to imitate him was the freshness and originality of his ideas. His mind was always taking conventional and commonplace ideas and making something fresh and new out of them. He thought much of the philosophical bearing of scientific things. "The Psychophysical Basis of Feelings," "Psychological Corollaries of Modern Neurological Discoveries" are two of many titles of his scientific papers indicating his tendency to philosophize upon the results of his scientific observations.

Besides the four mental traits which I have mentioned in attempting to account for the power he possessed of energizing others into scientific activity, there were moral attributes which contributed still more to the same end.

One of these was closely connected with his originality and mental independence, namely his courage in over-riding false traditions and calmly undertaking the solution of difficult problems. His was the pioneer type of mind. And so he frequently introduced novel methods in his teaching which aroused attention and interest. Although his connection with Denison was not a long one, he introduced at least four striking innovations which have already stood the test of years and bid fair to be permanent. These were (in chronological order) the Scientific Association, the Bulletin of the Scientific Laboratories, the Neurological Journal and the courses of study which lead to the degree of Bachelor of Science at Denison.

At the time of its introduction each one of these innovations seemed to be a questionable proposition, hardly likely to succeed. Professor Herrick had a larger faith than I. Yet so great was my respect for his opinion and my desire to help him in any plan upon which his heart seemed to be set, that I could not bring myself to express the doubts of success which I really felt. In three of these enterprises he very early sought my co-operation and so the question of practicability was forced upon my attention in each case at the very outset. As I look back over the years, I have to confess that his judgment was better than mine. Note briefly how his larger faith has been vindicated.

He started the first volume of the Bulletin of the Scientific Laboratories the year following his coming to Denison. Whether looked at from the point of view of the probability of getting suitable financial support, of the small number and imperfect training of the students and other local workers who might be expected to furnish articles for it, or whether considered with reference to the likelihood of its receiving recognition abroad in the shape of exchanges with the really worthy scientific periodicals of this and foreign countries—viewed from any of these standpoints the enterprise seemed to many a hazardous one. But how has it turned out? The trustees of the University voted a sum of money to help publish the first volume and have continued to do the same year after year for now nearly twenty years. Sometimes when they did not see how they could do so, with the many pressing financial needs, some of their number have put their hands into their own pockets and extracted therefrom what was necessary to prevent any interruption or delay in the appearance of a publication, which they have come to recognize as of great value to the University. With regard to the question of finding contributors, examination of its index shows that twelve volumes have been issued, aggregating nearly 2,000 pages of valuable scientific material. In the first ten volumes (complete indices of the last two are not just now at my disposal), I find that there are 85 articles written by many different authors, most of them Denison men, students or faculty members, and not a few of them those who have become original workers mainly through the influence and example of Professor Herrick himself.

Undoubtedly its success has been mainly due to the fine start it made through the unremitting labors of Professor Herrick as editor. Of the 26 articles, which constitute the first four volumes issued under his editorship, no less than ten were from his own pen. And after ill health compelled him to seek another climate, and in spite of the fact that he had taken the editorship of the Journal of Comparative Neurology upon his hands, we find him a frequent and valued contributor. So late as June, 1900, (in Vol. XI) we find an elaborate article of more than 60 pages with a map and 34 of the beautiful plates for which he was so well known.

As to his success in receiving recognition in the form of exchanges from the scientific institutions which issue publications made up principally of original contributions to science, witness the long rows of shelves in the library of the Association in Barney Science Hall, filled with several thousand valuable works from about 200 of the most famous learned societies of North and South America, Europe, Japan, and Australia. Through this means the name of Denison is known and honored in New York, Boston and Washington; in London, Edinburgh, Paris, Brussels, Berlin, Prague and Vienna; in Tokio, Sidney and Melbourne and most of the capitals of four continents.

In 1887 Professor Herrick founded the Denison Scientific Association, whose object, aim and history during seventeen years are well known to most of you. Very faithfully has it carried out its aims, as he expressed them in its constitution, "To collect, record and disseminate information bearing on the sciences, and to stimulate interest in local natural history and preserve specimens illustrating the same." I think very few of us who tried to help him start the Association expected that it would continue and develop as it has done. My own feeling concerning it is well expressed in a letter recently received from another of its charter members, Professor J. E. Woodland of the Rochester Athenaeum and Mechanics Institute. He says:

"I recall vividly the organization of the Denison Scientific Association and the enthusiasm with which Professor Herrick directed the work and gathered the material for the programs. I have been associated with other Scientific Associations since then but have yet to find the genuine local interest and enthusiasm that characterized the one in Granville."

During the three years which he spent on the Faculty of the University of Cincinnati, he started the Journal of Comparative Neurology, and when he returned to Denison (in '92, I think) he had the courage to continue the publication of the new periodical, altho' the "Bulletin" was still being published. The success of the "Journal" has continued under the able leadership of his brother, Professor C. Judson Herrick, so that we have for a long time had the singular spectacle of one small college issuing regularly for a long series of years, two high class periodicals devoted to different fields of scientific investigation, each honored with a long list of valuable exchanges of its own class. I do not believe any American college of equal size can duplicate this record. And it is due principally to the courageous initiative and devoted labors of him whose memory we honor tonight.

The fourth innovation, due principally at least to Professor Herrick, was the complete revision of the work in science in the course of study leading to the B. S. degree at Denison. When he returned to Denison in 1892, after his three years' absence at the University of Cincinnati, he was relieved of the work in Geology and enabled to give all his time to Biology. He planned a number of new courses and advocated a complete revision of the last two years of the B. S. course. At this time the B. S. student at the beginning of his junior year had had two years' work distributed over four sciences (chemistry one year, mineralogy, physiology and botany, one term each) in addition to the elementary science required for admission to college. Before him lay 2 1/3 years' work required, 2/3 elective, distributed over five sciences (a year of physics, zoology, astronomy, one term each, and geology two terms, with the possibility of electing one term each of chemistry and histology). In a word he could not get more than one year of work in any one science during his whole college course (except in the case of chemistry where the maximum was four terms). Professor Herrick proposed to change this, so that each student at the beginning of his junior year should continue some one science through the remaining two years of his course, this science to be either biology, chemistry, geology or physics. (Civil engineering was later added to the list.)

Professor Herrick came to me with the general plan, and after we had worked it out in detail, it met the approval of the Faculty and was adopted. It has always seemed to me that this marked an educational epoch at Denison. It was a definite adoption of the Johns Hopkins plan of electing one fixed, logical course of study out of a considerable number of carefully planned courses, instead of the hap-hazard election of a lot of isolated terms work having no unity or logical sequence among themselves. It was another case where Professor Herrick's independence of tradition led to important results for Denison.

A sixth reason for Professor Herrick's ability to arouse the spirit of scientific research in others we find in the breadth of his interests and sympathies. He did not follow the fashion of extreme specialization so characteristic of our time. Before he came to Denison he was State Mammalist of Minnesota, at Granville he was botanist, zoologist, geologist and neurologist, not merely teaching but investigating along all these lines. While in New Mexico he added work as a mining engineer to that of geologist and neurologist, and in his last months we hear of his resuming study and writing along philosophical lines, a labor which had been begun many years before. And so under his tutelage we find one of his students inspired to be a botanist, another a biologist; several became geologists and others neurologists. And to all he was able to extend such counsel, stimulus and sympathy, that his influence became one of the determining forces in their lives.

And this brings us to the last reason that I will name to explain Professor Herrick's power over his students; namely, his personal interest in them, not alone in their scientific development, but in all their joys and troubles. Quoting again from Mr. Woodland's letter: "To the student he was never a professor with awe-inspiring dignity, but rather a companion and friend. . . . . There seemed to be some great pressure incessantly driving him to work, yet wth it all we never entered his room that he did not make us feel entirely welcome. . . . His talks to the boys were full of interest and heart-sympathy —he never spoke a word of discouragement to anyone."

And now in conclusion let me illustrate several of these sources of Professor Herrick's power to inspire students by reading to you a letter which I received today from W. E. Castle, now Professor of Zoology in Harvard University, one of the many young men who honor Professor Herrick's memory in the highest possible way, by following in his footsteps.

"While in conversation with a Zoölogist from a distant state I was asked from what college I came. 'From a college,' I replied, 'of which very likely you never heard, Denison.' 'O yes,' was the prompt reply, 'I know of Denison; the Herricks have made Denison famous.' This incident gives evidence of the high regard in which the scientific work begun at Denison by Professor C. L. Herrick, is held among workers elsewhere in similar lines.

In the opinions and affections of his pupils Professor Herrick occupied a still larger place. His coming to Denison marked an epoch in the intellectual life of many who were then undergraduates. It was to them what the Reformation was to Europe. It marked the termination of authority, the beginning of intellectual liberty. Through all their previous studies they had dealt with facts carefully marshalled, concerning which two opinions could not exist. Knowledge was something to be mastered and used. It was given to them on authority, which they had neither occasion nor disposition to question.

Now came a man who quietly brushed aside authority and invited them to create knowledge. The idea was so novel and preposterous that they looked at each other, half-puzzled, half-amused, wondering whether there really could be profit in studies so undeveloped that they offered anything but unquestioned verities to the beginner. This was venturing on an uncharted sea; is it any wonder that like the sailors of Columbus we hesitated?

Not only were the methods of our new teacher unusual, his subject matter too was un-school-like. Birds, flowers, and pebbles had been our playthings and companions in the fields from childhood, but in the school-room never. Any boy caught with them on his person was in disgrace. Our new master threw open the door and invited us to come out and know these same playmates of our childhood better, and to know them not as someone else had seen them, not as he saw them, but just as they came from God's hand. We went and we looked, and little though we saw, some of us were so entranced with the seeing that we are looking still. Others more mindful of duties elsewhere, have gone to the school-room or the home, but I venture not one has forgotten what he learned from Professor Herrick, to see for himself and think for himself and to love and try to understand God's world."

A. D. Cole.

CLARENCE LUTHER HERRICK.

We are called upon with the present issue of the *Bulletin* to lament the sad and untimely death of its founder and editor-in-chief at Socorro, New Mexico, on the 15th of September. For the past ten years, dating from his last connection with Denison University, he has struggled heroically against tuberculosis of the lungs, together with other complications, which at last cut him off in the midst of his labors and in the prime of life. Untimely as his death must seem when regarded from the point of view of his plans and hopes, yet Dr. Herrick had done an amount of scientific research and philosophical writing, some of which he was preparing for the press when he was taken, which assures him an enduring name in the world of thought.

The end came in accordance with his own most earnest wish —he fell fighting for the truth. As one of those who were near him when he passed away has said: "He was taken literally in the harness. His laboratory and study tables showed the unfinished tasks. His morning mail brought its usual load of duties. He had contributed an article to the September number of the *American Geologist,* and his mail, on the morning of his death, brought a request from Dr. N. H. Winchell for some further contributions to the October number. Thus in the midst of his labors he passed into the larger sphere."

Very early in his career he seems to have laid out, at least in a general way, a plan of action, including for the first part of his life miscellaneous research and study under direction in the broad field of general natural history. Upon the basis of this foundation, was to follow a period of intense specialization in a circumscribed field of zoological work leading up to a mastery of the anatomy and physiology of the nervous system. Finally the ripest years were to be devoted to physiological and comparative psychology on the basis of the mechanics of the nervous system and to philosophical correlation.

His life may be roughly divided into four periods. While these were marked by extraneous events and were apparently purely artificial and arbitrary, yet it may be said that the ideal scheme was in the end fairly achieved, though with great deviation in the details of the working.

Dr. Herrick was born near Minneapolis, June 21, 1858. He grew up in a home far from neighbors, a solitary child with few playmates, and very early showed his bent as a naturalist. While still in the Minneapolis High School he collected extensively and left at graduation a case of over a hundred mounted bird skins and other specimens to the high school. It was during this period that his father, despite his poverty, got him an eight dollar microscope. With this crude instrument and without guidance or library facilities he worked over the fresh water fauna of the neighboring brooks and pools so thoroughly that before graduation from the University of Minnesota in 1880 he had published several articles of value on the fresh water crustacea of Minnesota and four years after graduation, with somewhat better facilities, published a report on the micro-crustacea of Minnesota, which is still standard The materials for this report were elaborated before he graduated from college.

These years were filled with many bitter struggles, not the least of which was with poverty and the consequent lack of material for study. But, notwithstanding, he completed the college course in three years, at the same time partly supporting himself by assisting on the staff of the Geological and Natural History Survey of Minnesota. He had also showed so obvious a native gift with his pencil that upon his graduation the president of the university said to his father that he was uncertain whether to advise the young man to devote his life to science or to art. But there was no uncertainty in the mind of the graduate. Continuing his work on the Geological and Natural History Survey of Minnesota, he published many papers in rapid succession on the fauna of the state and began an extensive report, the first volume of which was completed in 1885. This was a large quarto on the Mammals of Minnesota, fully illustrated with many colored plates and pen drawings. It was accepted for publication, but for lack of funds in the Survey never saw the light. Years afterwards, in 1892, a small octavo was published by the Survey made up of the more popular parts of this work. The remainder is still preserved among his literary effects. The season of 1881-2 was spent at the University of Leipzig, and in 1883 he was married to Miss Alice Keith of Minneapolis. This, roughly, may be said to constitute the first period of his life, from 1858 to 1884.

He was called to the chair of Geology and Natural History of Denison University in the summer of 1884. He spent the fall of that year at Denison, then returned to Minneapolis to complete the work in progress in the Minnesota Survey, and in the fall of 1885 moved with his family to Granville. Meanwhile, in 1885, he took the degree of M. S. from his *alma mater.* It had been his intention to continue his zoological work, and there was great activity in this line during the entire period, but the routine excursions made in the course of the instruction of his geology classes showed him so much of interest in the local strata that his chief labors while in Granville were upon the fossils and stratigraphy of the Waverly free stones and shales of Ohio. This work was abruptly cut short by his removal from Granville in 1889 and, while never rounded out as he would have liked, is probably his most important geological work. In 1885 he founded the Bulletin of the Scientific Laboratories of Denison University, in which the greater part of his researches, and those of his pupils, on Ohio geology were published.

His phenomenal success as a teacher during this and the subsequent periods was due to factors, some of which are easily seen—others are harder to define. After his attractive personal qualities and magnetic enthusiasm, I should place his deep philosophic insight and the fearless way in which he disclosed his profoundest thinking to the least initiated of his pupils. The ability to do this without befogging the air was an exceedingly rare gift and was stimulating even to a dullard. He knew the philosophical classics thoroughly from original sources and the trend of his thinking was very early foreshadowed in the translation of Lotze's Outlines of Psychology published in 1885 in Minneapolis, with his own appended chapter on the structure of the nervous system.

Upon his removal to the University of Cincinnati in 1889, with which the third period of his life may be said to begin, the geological studies with which the preceding five years had been so fully occupied were summarily brought to a close and he threw himself with renewed energy into the study of the nervous system. Extensive papers on the brains of different animals appeared in rapid succession, of which the most valuable are two series, one on the brains of various fishes, the other on those of reptiles. In 1891 the *Journal of Comparative Neurology* was founded and served as the medium of publication for most of these researches. The founding of this Journal can best be designated as a piece of characteristic audacity. It was a purely private enterprise, with no fund to defray the expenses and very little outside coöperation promised. But without counting the cost he plunged boldly in, expecting a constituency to be developed as the work went on. In this he has not been disappointed, though recognition of financial needs has lagged sadly behind that of the scientific value of the Journal.

At the close of 1891 he resigned his chair in the University of Cincinnati to accept a chair of biology in the University of Chicago, then being reorganized. The early part of 1892 was spent in Europe, chiefly Berlin. Upon his return the adjustment at the University of Chicago presented unexpected difficulties and after a series of misunderstandings he finally withdrew from that institution, declining an offer to return to Germany for further study on full salary. He was immediately elected to his old post in Denison University with an assistant and the privilege of devoting only a part of his time to teaching, the remainder, either at home or abroad, to the further prosecution of his research. A year and a half of great productiveness followed. He bought a small tract of land adjacent to the college campus, built a residence upon it and planned to devote the remainder of his days to breeding animals on an extensive scale and studying the laws of heredity, comparative psychology and allied problems. But before this project was fully under way his health broke down completely and he was forced to abandon his home in the fight for life.

In December, 1893, he had a severe attack of la grippe, but, as was his custom in illness, went on with his work as usual. Upon completion of the last examination of the term he came home too ill to correct the papers, and in course of the following night was atacked by a severe hemorrhage from the lungs and for weeks his life hung in the balance. With the return of spring his strength increased sufficiently to enable him to remove to New Mexico, where the local physicians told him that he had a fighting chance for a few years. He accepted the challenge bravely and for more than ten years held the disease in check. During the spring of 1894 his college dedicated the Barney Science Hall, which had been built largely under the stimulus of his presence in the faculty; but he was never permitted to work in it.

The fourth period, from 1894 to 1904, covers the remaining years of his life.

This decade, filled with bodily pain and the worse torture of anxiety and mental unrest, is yet one of the most productive periods of his life. Much of the time was spent in the open with covered wagon and camp kit, and with the return of strength scientific interests again absorbed his attention. Naturally in this case he again turned to geology and an extensive series of articles on the geology of New Mexico bears testimony to the industry of these apparently aimless wanderings. The first scientific work done in the Territory, however, was a revision of his earliest important work, the Crustacea of Minnesota. As soon as his geological knowledge became known his services were in demand as a mining expert and during the later years of his life in the Territory he supported himself and his family chiefly by practicing this profession as strength permited. In 1898 he took the degree of Ph. D. from the University of Minnesota. For four years (1897-1901) he was president of the territorial university at Albuquerque, though at the close of the third year it became evident that the strain of the executive work and confinement were too hard for him, and the connection during the fourth year was mainly one of supervision and general control.

During his last year there was an obvious failing of physical strength, so that long field trips had to be abandoned. But the more quiet life gave opportunity for a thorough recasting of many questions and formulation of matters which had been in his mind all his life. So that before his death much of the philosophical correlation, of which mention has been made, was effected. A number of articles have already been published in the philosophical serials bearing on these matters and there is a considerable collection of MSS. remaining, much of which can doubtless be edited for publication. It is gratifying to know that he had the satisfaction of seeing this work so well rounded out before his death and that the latest months of his life were much more restful than those preceding, some of which were marked by extreme suffering. He continued in about the usual health until September 8, when he again had a series of uncontrollable hemorrhages, daily becoming weaker until on the morning of the 15th he peacefully passed away.

One essential feature of his success must receive mention here—the devoted heroism of his wife. His work was always stimulated by her interest and coöperation; but during the last decade his life was unquestionably preserved by her self-sacrificing care. She often accompanied him for weeks on wagon trips far from settlements in order to see that he had proper food and comforts, sometimes enduring severe hardships and sacrificing her own health for his welfare. He is survived by his wife and two daughters, Laura and Mabel, and his son, Harry N. Herrick, now a student in the School of Mines of the University of California.[1] It remains here to say something of Dr. Herrick first, as an investigator and thinker, and secondly, as a teacher and as a man.

In estimating the character of his work it is difficult to say whether he was primarily an investigator or a philosopher. And this is to his great credit for he combined in a remarkable degree the qualifications of an expert in both of these lines. He had at once acute perceptions, and keen insight for scientific details, and a broad philosophic horizon and perspective which peculiarly fitted him for the work he undertook of throwing light upon the nature of consciousness from the neurological side. A glance at the appended bibliography will show that a philosophic scope as well as a scientific specialization characterized all his work.

His work in every line was exteremely suggestive, and it should be added, seldom exhaustive, though certain of his neurological and geological papers reveal his power of accurate and detailed research. But his thought ever was moving forward, and he was impatient of the routine details which would put any check upon his richly developing insight.

His scientific labors fall in three states—Minnesota, Ohio, and New Mexico. Of his work in geology during the first and second periods of his life we have already spoken. His neurological work was done mostly during the second and third periods, while connected with the University of Cincinnati and with Denison University.

The first contribution in neurology was the elementary chapter on the nervous system appended to the translation of LOTZE's Outlines of Psychology, published in Minneapolis, in 1885. This is significant not so much for its content (though here the dynamic point of view is dominant) as for its context. The juxtaposition, in a manual designed for an elementary text-book, of LOTZE's lectures and original lectures on the mechanism of the brain was a decided novelty in those days.

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[1] He took his mining degree in 1907 and now holds a post in the same university.

In 1889 he began work in earnest on the nervous system and immediately there appeared a series of papers in rapid succession, some of great length and others mere jottings. The first long paper was published with Professor W. G. Tight in the Denison University Bulletin in 1890 and was entitled "The Central Nervous System of Rodents." This paper contains nineteen double plates and a vast amount of observation; and was designed as a preliminary survey of the field, the plates to form the basis of further detailed observations and correlation. But he soon became convinced that this correlation could best be attempted after a thorough study of several types of lower brains and the series was interrupted. At the time of his breakdown in 1894 he was just about to take up again by the degeneration methods a more thorough study of the mammalian brain. Thus this rodent paper stands now as an unfinished fragment.

This, however, illustrates well his plan of work, a plan which must be clearly understood in order to put a proper estimate on his published researches. He found correlation impossible and at once saw that only in primitive types could the key be found, and that too not in any one series, but only in the common features of many lower types. Accordingly he undertook to examine in rapid succession as material offered a large number of lower brains, taking voluminous notes and publishing the *observed* data as fast as they were ready. All of this work was fragmentary and much of it contained but little correlation. But the mass of facts gathered and recorded was enormous. He realized that the incessant strain on his eyes could not always be kept up, and planned to accumulate fact as rapidly as possible until failing eyes should impair his efficiency in this field. *Then* he hoped to review the whole field of vertebrate neurology systematically, using his own observations as the skeleton on which to build by study of literature and further research of his own on critical points, until the whole should take shape as a unity. When he settled in Granville the second time in 1893 he expected to begin that work of correlation, and this is doubtless the special significance of the announcement published at that time of a text-book on comparative neurology. But this period of work he was not able to enter far and the text-book is still unpublished. This manuscript, together with that of several other projected works on psychology and ethics, remains. It is yet too early to state how much of this matter can be edited for publication. If the last ten years of his life could have been spent in Granville, as was his plan, results of moment in the way of correlation would undoubtedly have followed. As it is, none of the papers in neurological lines were regarded by him as other than fragments.

The first important paper in neurology was published in the *Journal of the Cincinnati Society of Natural History*—"Notes upon the Brain of the Alligator." This is an elaborate descriptive article illustrated with nearly a hundred of the beautiful pen drawings which he used so freely in all of his work.

The second neurological paper of special importance was the leading article in the first issue of the *Journal of Comparative Neurology*, on the histogenesis of the cerebellum in correlation with its comparative anatomy. This paper was ignored largely by the workers immediately following, but its main points have been fully confirmed by later students. It is really, though very brief, one of his best contributions.

Of the remaining neurological papers, the most important were published in the *Journal of Comparative Neurology*, those in the *Anatomischer Anzeiger*, *American Naturalist*, etc., being for the most part summaries of the longer articles. These were descriptive articles in most cases, devoted mainly to the brain of fishes and reptiles, with some attention to amphibians.

The greater part of his descriptions of the fish brain have since been worked over with the same sections which he used in hand, and his descriptions have been found to be very exact, though often so brief as to make it difficult to understand them without reference to the preparations. Furthermore they stand the test of control by the more recent neurological methods very well, though of course not always in detail. His method of pushing a given research through rapidly enabled him to cover a great deal of ground with surprising fidelity to the facts of his material. But the method results in a positive hardship to his readers, since the matter was not fully digested and correlated before publication. While, therefore, this matter is of great value, it is hard to read and will not be used fully save by a few specialists until it is worked over and correlated within itself and with other more recent work. It is hoped that this may be done soon. The facts as stated must necessarily serve as the basis for any future work on the types which he studied.

After his departure for New Mexico a few brief neurological articles were published, but only fragments remaining from his earlier work or critical articles. This period was devoted chiefly to geology and other studies which could be pursued out-of-doors, and more recently to philosophical writing.

In 1892 he contributed a short paper to the Leuckart Festschrift. In 1893 he wrote four articles for the supplement to Wood's Reference Handbook of the Medical Sciences. He also wrote a few articles for the second edition of the Handbook, beginning in 1900. In conjunction with C. Judson Herrick, he prepared the neurological articles for the Baldwin Dictionary of Philosophy and Psychology, some of these being encyclopedic articles of considerable length.

The best years of his life were devoted to his neurological work and it is all of a high order of merit, yet one feels that in very little of it did he do himself justice. His impetuous temperament and phenomenal ability to turn off research rapidly is partly responsible for this; but its unsatisfactory character is largely due to the fact that it was cut off prematurely. He never had the patience to polish his work as some like to see it done, and it would have been much more accessible if he had put even the unfinished reports of progress into more systematic form. Yet, even as it is, the aggregate is a monumental work to stand as the out-put of only about half a decade of productive work.

Of his work in New Mexico one who had first-hand knowledge writes as follows:

"He first resided, with his family, in Albuquerque, and while gaining strength, began to study the local fauna and flora. Perhaps it may be allowable to give an incident from this period of his life, for it is most typical of him.

"While recovering strength he was accustomed to lie upon a couch in the open air. His microscope was close at hand, and he began at once the study of our fresh water crustaceans. For a few minutes he would study his creature under the microscope, make his exquisite drawings, write out his description, when, being seized with a coughing spell, he would be forced to his couch completely exhausted, to remain there perhaps half an hour before he could resume his study.

"This incident illustrates two characteristics. It illustrates first, his unremitting labors. Only when necessity compelled did he cease his labor. True, he had his recreations, but these were often of such character as to be downright labor for most men. The incident also illustrates, secondly, his deep thirst for knowledge. Only he who has drunk at the fountain of inspiration could labor so incessantly under conditions so unfavorable.

"After some months spent in Albuquerque, Professor Herrick and his family moved to Socorro. There he became interested in geological studies, and also collected a considerable herbarium of native plants. He contributed occasional articles to the *Journal of Comparative Neurology*. In the spring of 1897 he, in company with his son Harry and Dr. Maltby, made an exploring trip to the Tres Marias Islands, off the western coast of Mexico, where a large natural history collection was made.

"Upon his return from Mexico, Professor Herrick was elected President of the University of New Mexico, and began his new labors in 1897. His wide experience, having been connected with three universities, viz., Minnesota, Cincinnati and Denison, his several trips to Germany, where he met and worked with the leaders in the biological sciences, his national reputation in fields of zoology, geology, neurology, psychology and philosophy, gave him an ideal preparation as a college president. No wonder, then, that he drew to him immediately a number of advanced students who were inspired by his genius and broad knowledge, and who fairly worshiped him.

"In passing, it may be mentioned that under him the policy of the University was completely reversed. From a literary academy, it became a scientific school; from a preparatory school it developed into a college with a post-graduate department. In three short years the institution was placed where it belonged —at the head of the school system of New Mexico.

"Upon entering his new duties, Dr. Herrick commenced the biological and geological survey of the territory.

"Two volumes of original investigations in these lines speak for themselves. In addition, contributions were made to some of the leading journals of America, especially to the *Journal of Comparative Neurology*, the *American Geologist* and the *Psychological Review*."

Of Professor Herrick's contributions to philosophy a word should be said. That his interest was a deep and abiding one is abundantly evident from a glance at his writings which include many articles and discussions dating from the publication in 1882 of his translation of Lotze's lectures on psychology to the series of articles on "Dynamic Realism" which he had begun to publish in the *Journal of Philosophy, Psychology, and Scientific Methods*, at the time of his death. He made frequent short contributions to the *Psychological Review*, besides publishing various articles of a psychological and philosophical character in the columns of his own *Journal*. His interest in problems of ethics and religion is evidenced by divers articles in certain of the religious periodicals as well as by much unpublished MS.

Of his metaphysical writings it should be said that they were always inspired by his scientific researches. He never was satisfied with the easy philosophy of the "anti-metaphysical" standpoint of many fellow scientists. Psycho-physical parallelism he regarded as "the Great Bad." The aim of his life was to throw light upon just such so-called insoluble problems as the relation of consciousness to the brain. "Ignorabimus" is a word which never fell from his lips. The unity of the material and the mental is a truth upon which he came to lay increasing stress in his later years. Starting from a Lotzean spiritualistic idealism he never lost hold of the monism which characterizes that philosophic world-view, though in many respects he worked beyond it, his scientific studies serving to correct any tendency to an exclusive emphasis upon the mental. This is seen in the title under which his latest writings appear—"Dynamic realism"—in which many will find hints of a coming philosophic movement which is to reinterpret the fixed ontological categories of a past metaphysics in more dynamic and organic terms.

Of his contributions to the theory as to the nature of consciousness (equilibrium theory of consciousness), the physiological basis of the emotions, theory of pleasure-pain (summation-irradiation theory of pleasure-pain), his discussion of the reflex arc or organic circuit under the terms of his own coining ("aesthesodic" and "kinesodic"), and in general his interpretation of experience in dynamic and energic terms, we may not here speak in detail. But the attention of the readers of this *Bulletin* should be called to this side of his work as it is embodied in his various published writings and especially in certain writings which are yet to appear.

In the memory of his pupils Professor Herrick was greatest as a teacher. This statement can only be appreciated by those who knew him personally and were in his classes. There was no display or oratory. He was not what would be called a gifted public speaker, though he was often called upon for such services. It was in the class-room or about the seminar table or in general conversation that the inexhaustible fertility of his thought and fine suggestiveness of his language appeared. In his lectures one always knew that he was geting the best, the latest, the deepest results of his scientific research and philosophic reflection. Never was any work slighted in which his students were involved. Other things might be sacrificed—time, money, convenience, even health itself, but never the student. The result was that his teaching was not confined to the class-room or laboratory. There never was an occasion upon which he was not ready to suggest, advise, assist the groping mind in its search for the truth.

He was extraordinarily versatile in the class-room. He would lecture with a piece of chalk in each hand, sketching at the same time ambidextrously upon the blackboard the figure he was describing. Never did the lecture degenerate into a mere description of the figure. The figure he was describing was the figure in his mind, the figure that he was thereby suggesting in the student's mind. Such description and all the other instrumentalities of the class-room and laboratory were always kept in their proper place and proportion as means to the end of knowledge and insight. His artistic sense was too fine to allow them ever to degenerate into mere ends in themselves: the technique of his teaching was in itself a work of art, the more that it was unconscious on his part. His courses in neurology, embryology, and histology were primarily courses in thinking. This is no doubt the reason why so many of his students look back upon his teaching as the period of their intellectual awakening.

One of his colleagues at Denison University says of him: "All who knew Professor Herrick loved him. Different friends had different reasons for loving him, but all agreed in loving. Christian people loved him because he was a loyal Christian man. Intellectual people loved and admired him because of his brilliant and keen intellect; and men in general loved him because they saw in him a true and noble man loving the truth and living it out in his daily life."

As has been said of another: "He did his work with a quietness which concealed its power. He contributed to science our best example of the scientific temper. He was a profound thinker. He was a successful teacher. He was a lover, inspirer, and leader of youth."

H. Heath Bawden.

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THE CENTRAL GUSTATORY PATHS IN THE BRAINS OF BONY FISHES.

By C. JUDSON HERRICK.

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Studies from the Neurological Laboratory of Denison University. No. XVIII[1].

With Forty Figures in the Text.

CONTENTS.

SECTION I. INTRODUCTION.

The conception of the nervous system as a mechanism for putting the organism into correspondence with the external environment and, in higher animals, for coordinating the reacting apparatus itself (internal environment) may be said to give the key to its evolutionary history. These two factors have given direction to the differentiation of the nervous system into somatic and visceral systems respectively and the further subdivision of each of these.

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[1] This study was awarded the Cartwright Prize for 1905 by the Alumni Association of the College of Physicians and Surgeons, Columbia University, New York. It is published simultaneously in the *Journal of Comparative Neurology and Psychology* and the *Bulletin of the Scientific Laboratories of Denison University*, pages 375 to 456 of volume XV of the *Journal* being severally identical with pages 35 to 116 of volume XIII of the *Bulletin*.

The labors of the students of nerve components have given us for the peripheral nervous system a paradigm or schema which seems to hold for all vertebrates, though with infinite variation in its details ; and it now remains to correlate these peripheral components with the central conduction paths so as to give a detailed knowledge of the whole course of each reflex pathway.

In attacking this general problem there are obviously two general lines of procedure open to us :—(1) beginning with the simplest brains we may work out exhaustively for each critical species in the phylogenetic series the conduction paths as completely as possible by monographic treatment of types and thus in the end approximate to a reconstruction of the phyletic history of the nervous system. (2) Or we may take each sensori-motor reflex system as the unit and trace its phylogeny through the series of types. This second method has the obvious advantage that one can start with the system in question in some type where it attains maximum development and, having arrived at a thorough knowledge of its anatomy and physiology here, it will be easier to read this schema backwards to the more primitive animals, as well as forwards in its further evolutionary modifications. It is hardly necessary to call attention to the fact that the human nervous system is the least favorable starting point for this sort of a research except for the neo-pallium and its appendages.

Each method has its advantages. The monographic treatment of type brains is really far more difficult, even in the lowest vertebrates, because of the difficulty in interpreting such simple undifferentiated pictures and analyzing a complex where there are few salient features. But nature has effected the analysis for us in some of the more specialized types by the hypertrophy of isolated systems ; and if, as sometimes happens, the other functional systems are in a primitive or reduced condition, we have a favorable point of approach for a monographic study of the exaggerated functional system (cf. JUDSON HERRICK, '03).

The purpose of this study is to make such a detailed analysis of a single functional system of neurones—the gustatory system—in types where it reaches its maximum development and is obscured as little as possible by a high development of other systems. These conditions are fulfilled perfectly in the cyprinoid and siluroid fishes, whose brains are uncomplicated by any pathways leading to or from the cortex of the fore-brain and are in the main merely reflex mechanisms, but whose peripheral gustatory pathways are more highly developed than in any other vertebrates.

SECTION II. THE PERIPHERAL GUSTATORY SYSTEM IN FISHES.

As is well known, taste buds occur freely scattered over the mucous lining of the mouth and gills of nearly all fishes from the lips to the oesophagus. These are innervated by the VII, IX, and X cranial nerves. Similar taste buds, commonly called terminal buds, occur in the outer skin of some fishes and these also have been recently shown to be gustatory in function (JUDSON HERRICK, '04). They are, in all cases where the innervation is known, supplied by the facial nerve. All taste buds in the pharynx and back part of the mouth, then, are supplied from the vagus and glossopharyngeus, those in the front part of the mouth, lips and outer skin from a root of the facialis which apparently corresponds with the portio intermedia of human anatomy.

Associated with each of these roots are unspecialized visceral sensory fibers ending by free arborizations in the mucous membrane of the mouth cavity, these being very numerous in the region of the lower vagal roots and diminishing cephalad. The central connections of these two elements have not as yet been clearly differentiated, and both are provisionally designated the "communis system" of nerves by students of nerve components. With the unspecialized fibers we are not here concerned. The specialized communis fibers related with taste buds, either within or outside the mouth, and the ganglion cells from which they are derived will be termed the *peripheral gustatory system of neurones.*

The peripheral gustatory system has recently been worked up both anatomically and physiologically in a number of fishes, most thoroughly in the siluroids, or cat fishes (JUDSON HERRICK, '01 and '04). From the paper last cited we copy the accompanying figure (Fig. 1), which gives the peripheral distribution of the cutaneous branches of the communis root of the facial nerve to supply the taste buds in the outer skin, in the horned pout, Ameiurus.

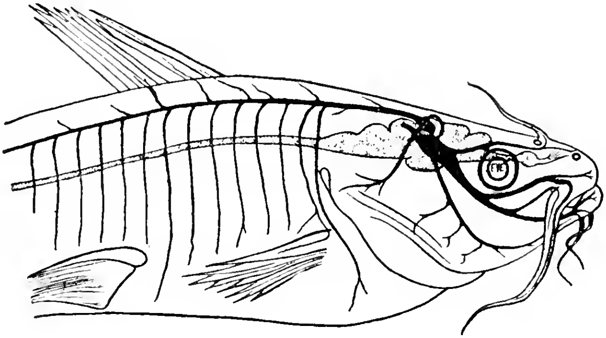

Fig. 1. A projection of the cutaneous branches of the communis root of the right facial nerve in *Ameiurus melas*, Jordan and Cope. Natural size.

The branches of this nerve which supply taste buds within the mouth are not drawn. All of the branches shown are gustatory in function. From the *Bulletin of the U. S. Fish Commission* for 1902 (JUDSON HERRICK, '04).

The general form of these buds of Ameiurus and their relations to the skin are shown in Figure 2. Practically all parts of the skin in these fishes are provided with taste buds supplied by this root, these same areas receiving also general cutaneous nerves for tactile sensation from other nerve roots, and the barblets being especially richly supplied with both sorts of nerve endings.

It has been determined by an experimental study of a series of both fresh water and marine fishes (JUDSON HERRICK, '04) that the cutaneous communis nerves are gustatory in function and that this function is absent from the skin in species where these nerves and their sense organs are not developed. When edible substances or sapid solutions were brought in contact with these cutaneous sense organs the fishes would react by the appropriate movements to approach and seize the food and in the case of the horned pout, Ameiurus, it was found possible to differentiate a gustatory reaction from a tactile reaction and to prove that both senses possess a "local sign;" i. e., both the tactile and the gustatory reaction can be localized in space.

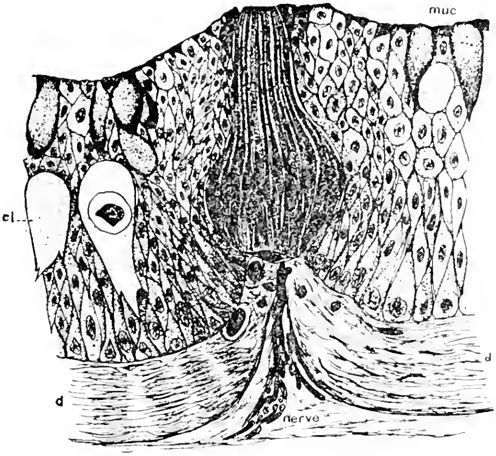

Fig. 2. Section through the skin of the top of the head of *Amiurus melas*, showing a terminal bud. From the *Journal of Comparative Neurology* (JUDSON HERRICK, '01).

At *d* is the dermis which is raised into a low papilla under the sense organ and whose center is pierced by the nerve for the organ; *cl.*, clavate cells of LEYDIG; *muc.*, mucus cells of the epidermis.

The peripheral pathways for these motor responses are now well known and the problem of the present research may be thus stated: Given the terminal relations of the peripheral gustatory neurones and the peripheral motor neurones involved in the known gustatory reflex movements of these fishes, what are the central connections between them?

Experiment has shown that the taste buds in the outer skin function in substantially the same way as those within the mouth, though there are certain obvious differences, particularly the fact that the stimulus if applied to the cutaneous taste buds usually calls forth a movement of the whole body toward the food object, while this is unnecessary in the case of a gustatory stimulus received within the mouth. This is the probable reason for the differentiation of a special center in the medulla oblongata for the reception of the facial root of the communis system, the lobus facialis, or "tuberculum impar," in those species which possess large numbers of terminal buds in the outer skin.

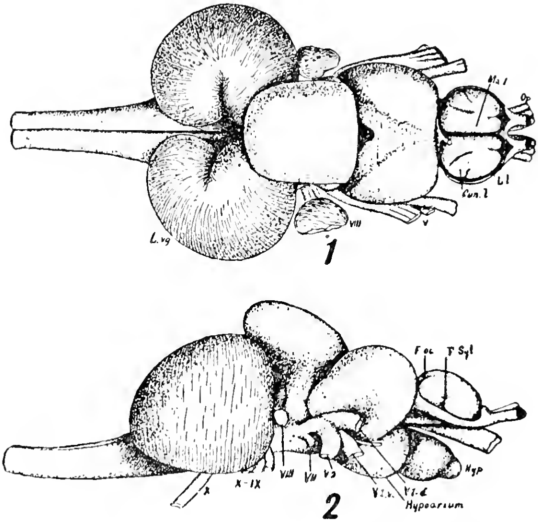

Fig. 3. Two views of the brain of the buffalo fish, *Carpiodes velifer* (Raf.), (1) from above, (2) from the right side. × 2. After C. L. HERRICK.

The vagal lobes (*L. vg.*) are relatively larger than in the carp and, with the overhanging cerebellum, completely conceal the facial lobe. In the lower figure the branches of the trigemino-facial root complex are marked *V1.d.*, *V1.v.*, *V2*, *VII*, and the root of the auditory nerve *VIII*. Between the latter and the caudal tip of the optic lobe is a well-defined protuberance ventrally of the cerebellum. This is the lateral portion of the superior secondary gustatory nucleus (*Rindenknoten*, MAYSER). Caudad of this, immediately dorsally of the VIII root, is the small lobus lineae lateralis (JOHNSTON) from which the tuberculum acusticum and cerebellar crest extend caudad beneath the vagal lobe. In the upper figure, the median shaded part of the roof of the optocoele is membranous, the optic lobes being widely divaricated by the enormous valvula cerebelli. In both figures the membranous roof of the fore-brain is dissected away to show the lobules of the basal ganglia, and the olfactory bulbs are cut away.

With the exception just noted, it is probably safe to assume that there will be found broad lines of similarity between both the peripheral and the central gustatory paths in all vertebrate types and that fishes like the carp with enormous hypertrophy of the gustatory roots of the VII, IX and X nerves may safely be used as guides to point the way for further researches upon the gustatory paths of higher vertebrates where the system is less easily analyzed. Such being the case, our problem assumes a measure of importance when we remember that the central gustatory pathway is at present almost totally unknown in all vertebrates, including man, and that even the peripheral pathway is still in dispute among students of human anatomy.

It has been already pointed out (JUDSON HERRICK, '04) that the siluroids (cat fishes and horned pouts) and the larger cyprinoids (carps, suckers, etc.) present a striking similarity to each other and contrast to other teleosts in both the peripheral and the central nervous systems, and that these features center about the gustatory pathways. In teleosts generally the gustatory pathway from the lining of the mouth in the branchial region, entering the brain by the communis roots of the IX and X nerves, and the gustatory pathway from the anterior part of the mouth and from the outer skin, entering by the communis VII root, terminate together in a single cerebral enlargement, the lobus vagi. But in these two groups of fishes we have a second tuberosity, as mentioned above, developed for the communis root of the facialis to provide for the unusually large number of taste buds in the outer skin supplied by this nerve.

In the cyprinoids, particularly the carp-like forms, both of these lobes are enlarged, correlated with a high development of the taste buds in each of the corresponding peripheral regions, but particularly in the vagal region to supply the remarkable collection of taste buds on the palatal organ. In the siluroids, on the other hand, there is no hypertrophy of the gustatory organs in the branchial region and the vagal lobes, accordingly, are essentially similar to those of other teleosts. But the highly developed cutaneous gustatory organs innervated by the facialis have called forth an enlargement of the facial lobe greater than that of cyprinoids. Since in the siluroids all of the taste buds of the outer skin are supplied by the communis root of the facialis (JUDSON HERRICK, '01) and since the palatal and other branches of the communis VII root which supply taste buds within the mouth are not enlarged, as compared with other fishes, it is clear that the enormous communis VII root and the lobus facialis in which it terminates are related mainly to cutaneous taste buds in these fishes.

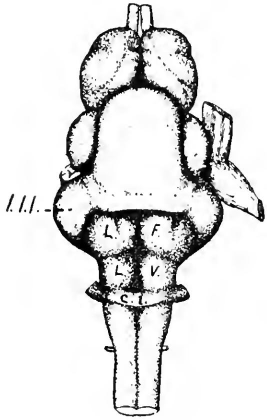

Fig. 4. Dorsal view of the brain of the yellow cat fish, *Leptops olivaris* (Raf.), × 2.

The olfactory bulbs are cut off; also the membranous roof of the fourth ventricle, exposing the facial lobes (*L. F.*) and vagal lobes (*L. V.*). This ventricle is bounded behind by a transverse ridge containing the commissura infima HALLERI (*c. i.*) and the commissural nucleus of CAJAL. The tuberosity laterally of the cerebellum and facial lobe is the lobus lineae lateralis (*l. l. l.*), which is greatly enlarged and entirely conceals the superior secondary gustatory nucleus.

SECTION III. THE CENTRAL GUSTATORY SYSTEM OF CYPRINOID FISHES.

We shall now proceed with a description of the gustatory pathways in a selected series of teleosts, beginning with the larger cyprinoids where it attains its maximum development. The results here obtained will be controlled by an equally careful examination of the brains of siluroid fishes (particularly Ameiurus), whose gustatory centers differ greatly in detail from those of the carp-like forms. These minor differences will serve to bring out more clearly the points of fundamental resemblance, which are very striking.

The end-station of the gustatory neurones of the first order (peripheral neurones) is the nucleus of origin for the neurones of the second order, giving rise to secondary gustatory tracts, and these in turn to tertiary tracts. The nomenclature of these tracts and centers offers almost insuperable difficulties and some new terms will have to be introduced and old ones more narrowly defined. A summary of the nomenclature here employed for the gustatory system of these fishes is given in tabular form in Section V, to which frequent reference should be made.

1. Primary Gustatory Centers.

The general topography for the vagal and facial lobes of cyprinoid fishes has often been described, and the reader is referred for the details to the classic paper of MAYSER ('82), and also to the figures of BELA HALLER ('96), whose descriptions, however, I do not in all things confirm. I have found little in the extensive work of this author ('98) on the brains of Salmo and Scyllium which sheds further light on the secondary connections of the vagal lobe. However, I do not profess to have mastered the contents of this unsystematic and obscure paper, though I have dilligently studied it. Nor is there anything of importance from our present point of view in the recent dissertation on the vagal lobes of cyprinoids by GROTH ('00), whose purpose was merely to test the accuracy of some of HALLER'S observations on nerve anastomoses in these fishes.

The vagal lobe of the cyprinoids, as compared with that of the siluroids and the teleosts generally, represents an enlargement of both the sensory and the motor centers of the vagus and glossopharyngeus. This enlargement is correlated with the development of the curious palatal organ in the mouth of these fishes, the sensory fibers being derived from the taste buds which cover the surface of this organ and the motor fibers going out chiefly to the small muscles which permeate its interior. The "motor layer" of the vagal lobe, from which these motor fibers are derived is a dorsal extension of the nucleus ambiguus. The latter nucleus has the typical position and relations, supplying the branchial musculature, and is not commonly regarded as a part of the vagal lobe.

We shall describe, so far as the material at command permits, the conduction pathways in the vagal lobe of the larger cyprinoids on the basis of sections of adult and young brains cut in various planes and stained by DELAFIELD'S haematoxylin and the methods of WEIGERT-PAL and GOLGI. The illustrations given throughout the remainder of this paper are all camera drawings of single sections, except Fig. 20, which is a composite, and the schemata, Figs. 38, 39 and 40.

First a few words by way of general orientation. The vagal and facial lobes are dorsal structures in the oblongata, but they do *not* represent, as commonly taught, the morphological continuation of the dorsal horns of the spinal cord. These are represented in the spinal V tract and its associated substantia gelatinosa Rolandi, their ventro-lateral position in the vagus region of these brains being due to crowding by the more mesially placed gustatory centers. The latter centers, therefore, if morphologically related to anything in the spinal cord, must represent spinal structures lying dorsally of the canalis centralis and beneath the floor of the dorsal fissure. In the oblongata this fissure opens out and its floor becomes greatly extended to form the membranous roof plate (HIS), or velum medullare posterior, *beneath* which the lobes in question are developed (cf. JUDSON HERRICK, '99, p. 213).

Figure 5, taken midway of the vagal and facial lobes of the carp, illustrates how these structures are superposed upon the great longitudinal conduction paths which constitute the chief landmarks of morphological relationship. The spinal V tract, whose substantia gelatinosa at this level is reduced to a mere vestige, lies ventrally of both the sensory and motor vagus roots. Crowded into the space ordinarily occupied by the substantia gelatinosa Rolandi are the great longitudinal secondary gustatory paths, ascending and descending. Mesially of these is the substantia reticularis, shown by CAJAL and others to be the continuation of the ventro-lateral funicle of the spinal cord and to be composed of short paths, mostly sensory fibers of the

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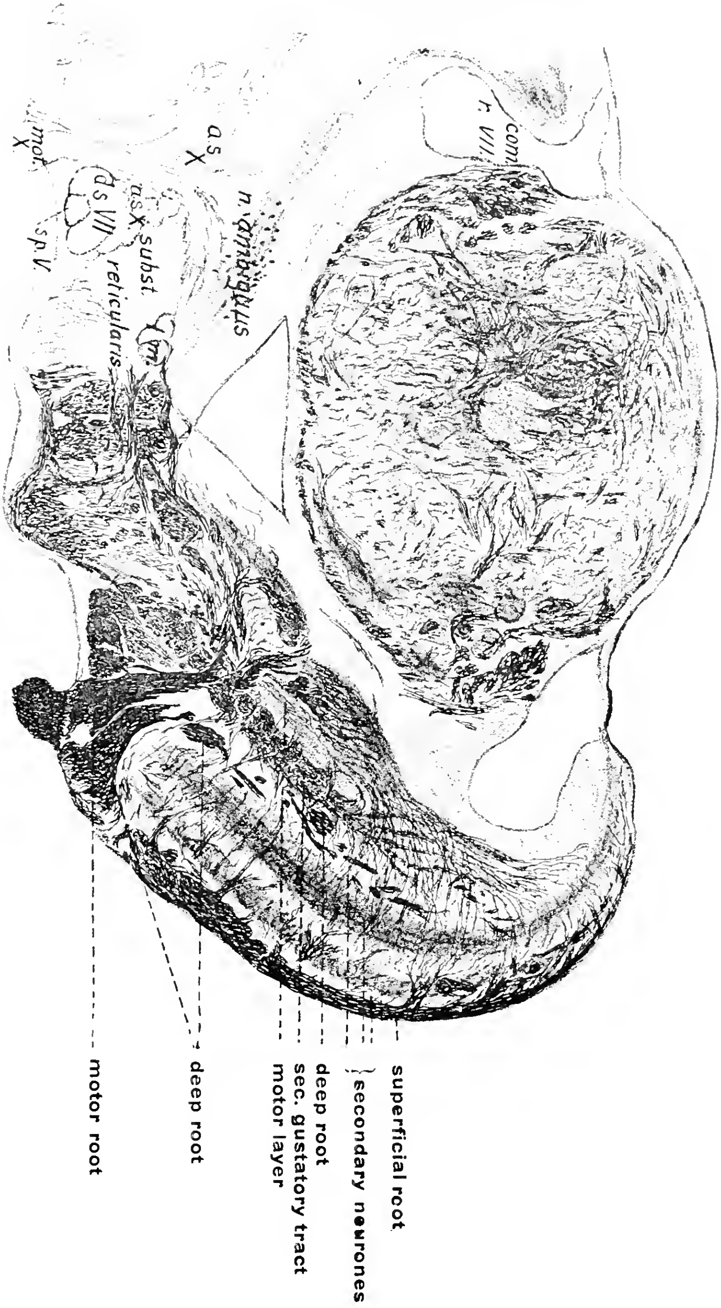
Fig. 5. A transverse section taken through the middle of the vagal and facial lobes of an adult carp stained by the method of WEIGERT-PAL. × 16.

The layers of the facial lobes and the vagus roots are designated at the right. *a. s. X.*, ascending secondary gustatory tract from the vagal lobe; *com. r. VII*, communis (gustatory) root of the facialis entering the facial lobe; *d. s. VII*, descending secondary gustatory tract from the facial lobe; *lm.*, lemniscus (laterales Längsbündel, MAYSER); *sp. V.* spinal root of the trigeminus.


mot. X
a.s. X
com
r. VII
n. ambiguus
d.s. VII
a.s. X
subst. reticularis
sp. V
f.m.
motor root
deep root
motor layer
sec. gustatory tract
deep root
secondary neurones
superficial root

third order designed to distribute sensory excitations over a large field of motor nuclei of the oblongata. Close to the raphé in the median line is the fasciculus longitudinalis medialis, likewise composed largely of short paths and chiefly motor. Between this fasciculus and the substantia reticularis, there is ventrally the continuation of the ventral funicle of the spinal cord and dorsally the lemniscus (funiculus lateralis, FRITSCH; laterales Längsbündel, STIEDA and MAYSER).

The *lemniscus* is very complex. It clearly is composed in the main of crossed ascending fibers from the primary sensory centers of the spinal cord and oblongata to the mid-brain. These fibers correspond closely with the lemniscus lateralis or lateral fillet of mammals. The lemniscus medialis, or direct pathway to the cerebral cortex, as found in mammals, is of course not present here and this whole ascending path I shall term simply lemniscus. It probably receives fibers from the whole length of the spinal cord with a large accession of similar fibers from the funicular nuclei and enormous numbers of fibers from the tuberculum acusticum. It receives no appreciable number of fibers from the vagal lobes or other visceral sensory centers and therefore may be considered a somatic sensory secondary tract. It terminates in the mid-brain beneath the tectum in the protuberance into the optocoele which is so characteristic of the teleosts and is termed the torus semicircularis (nucleus lateralis mesencephali, EDINGER). This body, in fact, seems to be primarily the end-nucleus of this tract. Whether this bundle also contains descending fibers I do not know, but am sure that if present they are relatively few in teleosts. Such descending fibers would of course have to be excluded from the designation lemniscus.[1]

Some of the smaller cyprinoids (e. g., Notropis) exhibit but little enlargement of the vagal lobes. In the gold fish (*Carassius auratus*) the vagal lobe is greatly enlarged, but the

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[1] The reader will note that this tract is designated *lemniscus* on account of its partial homology with the tract of that name in the mammals, and that it has nothing to do with the so-called lemniscus of MAYSER and others, or tractus tecto-bulbaris et spinalis.

sensory roots of the IX and X nerves penetrate at once to its deeper layers and then turn outward to end near the surface much as will be described in Ameiurus. In Cycleptus the lobe is larger and the sensory roots penetrate but little before they spread out to end in a superficial layer of large cells which stain very pale in haematoxylin. And in the carp (Fig. 5), whose vagal lobes are still more enlarged, the greater part of the sensory roots do not penetrate, but spread out over the whole outer surface of the lobe (constituting MAYSER's first layer), thence to pass in separate strands directly into a thick layer exhibiting alternate bands of crowded small cells and dense neuropil (MAYSER's second layer).

This will be termed the *layer of secondary neurones.* Sections stained by DELAFIELD's haematoxylin show within it seven concentric bands of cells and neuropil which are more or less sharply distinguishable, of which the two outer are of greatest importance. The first is a thin layer of crowded cells of relatively large size which take up a very pale stain—the chief secondary gustatory neurones. Immediately internal to and among these cells are smaller very closely crowded cells whose nuclei take up a very intense stain. These will be termed the smaller gustatory neurones. The other bands contain chiefly minute cells with deeply staining nuclei and occasionally larger, irregularly shaped cells among them, while the inner border of this layer is a band of neuropil containing a few large cells which take a very pale stain. Sections stained by the method of PAL show sensory root fibers entering this band at its inner border. These root fibers will be termed the deep communis root of the vagus, as distinguished from the larger superficial root (Fig. 5). The fibers of the deep root turn outward to end in the second layer along with those of the superficial root.

This layer of secondary neurones is very wide in Cyprinus and is traversed radially by unmedullated and delicately medullated fibers for the deeper layers of the vagal lobe. The large pale cells forming its outer boundary are the most important and characteristic cells of the lobe, for they give rise to the great secondary gustatory tracts which leave the lobe for distant centers. The narrow layer of smaller cells adjacent to these may share this function, but their neurites are mostly shorter. The small cells of the other bands of this layer have short neurites which terminate for the most part within the lobe and are therefore called intrinsic secondary gustatory neurones.

Immediately internal to the seventh band of the layer of secondary neurones is MAYSER's third layer, the *layer of secondary gustatory fibers*, which pass ventrally to constitute the "secondary vagus bundle" of MAYSER. These fibers are of small caliber with thin sheaths which take a very pale stain by the WEIGERT method.

Internally from the secondary gustatory tract is the *motor layer* (MAYSER's fourth), containing large cells which give rise to motor root fibers of the IX and X nerves. The thick ependyma containing large blood vessels is MAYSER's fifth layer. Some of its supporting elements are shown in Fig. 6.

The endings of the peripheral neurones which compose the superficial layer of root fibers of the vagal lobe of the cyprinoids are richly impregnated in many of my GOLGI preparations. Those of the deeper layers impregnate with much more difficulty. They are seen in Fig. 6. The superficial fibers end by extensive terminal arborizations which ramify widely among the dendrites of the chief secondary gustatory neurones, forming a very dense neuropil in the more superficial parts of the layer of secondary neurones, though some penetrate through the whole thickness of this layer. These endings are shown in Figs. 6 and 15 and somewhat imperfectly in Fig. 8. Fig. 6 shows that the slender strands of root fibers pass from the superficial to the deep layers of root fibers throughout the whole extent of the vagal lobe.

The most caudal fibers of the vagus constitute the descending or spinal root of this nerve, which passes a very short distance caudad to terminate in the grey centers associated with the commissura infima HALLERI and funicular nuclei as CAJAL ('96, p. 46) describes the endings of the fasciculus solitarius in the nucleus commissurale of the mouse.

The general arrangement of the *chief secondary neurones* may be understood by reference to Fig. 7, drawn from a sagittal section of a young carp, where these cells are richly impreg-

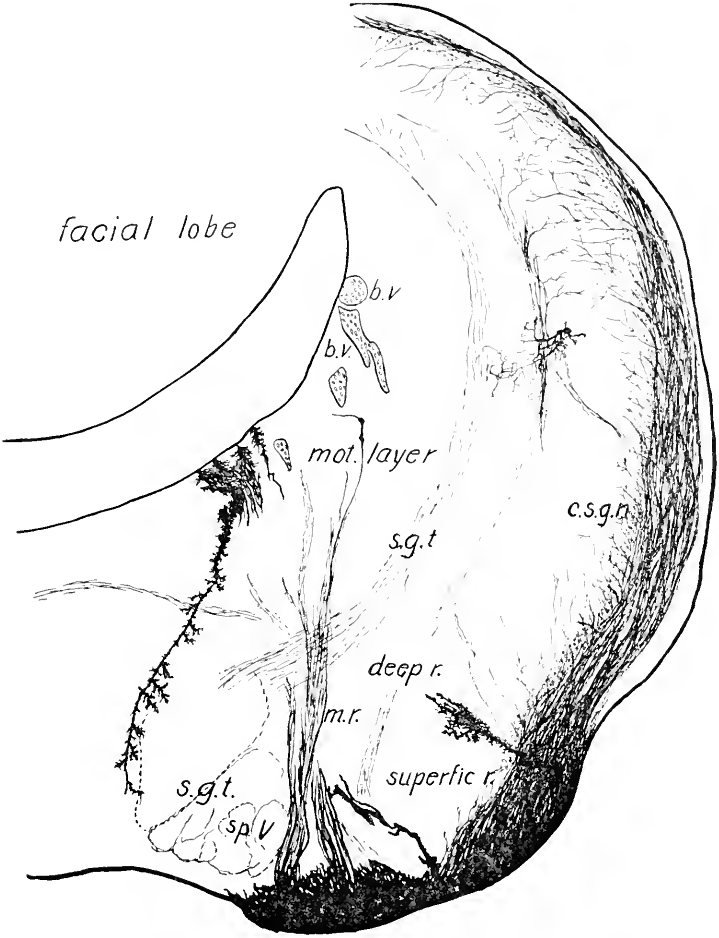

Fig. 6. Transection through the vagal lobe of *Catastomus commersoni.* GOLGI method. × 40.

The section illustrates the endings of the superficial and deep layers of root fibers of the vagus and the position of the chief secondary gustatory neurones (*c.s.g.n.*). An intrinsic neurone of type II is shown with dendrites in relation with the termini of the deep root. Two neuroglia cells of the superficial series are drawn and several of the deeper series (some of the latter having been drawn from an adjacent section). *b.v.*, blood vessel; *m.r.*, motor root of the vagus; *s.g.t.*, secondary gustatory tract; *sp. V*, spinal V tract.

nated. The layer of root fibers is not impregnated in this preparation, but its relations are suggested in Fig. 8 and more clearly in Fig. 6. In Fig. 8 root fibers are stained in the ventral part of the vagal lobe, but only secondary neurones in its dorsal part. In preparations where both are impregnated together the peripheral layer of secondary neurones presents an indescribably intricate complex of interlacing fibers. Fig. 9 shows a single one of the chief secondary neurones of Fig. 8 drawn separately on a larger scale.

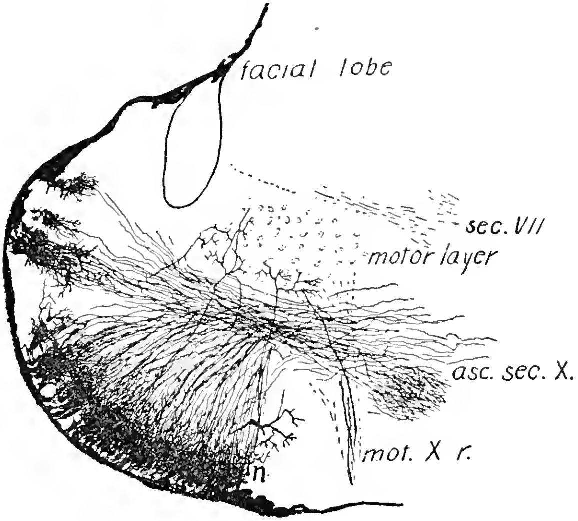

Fig 7. Section through the vagal lobe of a young carp, 5 cm. long. Golgi method. × 40.

The section is approximately sagittal, but strongly inclined so that, while the caudal end (at the left of the figure) is near the median line, forward it passes toward the right. It includes, therefore, the motor nucleus of the right vagal lobe and the right side of the facial lobe, only the extreme caudo-ventral border of which is indicated. The preparation gives a typical view of the chief secondary gustatory neurones of the vagal lobe. One of the smaller secondary neurones (*n*) is shown at the extreme ventral (lower) side of the vagal lobe (cf. Fig. 11). A few scattered neurones of the deeper portions of the layer of secondary neurones are imperfectly impregnated. A few thick fibers are seen to pass from the layer of secondary neurones into the motor layer to arborize widely among its cells. Their origin could not be determined, but is probably from some of the deeper cells of the layer of secondary neurones. *Asc. sec. X.*, ascending secondary gustatory tract; *mot. X r.*, motor root of the vagus.

These neurones are densely crowded in radial arrangement over the entire periphery of the vagal lobe and are of very peculiar form. They are unipolar with irregularly elongated cell body and dendrite springing from the inner end. The peripheral end of the cell body is drawn out to a point which seems usually to reach the external limiting membrane of the vagal lobe. In these young fishes the external layer of root fibers is relatively thin. In older carp this layer is much thicker and there is no well defined external limiting membrane. The bushy dendrite breaks up at once into a very dense mass of

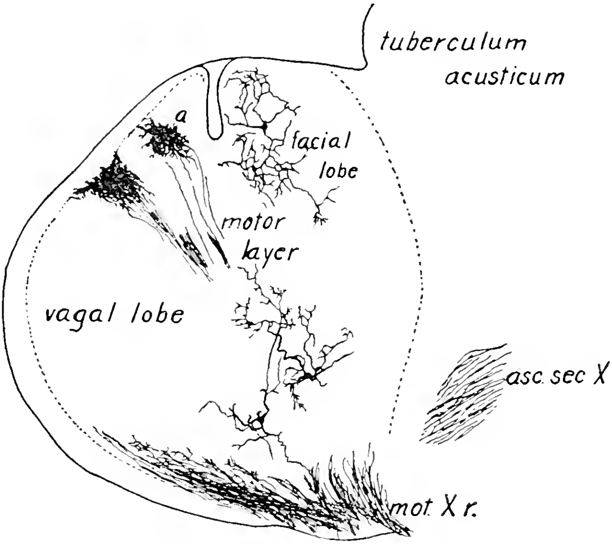

Fig. 8. Sagittal section through the vagal lobe of a young carp. GOLGI method. Drawn from the same series as Fig. 7, but farther toward the right side, so as to cut tangentially the extreme right borders of the vagal and facial lobes. × 40.

The figure illustrates a few gustatory neurones of the vagal lobe and (imperfectly) endings of the gustatory root fibers, also two neurones of the deeper portion of the layer of secondary neurones whose processes reach the motor layer (cf. Fig. 7). These cells appear to be of the same type as the large cell lying in the layer of secondary tracts in Fig. 13. The neurone in the facial lobe is sketched in from the section lying next mesially, It occupies the area intermedia of the facial lobe and spreads out over the whole of the lateral aspect of the latter, its neurite not being shown. It is evidently of the same type as the one figured in Fig 18 at *a*.

exceedingly fine branchlets among which the arborizations of the root fibers end. From one or more of the terminal branches of this dendrite a very delicate neurite arises and goes by the shortest path directly into the layer of secondary tracts by which it leaves the vagal lobe to enter the longitudinal secondary gustatory tracts of the oblongata, meanwhile taking up a very delicate medullary sheath. In its passage through the layer of secondary tracts it sometimes gives collaterals into the motor layer of the vagal lobe (Fig. 10).

Fig. 9. A chief secondary gustatory neurone from the vagal lobe of the carp—the neurone designated *a* on Fig. 8. × 250. The black mass at the left of the neurone is precipitate deposited in the external limitating membrane of the vagal lobe.

Upon casual examination these chief neurones might suggest the appearance of neuroglia elements. The latter, however, are of totally different form (Fig. 6) and there is no opportunity for confusion. The gustatory neurones have exceedingly fine and densely branched dendrites, while the branches of the neuroglia are thicker and of the peculiar mossy or pulverulent appearance so characteristic of the supporting elements. The neuroglia, moreover, as a rule impregnates with a dark brown instead of black color.

Besides the chief gustatory neurones just described, there are closely associated with them just internally the smaller gustatory neurones shown in Figs. 11 and 12. These have the same general form and arrangement, but are much simpler. The cell body is smaller and usually rounded and the dendrite less profusely branched. The slender neurite arises from the tip of the dendrite and enters the layer of secondary tracts.

Some of these fibers or their collaterals enter directly the motor layer and there arborize. Others end by simple arborizations in the substantia reticularis and others turn caudad in the descending secondary communis tract. Whether any go cephalad

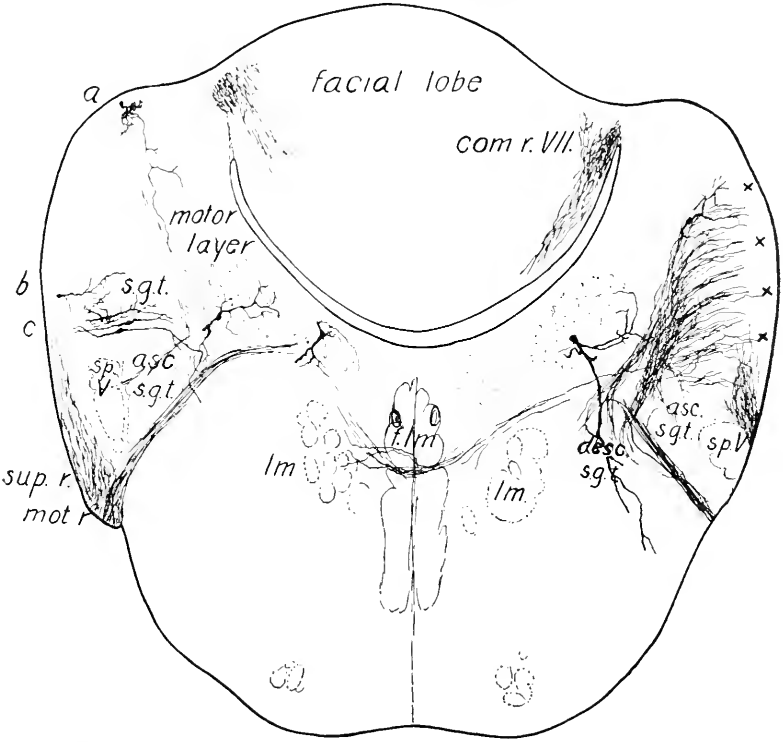

Fig. 10. Transverse section through the vagal and facial lobes of the spotted sucker, *Minytrema melanops* (Raf.) from a fish 8 cm. long. GOLGI method. × 40.

On the left at *a* a single chief secondary gustatory neurone is impregnated whose neurite sends collaterals into the dorsal part of the motor layer of the vagal lobe. On the right the area marked by the crosses is filled with a rich impregnation of similar cells which are not sketched in. At *b* is a single secondary neurone of the type shown in Fig. 12, and at *c* imperfect impregnations of deeper secondary neurones of the intrinsic type. On the right one cell of the motor layer is impregnated whose dendrites reach secondary gustatory tracts partly within the vagal lobe and partly in the substantia reticularis.

asc.s.g.t., ascending gustatory tract; *com.r.VII*, communis (gustatory) root of the facialis; *desc.s.g.t.*, descending secondary gustatory tract, entering substantia reticularis; *f.l.m.*, fasciculus longitudinalis medialis; *lm.*, lemniscus; *mot.r.*, motor root of the vagus; *s.g.t.*, secondary gustatory tract from the vagal lobe; *sp. V*, spinal V tract; *sup.r.*, superficial gustatory root of the vagus.

in the ascending secondary tract I have not determined.

These neurones clearly are of the same type as the chief gustatory neurones, but their neurites have a shorter course as a rule. Cells of this type in my preparations are impregnated chiefly in the more superficial parts of the layer of secondary neurones; but sections stained with haematoxylin show very numerous nuclei of the same appearance throughout this layer and occasional Golgi impregnations show that they are in fact scattered less freely throughout the thickness of the layer.

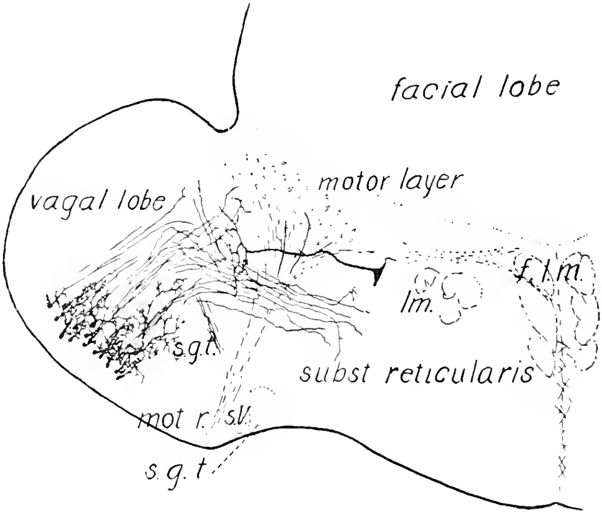

Fig. 11. Transverse section through the vagal and facial lobes of a young carp 5 cm. long. The section is obliquely inclined with the left side a little farther caudad than the right and the dorsal side much farther cephalad than the ventral. Golgi method. × 40.

The section passes through the extreme cephalic end of the vagal lobe. None of the chief gustatory neurones are impregnated in this preparation, the superficial cells drawn being of the smaller variety. Among them are two intrinsic neurones of the vagal lobe. There is impregnated also a single large neurone in the dorsal part of the substantia reticularis one of whose dendrites reaches the layer of secondary gustatory tracts and whose neurite passes toward the ventral commissure.

f.l.m., fasciculus longitudinalis medialis; *lm.*, lemniscus; *mot.r.*, motor root of the vagus; *s.g.t.*, secondary gustatory tract; *s. V*, spinal V tract.

There are frequent impregnations, usually very imperfect, of larger cells of different kinds in the deeper parts of this layer, as shown in Figs. 7, 8, 10 and 13; but I have not been able to trace the connections of all these types of cells. There are many indications that they reach the motor layer of the vagal lobe (Fig. 14) and substantia reticularis of the oblongata immediately below the vagal lobe. In most of these cases the dendrites spread irregularly among the other cells of this layer and the processes which penetrate the motor layer do not differ essentially from the others. There is one type of cells, however, among these whose dendrites extend tangentially over a very wide area (Fig. 16, *b* and Fig. 18, *b*). In one case (Fig. 13) a neurite from a cell was seen to enter the secondary gustatory tract; but its further course is unknown. Fig. 13 also shows one of the smallest of these intrinsic cells whose thorny dendrites are sharply contrasted to the very delicate much branched neurite (neuropodium), giving the cell the characteristic form of GOLGI's type II.

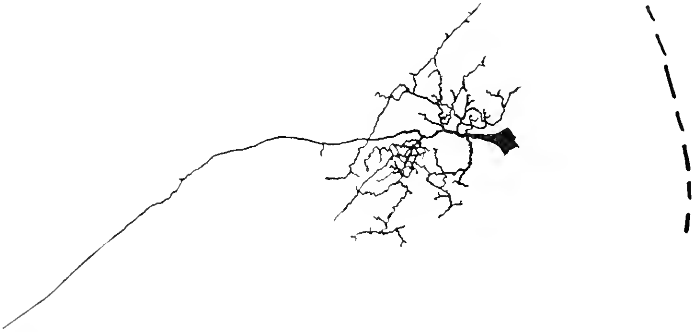

Fig. 12. A single neurone of the smaller gustatory type from the right vagal lobe of the carp. Drawn from the same series as Fig. 11, two sections farther caudad. GOLGI method. × 250.

The main axis of the dendrite is directly prolonged to form the neurite. Terminal arborizations of the gustatory root fibers occur among these dendrites. The broken line represents the outer border of the vagal lobe.

This is apparently the most frequent type of these intrinsic cells, though the neurite is rarely impregnated in recognizable form. Fig. 6 illustrates a different form of this type of cell, with cell body and dendrites among the endings of the deep layer of root fibers and neuropodium between this layer and the layer of secondary tracts.

Stannius ('49, p. 82) has shown that mechanical stimulation of the vagal lobe of the carp produces movements of the intrinsic muscles of the palatal organ. Since the nucleus ambiguus of the cyprinoids does not differ from that of other teleosts, in which it is known to innervate the branchial musculature, it is extremely probable that the cells of the motor layer of the vagal lobe give rise to the nerve fibers for these intrinsic muscles, for these two structures (the palatal organ and motor layer of the vagal lobe) are always developed proportionately with each other.

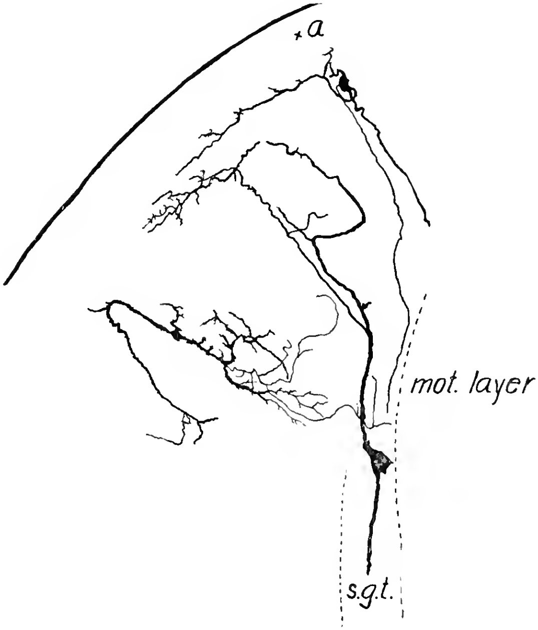

Fig. 13. Portion of the vagal lobe from a transverse section of the brain of *Minytrema melanops* (Raf.) 8 cm. long. Golgi method. × 187.

This is drawn from the same series as Fig. 10, the sections being adjacent. For ease of orientation the position of the neurone marked *a* on Fig. 10 is designated *a* in this sketch. The large neurone at the bottom of the figure in the layer of secondary gustatory tracts sends one of its two chief dendrites outward into relation with the arborizations of the peripheral gustatory neurones, the other is cut off. The neurite is not shown. The intrinsic neurone to the left of it is a characteristic type II cell. The intrinsic neurone at the top of the figure is drawn in from the adjacent section. Its neurite enters the secondary gustatory tract (*s.g.t.*)

Weigert sections show very clearly that fibers of the motor roots of the vagus and glossopharyngeus arise not only from the nucleus ambiguus but also from the motor layer of the vagal lobe, as has been well known since Mayser.

My Golgi preparations very rarely show good impregnations either of the cells of the motor layer or of the nucleus ambiguus. The latter have the form and arrangement which have been often figured, the main dendrites spreading out in the substantia reticularis and reaching the extreme ventro-lateral border of the oblongata. Other smaller dendrites spread out within the nucleus itself and the neurite usually springs from the base of the main dendrite. The dendrites of the cells of the motor layer in some cases spread out within this layer, where they come into relation with the radial fibers which enter it from the layer of secondary neurones. Others reach out into the layer of secondary tracts and into the substantia reticularis (Fig 10), in both of which places they reach collaterals from the secondary gustatory tracts.

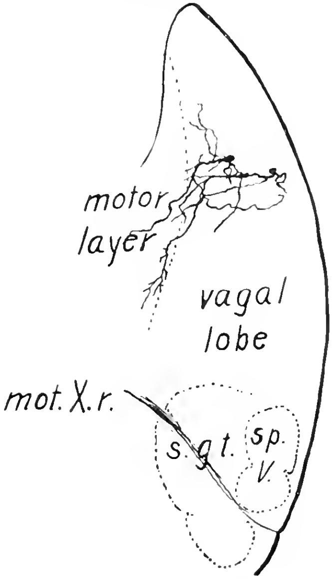

Fig. 14. Transverse section of the vagal lobe of the right side of a young carp, 5 cm. long. Golgi method. × 50.

Illustrating two intrinsic secondary neurones of the vagal lobe whose processes extend inward to reach the motor layer. *s.g.t.*, secondary gustatory tract; *sp. V*, spinal V tract.

It appears that in no case do the peripheral motor neurones come into direct relation with the peripheral gustatory neurones, but at least one intermediary element is always interposed. These elements may be the intrinsic neurones of the vagal lobe, for short reflex arcs, or the chief secondary gustatory neurones for more complex reflex connections reaching beyond the vagal region of the brain.

The substantia reticularis is clearly the chief medium of communication between the sensory and motor centers for simple reflex paths here, as in higher vertebrates. This reticular substance receives gustatory fibers both from the secondary gustatory tracts and from the intrinsic neurones of the vagal lobe. We shall see beyond that it also receives fibers from the facial lobe.

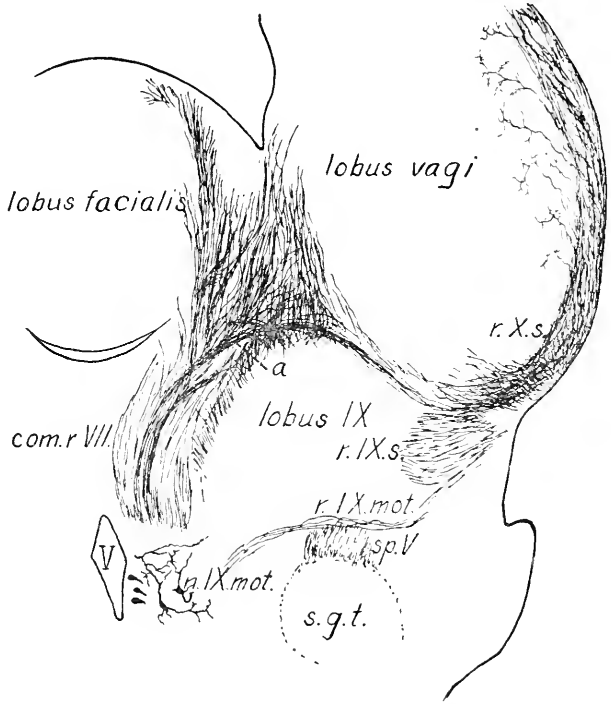

Fig. 15. Section through the right lobus glossopharyngei of a young carp 8 cm. long. Golgi method. × 40.

The section is approximately transverse, but very oblique, so that the right side and the ventral surface are much farther cephalad. It cuts the lobus IX at its widest part and shows a strand of the communis root of the facialis (*a*) arching over its dorsal side and apparently entering both this lobe and the cephalic part of the lobus vagi. Terminal arborizations of the communis root of the vagus are also shown ending in the layer of secondary neurones of the lobus vagi.

com.r. VII, communis (gustatory) root of the facialis; *n.IX.mot.*, motor nucleus of the IX nerve; *r.IX.mot.*, motor root of the IX nerve; *r.IX.s.*, sensory root of the IX nerve; *r.X.s.*, superficial gustatory vagus root; *s.g.t.*, secondary gustatory tract; *sp. V*, spinal V tract; *V*, ventricle.

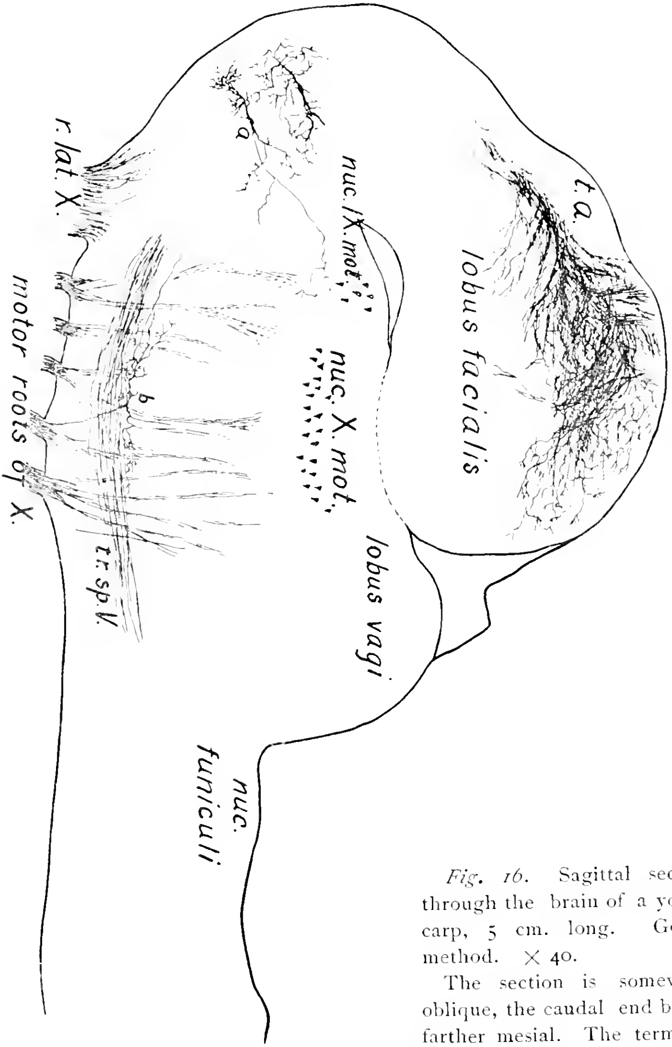

Fig. 16. Sagittal section through the brain of a young carp, 5 cm. long. GOLGI method. × 40.

The section is somewhat oblique, the caudal end being farther mesial. The terminal arborizations of the gustatory root of the facial nerve are richly impregnated. Two neurones are shown in the extreme cephalic part of the lobus IX, one of whose neurites (*a*) arborizes in the motor IX nucleus. These neurones lie in about the transverse level indicated in Fig. 17 and at the level of *r.IX.sen.* in Fig. 18. Their dendrites are reached by gustatory root fibers of the IX nerve. The neurone marked *b* is evidently of the same type as the one similarly designated in Fig. 18. *r.lat.X.*, ramus lateralis vagi; *t.a.*, caudal tip of tuberculum acusticum; *tr.sp.V.*, spinal V root.

Before proceeding with the description of the long secondary gustatory tracts from the vagal lobe we shall describe the internal structures of the glossopharyngeal and facial lobes, as the long tracts from all these centers can best be described together.

Between the vagal and the facial lobes of cyprinoids is a small tuberosity which, as pointed out by B. HALLER ('96, p. 93 and Fig. 12), receives the glossopharyngeus nerve. It may be termed the *lobus glossopharyngei.* It is very distinct in forms like the gold-fish, Carassius, whose glossopharyngeus nerves are far separated from the vagus, the sensory IX nerve entering its dorsal side and the motor IX its ventral. It appears in the carp at a level somewhat cephalad of that shown in Fig. 5 along the line of union of the vagal and facial lobes. In this type it appears to receive from behind some fibers from the vagus roots; at any rate the IX and X roots are somewhat confused in this region. In both the carp and the gold-fish it receives from in front filaments of the communis root of the facialis. These filaments are very clearly shown arching over the dorsal side of the lobus IX in an oblique GOLGI section (Fig. 15, *a*); a certain part of the facial root apparently also reaches the cephalic end of the lobus vagi. It would be interesting to learn whether these facial fibers which separate from the facial lobe to end in connection with gustatory fibers from the mouth cavity coming in by the IX and X nerves are derived from the palatine and other facial branches which also supply taste buds within the mouth.

The lobus glossopharyngei has essentially the same connections as the lobus vagi. Fig. 16 gives an impregnation of two of the intrinsic neurones of the extreme cephalic part of the lobus IX in sagittal section of the brain of a young carp. The sensory (gustatory) fibers of the IX nerve end among the dendrites of these neurones. The neurone at the extreme left does not show its neurite, but the neurite of the one marked *a* is shown completely, arborizing in the motor IX nucleus, thus completing the simplest gustatory reflex arc for the IX nerve.

The structure of the *facial lobe* (tuberculum impar, "lobus trigemini," MAYSER) of the carp is considerably simpler than that of the vagal lobes. It is in general similar in internal organization to the facial lobes of Ameiurus, though its cells are of quite different form and it differs externally in that there is a complete fusion in the middle line of the right and left lobes with no clearly defined external or internal boundary between them.

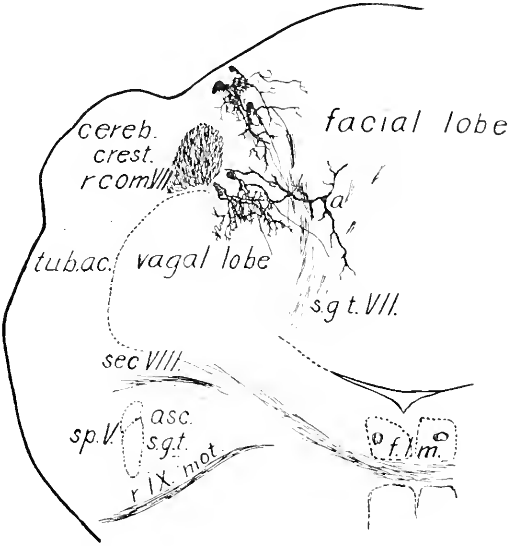

Fig. 17. Transverse section through the facial lobe of *Minytrema melanops* (Raf.). GOLGI method. × 40.

The section passes through the cephalic part of the facial lobe and includes the extreme cephalic end of the vagal lobe and the caudal end of the tuberculum acusticum. It shows five chief secondary gustatory neurones at the surface of the lobe and internally at *a* an imperfect impregnation of a cell of the intermediate zone of the same type shown in Fig. 18, *a*.

asc.s.g.t., main ascending secondary gustatory tract; *f.l.m.*, fasciculus longitudinalis medialis; *r.com.VII*, communis (gustatory) root of the facialis; *r.IX. mot.*, motor root of the glossopharyngeus; *sec.VIII*, secondary fibers from the tuberculum acusticum to ventral commissure; *s.g.t.VII*, secondary gustatory tract from the facial lobe; *sp.V*, spinal V tract; *tub.ac.*, tuberculum acusticum.

The center of the lobe is filled with very small intrinsic neurones arranged in dense clusters or rosettes of from 10 to 100 cells each. In Fig. 5 the clear spaces in the neuropil of the

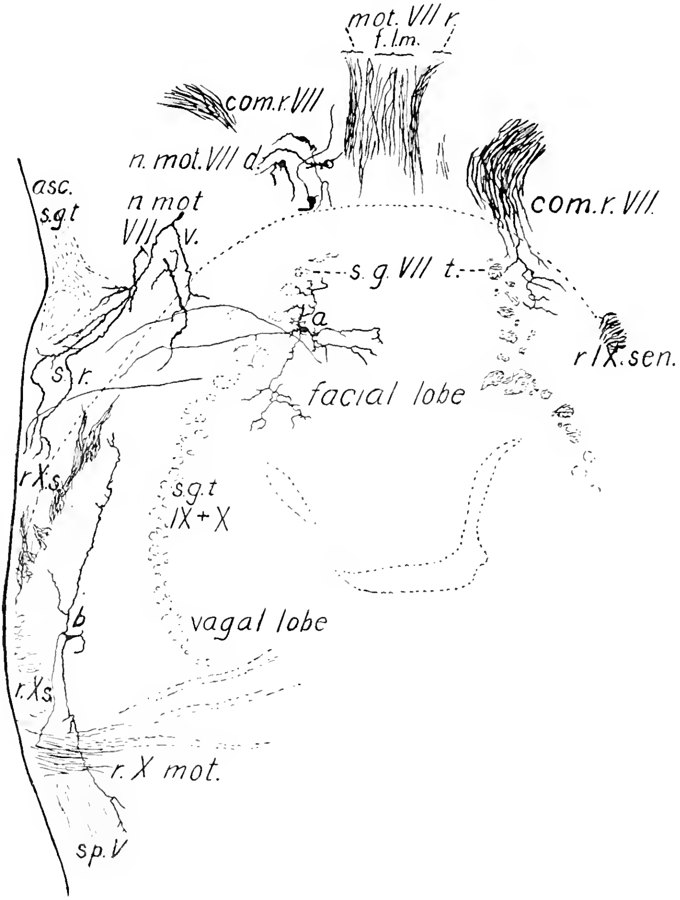

Fig. 18. Horizontal section through the base of the vagal and facial lobes of *Minytrema melanops* (Raf.). Golgi method. × 40.

The section is slightly oblique, the left side being farther ventral. It passes through the ventral part of the facial and vagal lobes, illustrating a neurone (*a*) of the intermediate zone of the facial lobe. The dendrites spread throughout the lateral part of the lobe and the neurite passes laterally to enter the substantia reticularis of the oblongata (*s.r.*), here coming into relation with dendrites of the motor VII nucleus, as shown in the figure, and with other motor nuclei. The section shows the position of the dorsal tip of the motor VII nucleus (*n.mot.VII.d.*) and the motor VII root springing from it. The motor VII dendrites which are shown ramifying in the substantia reticularis (*n.mot.VII.v.*) spring from cells of the motor VII nucleus lying ventrally and laterally of those figured and out of the plane of this section. The neurone *b* is drawn in from the section lying next ventrad in the same series.

facial lobe represent the positions of some of the larger of these rosettes. Superficially there is a layer of chief gustatory neurones of the same general form as those of the vagal lobe (Fig. 17), whose neurite springs from the tip of a dendrite and passes at once into the secondary gustatory tract. The peripheral gustatory neurones enter by the communis root of the facial nerve (= dorsal geniculate root of the trigeminus, MAYSER = portio intermedia of WRISBERG in human anatomy) and pass back to the lobe as a huge tract of heavily medullated fibers close to the median line, constituting the pre-vagal portion of the fasciculus communis of OSBORN (= fasciculus solitarius of mammals). Entering the lateral border of the facial lobe, it spreads out in many strands in the superficial layer among the dendrites of the chief gustatory cells (cf. Figs. 5, 16 and 20). These endings are thick, loosely branched arborizations of wide extent. One of the simpler forms of these endings is impregnated in Fig. 18 on the right side.

There is no well defined motor layer of the facial lobe corresponding with that of the vagal lobe, but the ventro-lateral portion along the line of attachment to the oblongata is of different structure from the rest and will be termed the intermediate zone, or *nucleus intermedius facialis.* It contains rather large neurones whose dendrites spread widely through the whole lateral part of the facial lobe and whose neurites reach the substantia reticularis (Figs. 18, *a* and 17, *a* and 8). Here they reach directly the dendrites of the motor VII and less immediately those of the motor V, IX and X nuclei. This is the main pathway for short reflexes from the facial lobe to the oblongata. The absence of a motor layer in the facial lobe which gives rise directly to motor root fibers, like that in the vagal lobe, is to

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a, neurone of the intermediate zone; *asc.s.g.t.*, main ascending secondary gustatory tract; *com.r. VII*, communis (gustatory) root of the facialis; *f.l.m.*, fasciculus longitudinalis medialis; *n.mot. VII.d.*, dorsal part of motor VII nucleus; *n.mot. VII.v.*, ventral part of motor VII nucleus; *mot. VII.r.*, motor root of facial nerve; *r.IX.sen.*, sensory root of the IX nerve; *r.X.mot.*, motor root of the vagus; *r.X.s.*, gustatory root of the vagus; *s.g.t.IX+X*, secondary gustatory tract from X and IX lobes; *s.g. VII.t.*, secondary gustatory tract from the facial lobe; *s.r.*, substantia reticularis; *sp. V*, spinal V tract.

be correlated with the fact that its gustatory impressions come mainly from the outer skin and so give rise to more general body movements, such as turning and seizing, rather than to movements of the intrinsic musculature of the palatal organ, for which the root fibers of the motor layer of the vagal lobe are mainly designed. The substantia reticularis is known to be related not only to the cranial motor nuclei of the branchial or visceral type, as mentioned above, but also to contain cells whose neurites reach the fasciculus longitudinalis medialis and other paths with somatic motor connections (see CAJAL, '96, p. 129 and Fig. 16), so that we have here a very direct mechanism for producing the movement of eye-muscles and trunk-muscles necessary for locating and approaching a sapid substance which has been perceived by contact with taste buds of the outer skin.

2. *Secondary Gustatory Tracts.*

The secondary connections of the vagal, glossopharyngeal and facial lobes are of two general types:—(1) short paths, by way of the intrinsic secondary neurones or of collaterals of the neurites of the chief cells, directly to the motor layer of the vagal lobe and to the substantia reticularis of the oblongata; and (2) long paths to regions above and below the oblongata, arising from the chief gustatory neurones. The connections of the first type are diffuse and largely unmedullated; they have been briefly described above. The connections of the second type are compact well defined tracts of medullated fibers which will be termed the ascending and descending secondary gustatory tracts.

A word of further explanation may be necessary here in justification of the term *gustatory* as applied to these tracts. We have seen above that the communis roots of the VII, IX and X nerves in fishes generally contain fibers from taste buds in the mucous membrane of the mouth or in the outer skin and also fibers which end peripherally by free arborizations unrelated to any specialized sense organs—undifferentiated visceral endings. In view of the fact that these types of fibers, so distinct peripherally, have not as yet been clearly separated at their central terminations, these roots must for the present retain the name "communis system," pending the time when they can be separated into specialized (gustatory) and unspecialized visceral components. With the secondary pathways and centers, however, the first step in this analysis may already be taken, thanks to the advantages of the comparative method.

In forms like the mammals, where the gustatory system is reduced, the analysis of these two elements in the fasciculus solitarius and its associated grey and secondary tracts will probably be impossible save by a degeneration method. The same applies to the amphibia, where the term fasciculus communis was first applied to the homologous structure. In fishes, again, we have some forms with reduced organs of taste, where the problem offers the same difficulties as in the cases cited, and also forms with enormous hypertrophy of the peripheral gustatory system with no appreciable change in the unspecialized component. In the latter cases whatever enlargement of the primary and secondary centers has taken place may clearly be assigned to the gustatory and not to the general visceral system. This is the case presented by the cyprinoid and siluroid fishes particularly, where the whole of the facial lobe and its connections and the greater part of the vagal lobe and connections have clearly arisen in response to the demands of the enormous peripheral gustatory system. While the diffuse connection of these centers with the substantia reticularis is known to have a parallel in the similar connections of the fasciculus solitarius of mammals and therefore doubtless in part pertains to the unspecialized visceral component, the long secondary paths which we here term the secondary gustatory tracts are highly developed only in those fishes possessing elaborate peripheral gustatory systems. This seems to constitute sufficiently good evidence that these long paths are mainly and perhaps wholly gustatory in function.

The neurites of the chief secondary gustatory neurones of the vagal and facial lobes, as we have seen, pass out in thick bundles to the ventro-lateral border of the oblongata, where they turn to take a longitudinal course parallel with and often almost completely enclosing the spinal V tract. This secondary tract is largely composed of small and feebly medullated fibers, so that in WEIGERT sections it appears paler than the spinal V and the other great longitudinal conduction paths of the oblongata. Part of its fibers turn caudad and part cephalad. We therefore have descending and ascending secondary gustatory tracts (tractus gustus secundus descendens et ascendens) from both the vagal and facial lobes.

(1) Descending Secondary Gustatory Tract.

In the carp, as shown by WEIGERT sections of the adult, the descending tracts from both the vagal and facial lobes are very extensive. From the facial lobe they constitute a massive aggregate of medullated fibers in the "secondary vagus bundle" complex. But the descending tracts from the vagal lobe are largely unmedullated fibers scattered through the substantia reticularis grisea of the oblongata.

The descending secondary facial tract arises, as in Ameiurus, chiefly from the cephalic portion of the lobus facialis. The fibers pass ventro-lateral to gather in a compact bundle mesially and dorsally of the spinal V tract, farther caudad enclosing this tract on all but its external aspect (Fig. 5, *d.s. VII*). There is no obvious addition of descending fibers to this descending bundle in the region of the lobus vagi. It can be easily distinguished from the ascending secondary gustatory tract from the vagal lobe (Fig. 5, *a.s. X*) by the fact that the latter tract is much more feebly medullated at this level.

In the caudal part of the vagal lobe the motor zone is greatly thickened as is also the substantia reticularis grisea, which lies ventro-laterally of it and in intimate relations with the layer of secondary gustatory tracts of the vagal lobe, the descending secondary facial tract and the spinal V tract. This whole area contains descending secondary vagal fibers. These are chiefly very fine unmedullated or feebly medullated fibers passing from the layer of secondary gustatory tracts of the vagal lobe caudad and mesad through the substantia reticularis grisea

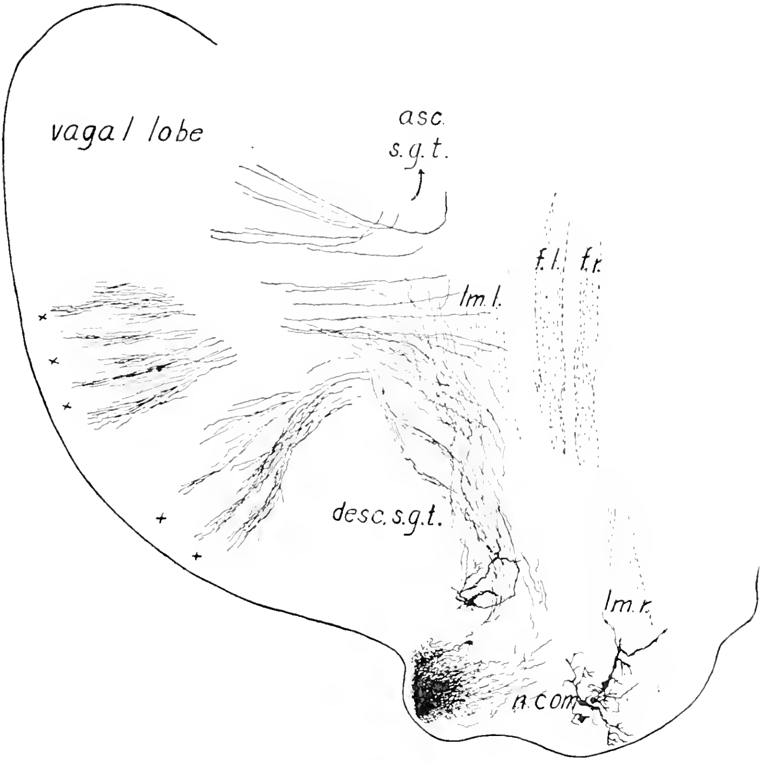

Fig. 19. Longitudinal section through the left vagal lobe of a young carp, 5 cm. long. GOLGI method. × 40.

The section is approximately horizontal, but strongly inclined so that the left side is farther dorsal. It shows the descending secondary gustatory tract (*desc. s.g.t.*) from the vagal lobe to the region of the nucleus funiculi. At the periphery of the vagal lobe in the regions marked by the crosses there is a very rich impregnation of cells among which the secondary fibers arise, which are omitted so as not to confuse the drawing, since they are too densely impregnated to permit an accurate determination of their relations to the fibers. These cells are partly chief secondary neurones like those of Fig. 7, and partly the smaller type as shown in Fig. 11. A very few fibers of the ascendlng secondary gustatory tract (*asc.s.g.t.*) from the vagal lobe are shown. This tract appears voluminously a few sections ventrad in the position indicated by the arrow. The median line is indicated by the position of the left and right fasciculi longitudinales mediales (*f.l.* and *f.r.*). The lemniscus on both the left (*lm.l.*) and right (*lm.r.*) sides is shown; also the position of the funicular nucleus and commissural nucleus of CAJAL (*n.com.*).

in diffuse formation to reach the region of the nucleus funiculi and commissura infima HALLERI (Figs. 19, 11). The indications are that it springs mainly from the smaller secondary neurones of the lobe (cf. Fig. 11), though I have no conclusive evidence that the chief secondary cells do not also participate in its formation.

In the region of the funicular nuclei the substantia reticularis grisea, related above with the vagal lobe, enlarges. This I term the *inferior secondary gustatory nucleus* (nucleus gustus secundus inferior). It receives the diffuse tracts from the vagal lobe just described, and also the greater part of the descending secondary facialis tract. A portion of the latter tract, however, continues into the spinal cord caudad of the funicular nuclei in the ventro-lateral tracts.

This inferior gustatory nucleus is intimately related with the termini of the spinal V tract, funicular nuclei, commissura infima HALLERI and commissural nucleus of CAJAL. It is clearly a coordination center between gustatory and tactile sensory impressions. In fishes with feebly developed gustatory system it is of insignificant size. Its great development in the cyprinoids and, as we shall see, in the siluroids is correlated with the known feeding habits of these fishes. It has been shown (JUDSON HERRICK, '04) that fishes with taste buds in the outer skin taste with these organs and habitually localize the food stimulus partly by the sense of taste and partly by tactile stimulation of the same cutaneous areas. It may safely be inferred that the descending secondary gustatory connections of these fishes are especially adapted to serve this correlation of the senses of taste and touch as employed in localizing peripheral stimuli in the search for food and to call forth the bodily movements necessary to seize the food when its position has been determined.

The detailed description of these connections involves the discussion also of the secondary connections of the general cutaneous (somatic sensory) system of neurones and must be reserved for a later contribution.

(2) Ascending Secondary Gustatory Tract.

This tract, which takes the greater part of the fibers arising from the chief secondary gustatory neurones of both the vagal and facial lobes, is one of the most distinctive features of the teleostean brain. In the two groups here treated, particularly, it attains enormous dimensions, constituting the "Sekundäre Vagus-Trigeminusbahn" of MAYSER, whose excellent description ('82, p. 318) is fully confirmed. It is included in the "system *γ*" of the descriptions of GORONOWITSCH ('88, and '96). The curious notion of B. HALLER ('96, p. 92) that this is a descending tract from the cerebellum and other higher cerebral regions to the sensory centers in the vagal lobe need not detain us, for he gives no evidence for such a view. The common designation of this tract as "secondary vagus bundle" is inadmissible, since in all fishes it contains secondary glossopharyngeus and facialis fibers also, the secondary facialis fibers preponderating in siluroids. Moreover, there are other secondary vagus tracts for general cutaneous and other types of fibers, besides the descending and short gustatory paths described in the preceding section.

The ascending or central gustatory tract takes its position ventrally and mesially of the spinal V and descending secondary facialis tracts and partly enclosing them (Fig. 5, *a.s.X.*). It ascends to the level of the superficial origin of the sensory trigeminus root from the oblongata, where it turns mesially and dorsally to enter its own terminal nucleus (superior secondary gustatory nucleus, Fig. 20). The axial portion of this nucleus was termed by MAYSER "Rindenknoten" and by JOHNSTON ('01) secondary vagus nucleus. It is included in the "Uebergangsganglion" of MAYSER's descriptions, this latter group of cells being very complex and not as yet fully understood. Its homologies are considered in the final section of this paper.

It lies in the dorsal part of the isthmus ventrally of the line of fusion of the valvula cerebelli with the body of the cerebellum. Typically it lies near the median line and projects into the aquaeductus, but in some cyprinoids it is so greatly enlarged as to reach also to the lateral surface of the brain at the isthmus and there project as a distinct tuberosity between the caudal end of the tectum opticum and the tuberculum acusticum

(Fig. 3, lower figure). It lies cephalad, dorsad and mesad of the motor V nucleus, the long dendrites of some of whose cells pierce it and come into relations with some of the termini of the gustatory fibers (Figs. 21 and 23). The motor V nucleus is very large in these fishes and extends far cephalad and dorsad in intimate relations with the termini of the secondary gustatory tract. The dendrites of these motor cells spread out widely in every direction and are not directed ventro-laterad so generally as in the case of the motor nuclei of the VII, IX and X nerves. In fact, the greater part of them take the opposite course, as figured, into the caudal part of the secondary gustatory nucleus and the adjacent substantia reticularis grisea.

This fact, together with others of similar import, suggests the morphological interpretation of this secondary terminal nucleus; viz., that it is merely a specialization from the substantia reticularis. CAJAL ('96, p. 128) has confirmed the view

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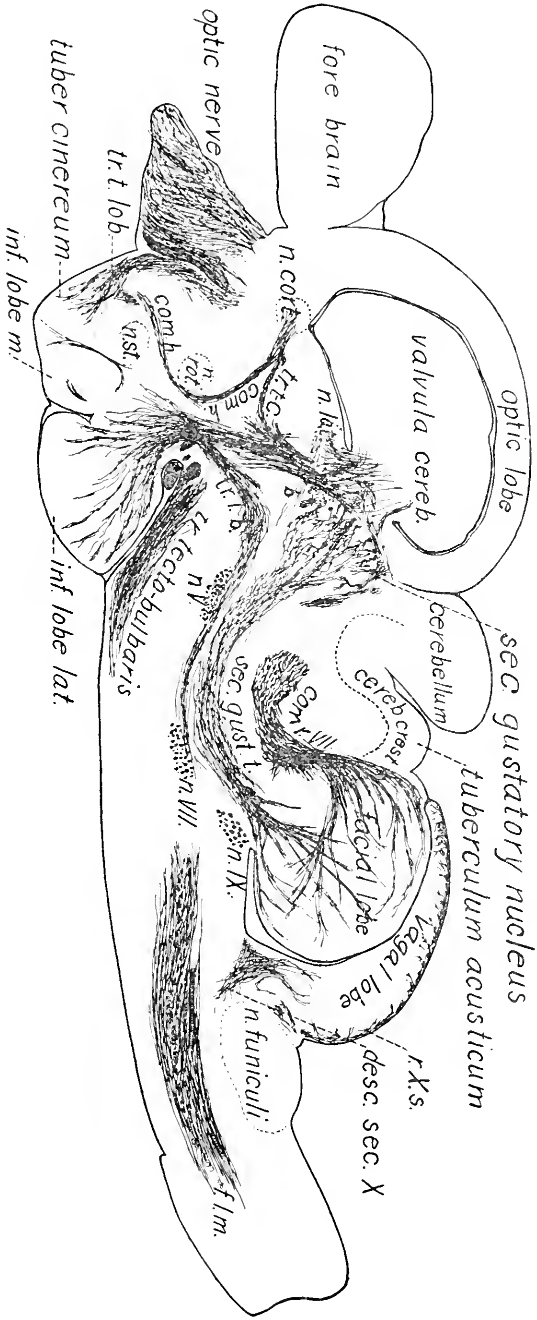
Fig. 20. Parasagittal section through the brain of the spotted sucker, *Minytrema melanops* (Raf.). GOLGI method. × 12.

The sketch is designed to illustrate the course of the ascending secondary gustatory tract and the connections of its terminal nucleus. The plane of the section is slightly oblique so that the caudal end and the ventral side are nearer the median line than are the cephalic and dorsal borders. The figure is a composite, made by outlining one section with the camera lucida and filling in the details from this section and the three sections of the same series on each side immediately adjacent, omitting irrelevant detail. The features introduced are schematized as little as possible. The whole course of the ascending secondary gustatory tract from the facial lobe is shown. The origin of the tract from the vagal lobe lies farther lateral.

b., tract between secondary gustatory nucleus and n. lateralis valvulae; *com.h.*, commissura horizontalis, FRITSCH; *com.r.VII*, communis (gustatory) root of the facialis; *desc.sec.X*, descending secondary gustatory tract from the vagal lobe; *f.l.m.*, fasciculus longitudinalis medialis; *inf.lob.lat.*, lateral lobule of inferior lobe (hypoaria, C. L. HERRICK); *inf.lob.m.*, median lobule of inferior lobe (mammillare, C. L. HERRICK); *n.cort.*, nucleus corticalis, FRITSCH; *n.IX*, motor nucleus of the glossopharyngeus; *n.lat.*, nucleus lateralis valvulae; *n.rot.*, nucleus rotundus, FRITSCH; *n.st.*, nucleus subthalamicus, C. L. HERRICK; *n.V.*, motor nucleus of the trigeminus; *n.VII*, motor nucleus of the facialis; *r.X.s.*, sensory root fibers of the vagus; *sec.gust.t.*, ascending secondary gustatory tract from the facial and vagal lobes; *tr.l.b.*, tractus lobo-bulbaris; *tr.t-c.*, tractus tecto-cerebellaris; *tr.t.lob.*, tractus tecto-lobaris, JOHNSTON (commissura ventralis, C. L. HERRICK). The area marked *n.funiculi* contains also the inferior secondary gustatory nucleus.


fore brain
optic nerve
tuber cinereum
tr. t. lob.
inf. lobe m.
n. cor.
com. h.
n. st.
n. rot.
com. h.
tr. t. c.
n. lat.
valvula cereb.
optic lobe
tr. l. b.
tr. tecto-bulbaris
inf. lobe lat.
n. V
sec. gustatory nucleus
cerebellum
cereb. crest
com. r. VII
sec. gust. t.
n. VII.
n. IX.
facial lobe
tuberculum acusticum
vagal lobe
r. X. s.
desc. sec. X
n. funiculi
f. l. m.

of KÖLLIKER that the substantia reticularis alba is composed of sensory bundles of the second order and that the substantia reticularis grisea is a sensory field of the third order, designed to distribute sensory excitations from the V, IX and X nerves (and also, it should be added, from the VII nerve) over a large

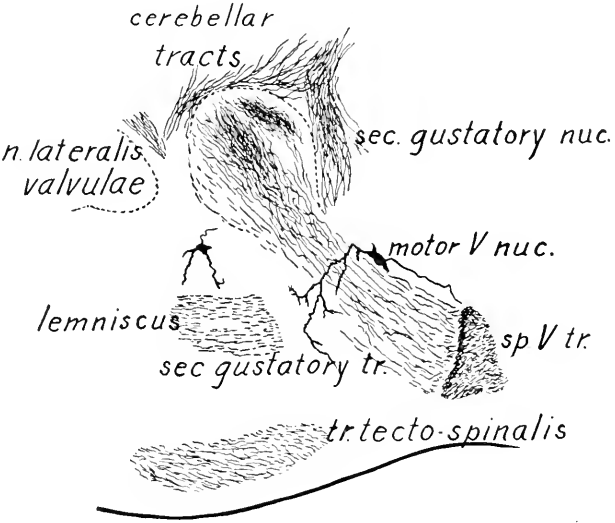


Fig. 21. Portion of a sagittal section of the brain of *Minytrema melanops* (Raf.). GOLGI method. × 40.

The section is quite oblique, the cephalic end and the dorsal side being inclined toward the median line. It passes through the ascending secondary gustatory tract at the point where it enters its terminal nucleus under the cerebellum (the cephalic end of the figure being at the left). The spinal V tract (*sp. V.tr.*) is cut close to its superficial origin from the periphery. A single neurone of the most dorsal part of the motor V nucleus is impregnated, one of its dendrites crossing the mesial side of the gustatory tract to ramify in the most ventral and caudal part of the layer of chief tertiary gustatory neurones, a single one of which is impregnated. The tertiary gustatory path does not lie in the plane of this section (cf. Fig. 23).

field of motor nuclei of the oblongata. This definition, it will be observed, carries also the secondary gustatory nucleus, save that in addition to direct relations of the secondary termini with the motor nuclei, like the trigeminal connection just described, there is here, as we shall see, a much more extensive development of tertiary neurones for connections of a higher order in the floor of the thalamus (central tertiary tract). The dorsal and mesial position of this derivative of the substantia reticularis is easily explained by the topographic features of the isthmus. Here the ventro-lateral region is occupied by the great conduction paths between the oblongata and the mid-brain—the tractus tecto-spinalis, tractus lobo-spinalis, lemniscus, etc. The dorso-lateral region is occupied by the tuberculum acusticum and its cerebellar connections. The enlarged secondary gustatory terminal is prevented from growing caudad by the great cerebellar crest and tuberculum acusticum. It must, therefore, grow upward, inward and forward into the optocoele. In this position it appears typically in all teleosts. But when still more enlarged, as in cyprinoids, further growth in this direction being prevented by the valvula cerebelli, which is also very large in these fishes, it is forced to grow outward until it appears as a superficial eminence cephalad of the tuberculum acusticum and dorsally of the great ventro-lateral conduction paths just referred to (Fig. 3).

The secondary gustatory nucleus does not, however, comprise the whole of the substantia reticularis grisea of this region of the isthmus. For caudo-mesially of this nucleus at the level where the secondary gustatory tract enters it from the lateral side of the oblongata is another considerable cellular area which represents a less highly specialized portion of the same sensory field. This also borders the ventricle, in some types forming a considerable projection into it from the lateral wall immediately caudad and ventrad of the commissure of the secondary gustatory nuclei. Its anomalous position is brought about by the same forces which were discussed above in connection with the secondary gustatory nucleus. It is in very intimate relation with the motor V nucleus which lies ventro-laterally of it and it apparently is the chief medium of communication between the various sensory pathways and that nucleus. Its neurones, in other words, are like the others of the substantia reticularis grisea in being of the tertiary sensory type and discharging into a motor field, in this case the V nerve. It may therefore be termed the *substantia reticularis grisea trigemini.*

The position of this area of the carp is indicated in Fig. 22. It is reached, as shown in the figure, by a slender branched process of one of the chief tertiary neurones, which may be a dendrite, but more probably is a collateral neurite, though it does not spring from the main neurite (*n*), which enters the tertiary tract separately. The neurone marked *a* lies in the adjacent section and is drawn enlarged in Fig. 25. From the base of its neurite is given off a collateral, only a part of which is shown, which is probably of the same type as the one here figured. Contiguous sections of the same series show fibers passing from this area of substantia reticularis directly into the axis of the secondary gustatory nucleus and there arborizing, which probably represent dendrites of the cells of the substantia reticularis which are not impregnated.

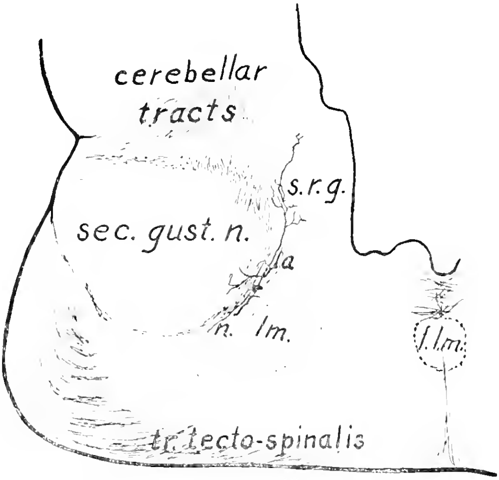


Fig. 22. Section taken through the superior secondary gustatory nucleus of the carp. GOLGI method. ×40.

The section is approximately transverse, but strongly inclined so that the dorsal and right sides are father caudad. A single chief tertiary gustatory neurone is shown, whose neurite (*n*) enters the tertiary gustatory tract. Its main dendrite passes out of the plane of the section (cf. Fig. 25). A much more slender process is completely impregnated, running dorsad and caudad to reach the substantia reticularis grisea trigemini (*s.r.g.*). At *a* is shown the position of the neurone drawn in Fig. 25, which lies in the section adjacent to the one here drawn. The secondary gustatory nucleus is bordered on the dorsal and mesial sides by the fibers of the tertiary tract.

These fragmentary data are sufficient to show that we have in addition to direct connections of dendrites of the motor V nucleus with secondary gustatory fibers, a similar but indirect functional connection via the substantia reticularis grisea trigemini. The numerous other connections of the latter area need not now concern us.

One of my GOLGI preparations of the carp shows dendrites of a very large neurone lying in the vicinity of the nucleus of origin of the IV nerve sending dendritic branches ventrad into the region caudad of the commissura ansulata and other large branches farther caudad and laterad into the same portion of the secondary gustatory nucleus which is reached by dendrites of the motor V nucleus. The impregnation is so imperfect that it is impossible to be sure whether this neurone belongs to the motor nuclei of the eye muscle nerves or to the fasciculus longitudinalis medialis or to some other neighboring structure.

3. Superior Secondary Nucleus and its Connections.

The superior secondary gustatory nucleus presents, broadly speaking, the same general arrangement as the primary end-station in the vagal and facial lobes. That is, the secondary neurones end in relation with two types of tertiary neurones (1) intrinsic neurones, filling the interior of the nucleus ("Rindenknoten," MAYSER) and (2) the chief tertiary neurones in a dense layer around the periphery. The chief difference between the arrangement of the primary and secondary end-stations lies in the fact that the latter is connected with its fellow of the opposite side by a broad commissure, the commissure of the secondary vagus nuclei of JOHNSTON. As was recognized by MAYSER, this commissure contains fibers of at least two sorts (1) neurites of the intrinsic tertiary neurones, (2) terminals of a portion of the secondary gustatory tract. From (2) it follows that the secondary tracts end partly on the same side and partly in the secondary nucleus of the opposite side, the former portion being much the larger. The uncrossed portion ends by free arborizations within the secondary nucleus and also extensively in the cortical portion among the chief tertiary cells (Fig. 23). The details of the endings of the crossed fibers I have not been able to observe, but there is every reason to believe that they are essentially similar.

I have no complete impregnations of the intrinsic commissural neurones. The evidence is that their delicate, feebly medullated neurites gather in the interior of the nucleus and terminate after crossing among the dendrites of the chief tertiary neurones of the opposite side. The layer of these chief cells envelopes the secondary nucleus on all sides except where it is interrupted by the secondary and commissural tracts. The neurites of these cells pass directly outward and become medullated as they enter the chief tertiary tract for the inferior lobe. Just external to the layer of tertiary neurones the gustatory nucleus is encapsuled by a dense layer of heavily medullated nerve fibers. These are partly the tertiary fibers, but chiefly cerebellar tracts. The position of the secondary gustatory nucleus in the isthmus is such that the cerebellar penduncles, passing downward from the cerebellum and valvula, almost entirely envelop it. It is this peculiarity which suggested to MAYSER the name "Rindenknoten." Surrounding this fibrous capsule is an aggregate of nuclei with very diverse connections to which MAYSER applied STIEDA's name, "Uebergangsganglion."

This region is perhaps the most intricate and difficult of analysis in the teleostean brain, as it contains several large centers and numerous important tracts, both medullated and unmedullated, all crowded into a very small space. The dorsal part of the isthmus is more than usually crowded in these types, not only by these great gustatory centers, but also by the enlarged cerebellum and valvula and their associated tracts.

The broad line of fusion of the valvula cerebelli with the torus semicircularis (colliculus) is occupied by a very dense mass of cells and medullated and unmedullated tracts whose relations are only imperfectly shown in my preparations. The whole complex, which lies mesially of the nucleus lateralis mesencephali (EDINGER), or colliculus, I term provisionally the nucleus lateralis valvulae. It is, apparently, the most cephalic part of the "Uebergangsganglion" of Stieda. This group of cells fuses behind with the dorsal and cephalic border of the secondary gustatory nucleus, but is separated from it more or less definitely by the medullated vertical cerebellar tracts which encapsule the secondary gustatory nucleus. Sections stained by the method of Pal show large tracts of fine fibers with exceedingly delicate medullary sheaths passing dorso-ventrally between the n. lateralis valvulae and the cerebellum and valvula (Fig. 24), and Golgi sections show diffuse unmedullated tracts taking the same courses (Fig. 20). Whether the medullated and the unmedullated fibers spring from neurones of the same type, I have not been able to determine. The neurones shown

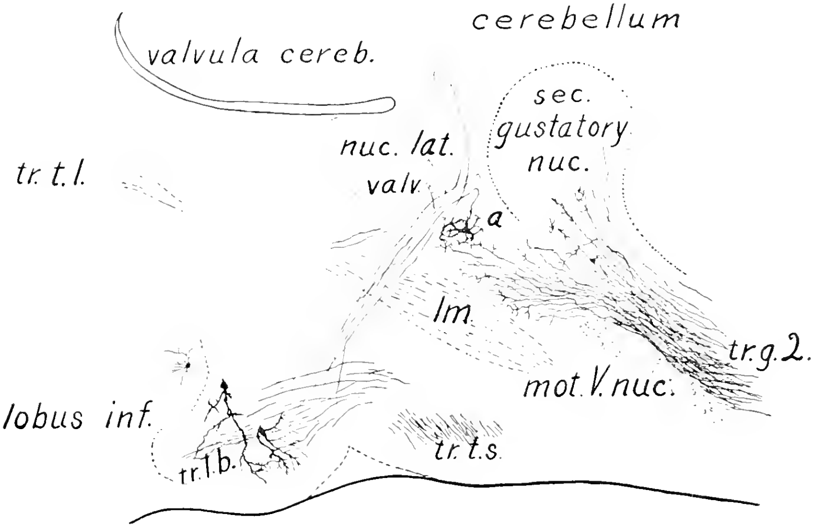


Fig. 23. Portion of sagittal section of the brain of a young carp, 5 cm. long. Golgi method. × 40.

The ventral side of the preparation is below and the cephalic end at the left. The section includes the superior secondary gustatory nucleus ("Rindenknoten," Mayser) and shows the origin and course of the tertiary path to the inferior lobe. A single neurone of the latter type is impregnated completely (*a*) save for the terminal arborization. Mingled with the neurites of these cells are those of the tract between the cerebellum and the inferior lobe (tractus lobo-cerebellaris, Edinger). Among the terminals of the tertiary tract are the cells of origin of the tractus lobo-bulbaris et spinalis (*tr.l.b.*); *l.m.*, lemniscus; *tr.t.l.*, tractus tecto-lobaris; *tr.t.s.*, tractus tecto-spinalis.

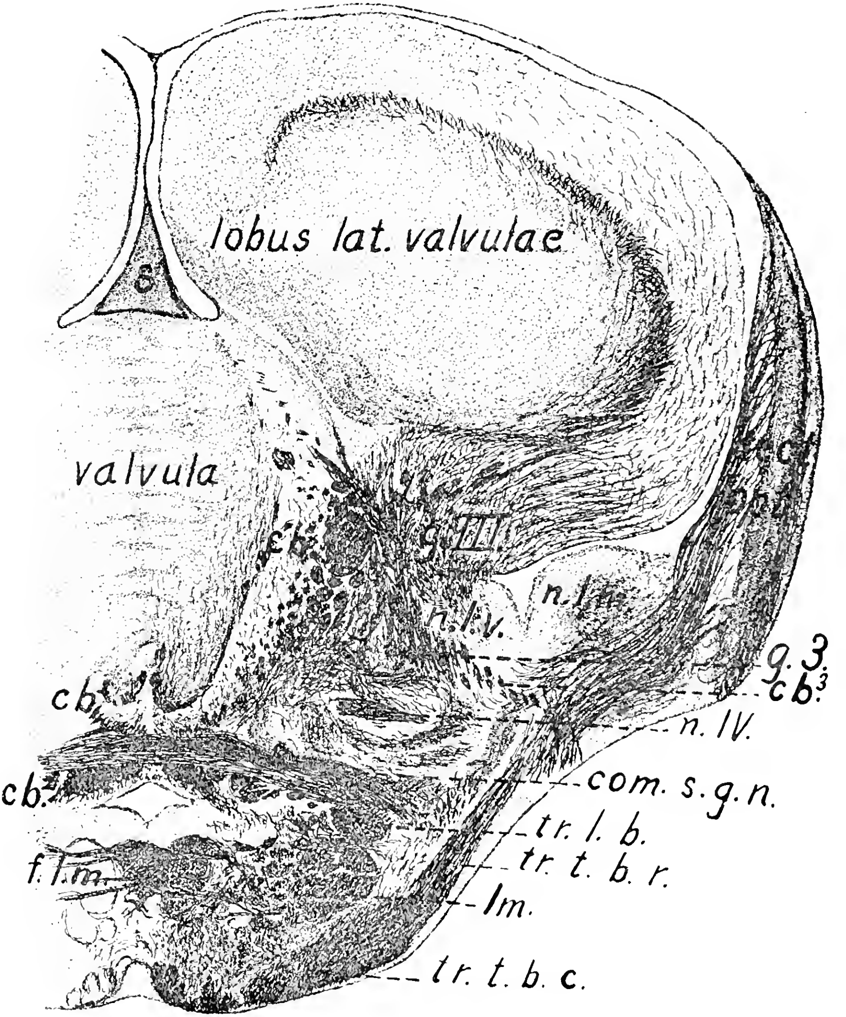


Fig. 24. Transection through the brain of a large carp just cephalad of the superior secondary gustatory nucleus. Stained by the method of WEIGERT-PAL. × 20.

The section passes through the most cephalic portion of the commissure of the secondary gustatory nuclei, and illustrates the relations of the nucleus lateralis valvulae to this nucleus and to the cerebellum. The trochlearis (*n. IV.*) decussates just cephalad of the gustatory commissure and in passing to its superby the GOLGI sections are like the cells of the granular layer of the cerebellum and probably are of that type, receiving afferent cerebellar impulses and transmitting them to the cortex cerebelli. Whether they receive their impulses from the adjacent gustatory nucleus or from other sources, my preparations do not show with certainty, but probably partly from the former.

There is also a broad unmedullated connection between the ventral part of the secondary gustatory nucleus and the cephalic part of the n. lateralis valvulae, running cephalad through the vertical cerebellar tracts (designated by *b* in Fig. 20). Horizontal sections of the brain of Catastomus show numerous delicately medullated fibers running between the whole cephalic face of the gustatory nucleus and the n. lateralis valvulae. These connections lend further support to the belief that the n. lateralis valvulae is in part a gustatory intermediary station for the cerebellum. This nucleus extends cephalad to the point where the valvula severs connection with the floor of the mesencephalon and here a large tract passes between its cephalic end and the nuclei of the third nerve and of the fasciculus longitudinalis which lie mesially of it. It is no doubt this connection which led B. HALLER to state ('98, p. 522) that the "Uebergangsganglion of FRITSCH and MAYSER is an "upper motor oculomotorius nucleus." The nucleus lateralis valvulae

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ficial origin become embedded in the most cephalic part of the secondary gustatory nucleus, the latter being represented in the figure by the neuropil surrounding *n.IV.* Sections immediately caudad show the gustatory nucleus occupying the entire space from near the median line to the lateral surface of the brain and from the level of the commissural fibers and tr. lobo-bulbaris (*tr.l.b.*) up to the valvula cerebelli.

cb., *cb*¹., *cb*²., *cb*³., cerebellar tracts; *com.s.g.n.*, commissure of the secondary gustatory nuclei; *f.l.m.*, fasciculus longitudinalis medialis; *g.III*, fibers arising from the granule cells of the nucleus lateralis valvulae and passing dorsally into the lateral lobe of the valvula cerebelli; *g.3.*, tertiary gustatory tract for the inferior lobe appearing as oval bundles among the strands of the cerebellar tract *cb*³.; *lm.*, lemniscus (fasciculus lateralis); *n.IV.*, root of the fourth nerve; *n.l.m.*, the extreme caudal end of the nucleus lateralis mesencephali (torus semicircularis, colliculus); *n.l.v.*, nucleus lateralis valvulae; *s.*, a large blood sinus between the lateral lobes of the valvula; *tect.opt.*, tectum opticum; *tr.l.b.*, tractus lobo-bulbaris; *tr.t.b.c.*, tractus tecto-bulbaris et spinalis cruciatus; *tr.t.b.r.*, tractus tecto-bulbaris et spinalis rectus.

has other connections (with the substantia reticularis of the oblongata, optic thalamus, etc.) which I have not yet fully worked out. Its homologies are discussed briefly beyond. Another part of the "Uebergangsganglion" which serves as a gustatory reflex center is the nucleus already designated as substantia reticularis grisea trigemini. There remain several considerable collections of cells in the "Uebergangsganglion" which may have gustatory functions, but their discussion would involve a more extensive analysis of the mesencephalon than we can here attempt.

A typical illustration of the chief tertiary gustatory neurones in the cortex of the secondary gustatory center of the carp is seen in Fig. 25. The dendrite plunges into the axial portion of the nucleus ("Rindenknoton," MAYSER) and there spreads out widely among the termini of the secondary gustatory fibers (cf. Figs 22, 23). The neurite passes downward to enter at once the tertiary gustatory tract for the inferior lobe of the same side, where it takes up a dense medullary sheath and so is rarely completely impregnated in GOLGI preparations. These medullated fibers mingle immediately with similar ones of the cerebellar tracts (lobo-cerebellaris and others) which encapsule the secondary nucleus and which likewise pass into the inferior lobe, so that I have found it impossible in WEIGERT sections to effect the separation of the two classes of fibers except at the origin of the tertiary gustatory tract from its nucleus. I have, fortunately, secured a sufficient number of complete GOLGI impregnations to show the origin of the tract without uncertainty. Its entire extent save the terminal arborization is shown in Fig. 23.

The combined tract passes ventrad and somewhat cephalad to enter the caudal border of the inferior lobe and spread throughout the whole of the lateral lobule of this organ. Whether any of these fibers reach the median lobule my preparations do not definitely determine, but apparently not. (The terms lateral and median lobules are used in the sense defined by DAVID ('92). The lateral lobules are the hypoaria and the median lobules the mammillary bodies of C. L. HERRICK ('92)).

The terminal arborizations of this tract in the inferior lobe of Ameiurus shown in Fig. 37 probably belong to the gustatory component.

The *tractus lobo-bulbaris* arises from the whole of the lateral lobule of the inferior lobe and its fibers mingle with those of the tertiary gustatory tract, the two tracts, however, being well separated where they leave the lobe (Fig. 20, 23). The tractus lobo-bulbaris is the main path for descending impulses from the inferior lobe (gustatory and other reflexes) and was termed in MAYSER's descriptions ('82, p. 319) "Nervenfaserbahn *x*." The fact that it is larger (as mentioned by MAYSER) in cyprinoids and the peculiarities of its course in the oblongata make it probable that it is the chief motor return path for the higher gustatory reflexes. This of course is not its only function, for it clearly serves as the chief path for all descending impulses from the inferior lobe to the oblongata and cord, and therefore carries olfactory and other reflex impulses in addition to gustatory.

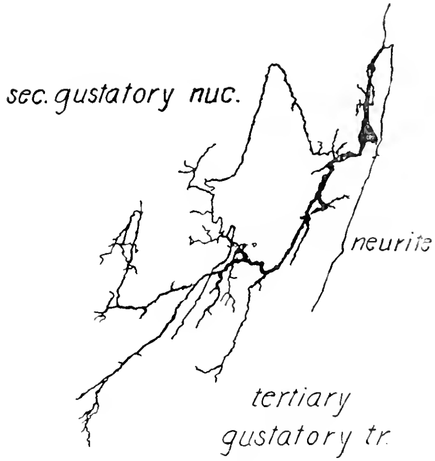

Fig. 25. One of the chief tertiary neurones of the superior secondary gustatory nucleus of a young carp. GOLGI method. × 187.

For the relations of this neurone to the surrounding structures, cf. Fig. 22, which is drawn from the section next caudad. The dendrites spread out in the mesial part of the secondary gustatory nucleus. The neurite at once enters the tertiary gustatory tract for the inferior lobe and either passes out of the plane of the section or becomes medullated and so fails to impregnate.

The course of the tractus lobo-bulbaris as it leaves the inferior lobe is clearly shown in some of my GOLGI preparations. In WEIGERT sections this tract is so confused at its origin with the fibers of the tractus lobo-cerebellaris and tertiary gustatory path that it cannot be clearly distinguished at first. Its fibers throughout their course are very fine and feebly medullated. The tract passes up from the inferior lobe and arches around the ansulate commissure to turn caudad along the inner border of the lemniscus. Upon reaching the level of the secondary gustatory nucleus it turns laterad over the dorsal surface of the lemniscus (Fig. 24) and takes up a position ventrally of the secondary gustatory nucleus (Fig. 20, *tr.l.b.*). Farther back it becomes partially enveloped by the ascending fibers of the secondary gustatory tract. The latter tract in cross section is crescent-shaped and the concavity of the crescent, which faces inward, is occupied by the descending fibers of the tractus lobo-bulbaris. This tract is thus placed along the dorso-lateral border of the substantia reticularis, which, as we have seen, is the chief avenue of communication with the motor nuclei of the oblongata. The tractus lobo-bulbaris diminishes caudad, breaking up in the substantia reticularis and so puts the gustatory center in the inferior lobe into relation with the peripheral musculature. It doubtless extends into the spinal cord, but it is impossible to distinguish its fibers from the others in the substantia reticularis alba farther back than the vagal lobes.

SECTION IV. THE CENTRAL GUSTATORY SYSTEM OF SILUROID FISHES.

As we have seen above, the anatomy and physiology of the peripheral gustatory system of the cat fishes, or horned pouts, is now well known. The cutaneous portion of the system is here hypertrophied, while the buccal portion is about as in other fishes. This is the explanation of the fact that the cat fishes possess enlarged facial lobes, while the vagal lobes are of the typical teleostean form. We shall now proceed to a description of the internal anatomy and secondary connections of these structures in Ameiurus and closely related species. The material consists of serial sections of ten adult brains cut in the three conventional planes and stained with Delafield's hæmatoxylin and by the methods of Weigert and Weigert-Pal, together with serial sections of about 100 younger brains prepared by the method of Golgi and cut in various planes.

The *vagal lobe* of the cat fish is essentially similar to that of most other teleosts. The general relations as seen in transections stained by Delafield's hæmatoxylin are shown in Fig. 26. The lobe is crowded with numerous small nerve cells, which take up a very pale stain in hæmatoxylin. Most of these intrinsic cells are neurones of Golgi's type II, whose processes do not extend beyond the lobe. Along the dorsal and lateral borders of the lobe is a layer containing larger cells whose nuclei stain very little in hæmatoxylin and whose cytoplasm practically not at all. The axones of these cells constitute the chief sensory conduction paths from the vagal lobe to other parts of the brain, and I shall term them the dorsal

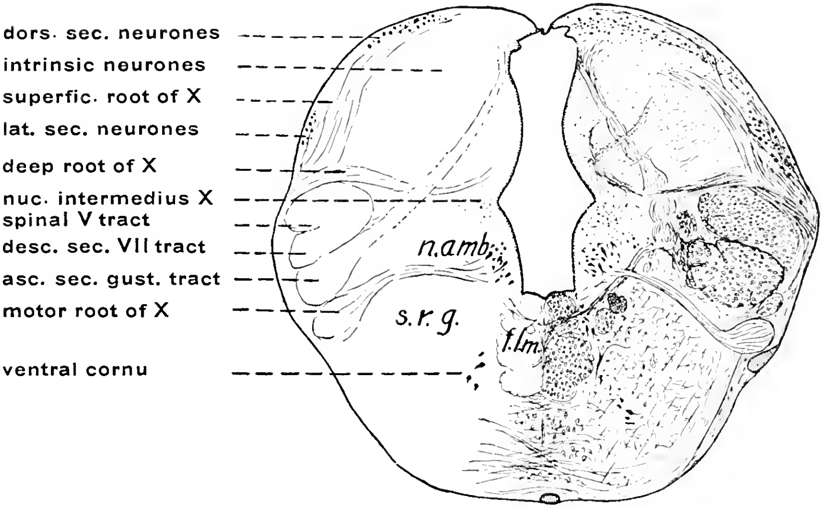

Fig. 26. Transverse section through the vagal lobes of a large adult of *Ictalurus punctatus* (Raf.). Drawn from a hæmatoxylin preparation. × 16.

f.l.m., fasciculus longitudinalis medialis; *n.amb.*, nucleus ambiguus; *s.r.g.*, substantia reticularis grisea.

and lateral chief secondary gustatory neurones. Deeply embedded in the substance of the medulla oblongata ventrally of the main body of the vagal lobe is an area filled with cells somewhat larger than the intrinsic neurones but much smaller than the chief secondary neurones, which may be termed intermediary neurones (nucleus intermedius vagi). Their neurites enter the substantia reticularis and other conduction pathways between the sensory and motor nuclei. Ventrally of the vagal lobe and not properly to be considered a part of it is the nucleus ambiguus, close to the median line in the floor of the fourth ventricle. The communis roots of the IX and X nerves enter the lobe at its ventro-lateral border, some descending along the lateral aspect of the oblongata to the region of the commissura infima Halleri, forming the descending communis root of the vagus, others passing directly inward under the lobe to terminate in the lobe along its inner or ventricular border, forming the deep communis roots of the vagus and glossopharyngeus, while

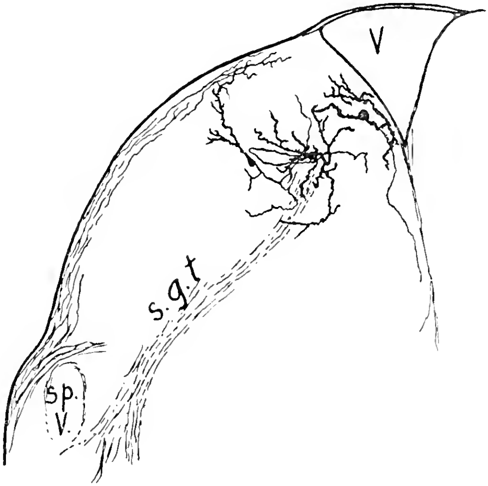

Fig. 27. Three intrinsic neurones of type II from the left vagal lobe of *Ameiurus nebulosus.* From a Golgi preparation. × 60.

The secondary communis tract (*s.g.t.*) which appears to arise among these cells, in reality springs from cells lying farther dorsally which are not impregnated in this preparation. Superficial root fibers of the vagus are impregnated at the border of the vagal lobe. *sp. V.*, spinal V tract; *V*, ventricle.

the main portion of the root fibers turn dorsally along the outer aspect of the vagal lobe to form the superficial communis roots of these nerves.

Communis root fibers, presumably bearing both general visceral and gustatory impulses, arborize freely in the entire inner, dorsal and lateral surfaces of the vagal lobe, some arborizations also occurring in the center of the lobe. Impulses from the latter are taken up by the intrinsic cells and diffused throughout the entire lobe. For the forms of these cells see Figs. 27, 28, 29, 30, 34. It may be conjectured that these cells receive mainly the unspecialized visceral root fibers, since the gustatory fibers are here, as in cyprinoids, almost certainly related chiefly to the superficial groups of secondary neurones. Type II cells are abundant in elasmobranchs (HOUSER, '01), whose taste buds are few and confined to the mouth, but were not demonstratable in any of JOHNSTON'S GOLGI preparations of

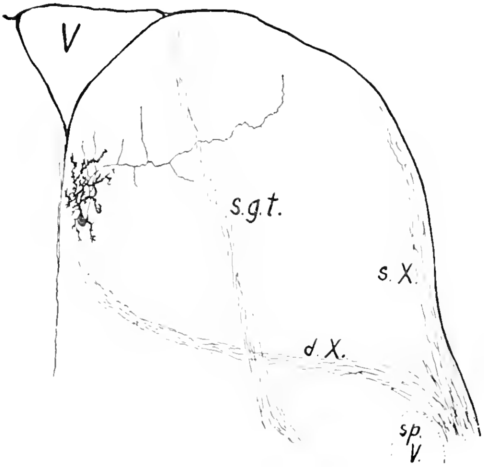

Fig. 28. An intrinsic neurone of the right vagal lobe of *Ameiurus nebulosus* seen in cross section. The cell body lies near the mesial border of the right vagal lobe and the neurite is directed laterally through the middle of the lobe. From a GOLGI preparation. ×60.

d.X., deep root of the vagus; *s.g.t.*, secondary gustatory tract; *sp.V.*, spinal V tract; *s.X.*, superficial sensory root of the vagus; *V*, ventricle.

Petromyzon ('02), though the secondary neurones of type I were found about as in teleosts. It Petromyzon, it is interesting to note in this connection, the cutaneous terminal bud system is well developed.

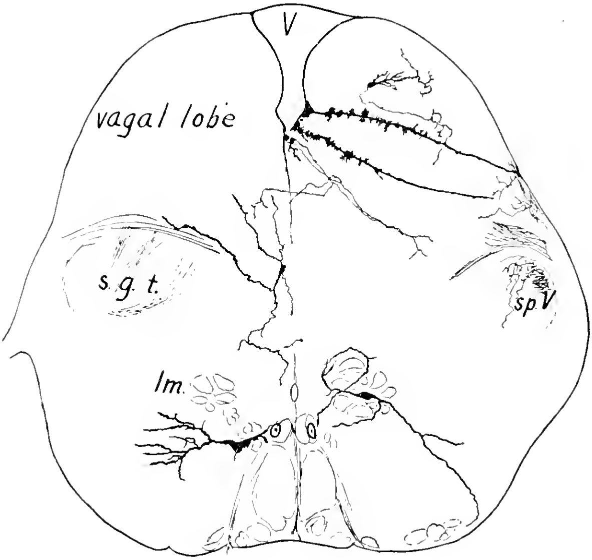

Fig. 29. Transverse section through the vagal lobes of *Ameiurus nebulosus* illustrating a type II cell within the vagal lobe similar to those in Figs. 27 and 28; also two other small cells at the ventral angle of the fourth ventricle, whose neurites terminates among the intermediary neurones of the same and opposite side. One of the latter cells is impregnated; also a ventral horn cell on the left side. Two supporting fibers of the neuroglia system are shown on the right side. GOLGI method. × 50.

l.m., lemniscus; *s.g.t.*, secondary gustatory tracts; *sp.V.*, spinal V tract; *V.*, ventricle.

The root fibers which end on the surface of the vagal lobe spread out in very wide arborizations (Figs. 30 and 31). These are most densely massed in two regions in intimate relation with the two groups of chief secondary neurones already referred to as the dorsal and lateral secondary gustatory neurones (Fig. 26). The general relations of the two groups of superficial secondary neurones are indicated in Fig. 31, where a dense neuropil richly impregnated indicates the positions of these two chief centers of secondary connection for gustatory root fibers.

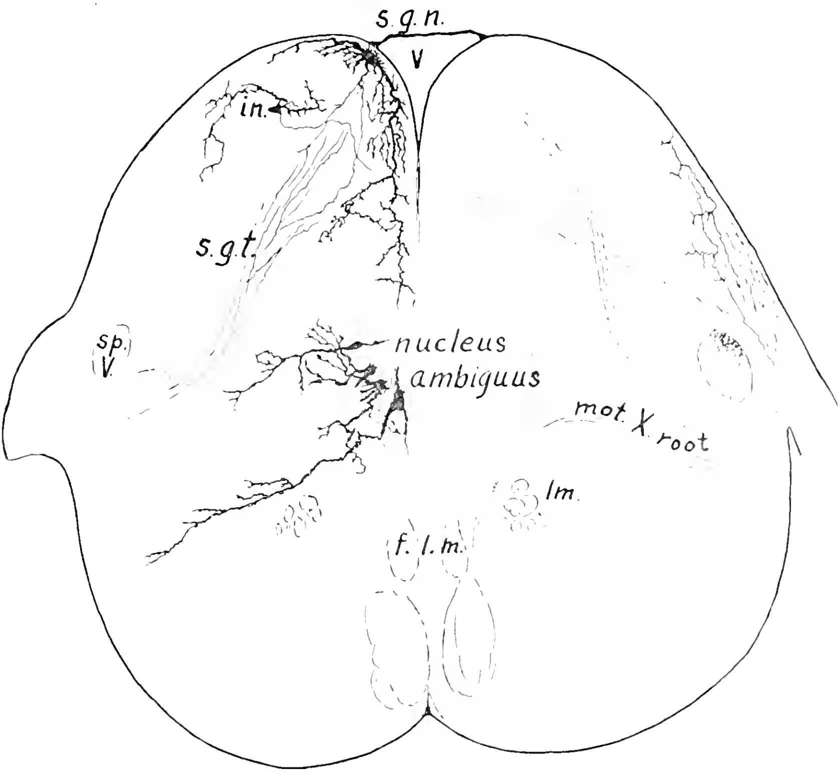

Fig. 30. Transverse section through the vagal lobes of *Ameiurus nebulosus.* GOLGI method. ×60.

On the left side is shown a gustatory neurone of the dorsal secondary group (*s.g.n.*), whose neurite enters the secondary gustatory tract (*s.g.t.*). The preparation shows one of the intrinsic neurones of the vagal lobe (*in.*), also several cells of the nucleus ambiguus. On the right side are seen some of the simpler termintions of the communis root of the vagus.

The dorsal portion of the superficial roots of the vagus and glossopharyngeus is the most important member of the complex. Its fibers arborize intimately intertwined with the thick thorny dendrites of the dorsal secondary neurones (Figs. 30, 31, 32). These are very highly differentiated cells whose neurites arise from the cell body and constitute the secondary gustatory tract, or central gustatory path. Their dendrites are

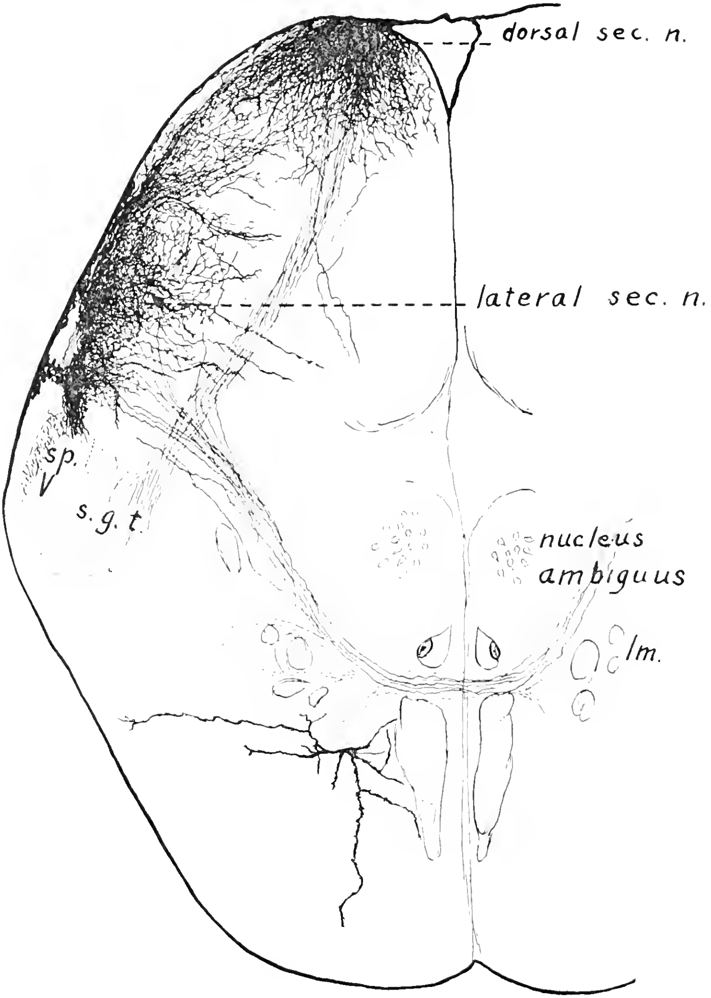

Fig. 31. Transverse section through the cephalic part of the vagal lobes of *Ameiurus nebulosus.* From a GOLGI preparation. × 90.

It illustrates the general relations of the termini of the gustatory fibers of the vagus. Dorsally these root fibers form dense arborizations about cells of the dorsal secondary group of the vagal lobe (*dorsal sec.n.*), and ventrally about cells of the lateral secondary group (*lateral sec.n.*). From the dorsal group neurites pass downward and outward into the secondary gustatory tract (*s.g.t.*); from the lateral group neurites pass to the opposite side through the ventral commissure (cf. Fig. 33).

very thick, thorny and much branched, interlacing with the root fibers to form a very dense neuropil in the most superficial layer of the vagal lobe.

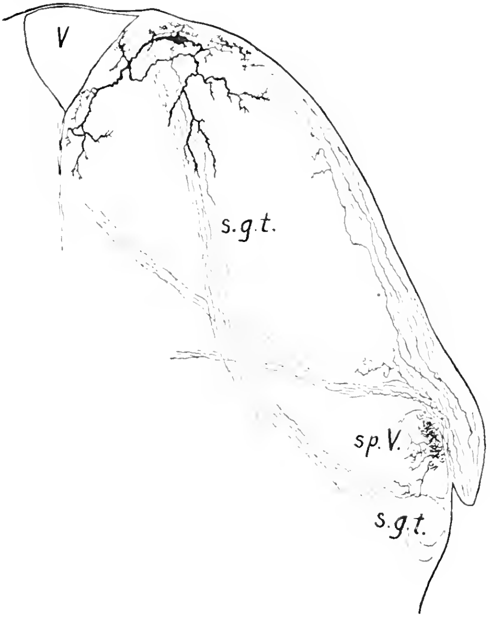

Fig. 32. Transverse section through the vagal lobe of *Ameiurus nebulosus*, illustrating a secondary gustatory neurone similar to that shown in Fig. 30. Golgi method. × 60.

As the figures show, they are very unlike the corresponding cells of the vagal lobe of the larger cyprinoid fishes, whose minute cell bodies are closely crowded around the periphery with the bushy dendrites thrust directly inward and giving off at the apex the neurite. These cells are exceedingly numerous in the carp and relatively few in the cat fish, and this fact doubtless explains the difference in form. Probably neither type is very near the primitive form. Johnston figures in his Petromyzon paper ('02, Figs. 7 and 21) chief cells of the vagal lobe of Lampetra whose cell bodies lie close to the ventricle and give off the neurite directly, while the busy dendrite is directed toward the periphery. Houser ('01) unfortunately secured no impregnations of the chief gustatory cells of the shark, his preparations showing only the intrinsic type II cells. In Acipenser Johnston ('01) finds these cells similar to my impregnations of the cyprinoids, but much simpler.

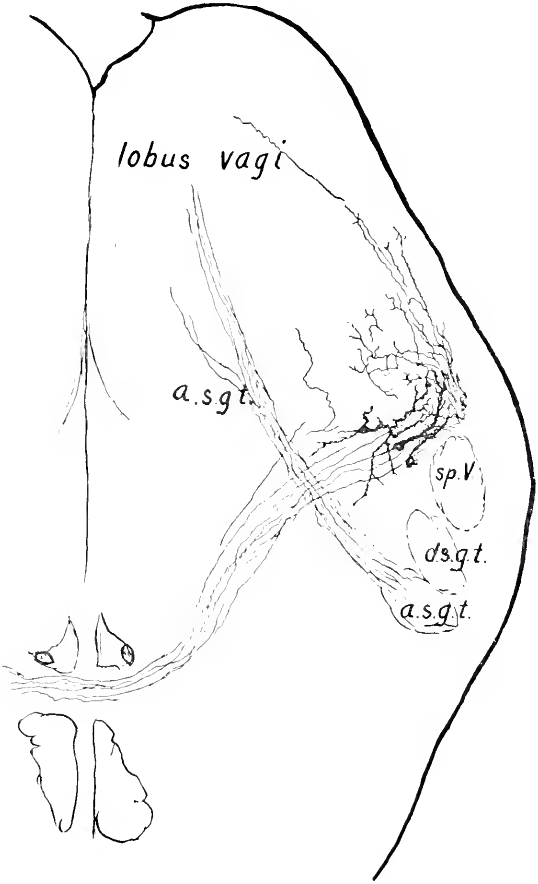

Fig. 33. Portion of a transverse section through the oblongata of *Ameiurus nebulosus* in the cephalic part of the vagal lobe. From a Golgi preparation. × 90.

The section illustrates terminal arborizations of the most cephalic fibers of the gustatory root of the vagus among the dendrites of the neurones of the lateral secondary group and the course of the neurites from the latter through the raphé toward the substantia reticularis of the opposite side. *a.s.g.t.*, ascending secondary gustatory tract from vagal lobe; *d.s.g.t.*, descending secondary gustatory tract from facial lobe; *sp. V.*, spinal V tract.

The neurites from the cells of the lateral secondary gustatory nucleus are in the main directed across the raphé through the ventral commissure to reach the substantia reticularis grisea of the opposite side of the oblongata (Figs. 31, 33). Here they may come into relation with the dendrites of the nucleus ambiguus and other motor nuclei. They are to be regarded as direct reflex paths, differing from those provided by the intermediary neurones in that there is no type II cell interpolated between the root fiber and the tract neurone. Since this arrangement prevails also for the main ascending gustatory path, it is probable that this is the path of direct motor reflexes excited by the gustatory communis root fibers rather than by the unspecialized visceral element.

The dorsal and lateral groups of chief secondary neurones receive by far the greater part of the vagal communis root fibers, and since most of these root fibers are gustatory in function, we may infer with great confidence that the more lateral group of secondary neurones is the chief path for direct gustatory reflexes in the medulla oblongata and spinal cord, while the more dorsal group is the main ascending or central gustatory path.

Neurites from the dorsal group of secondary neurones pass through the middle of the vagal lobe in slender compact bundles, directed downward and outward to a position ventrally of the spinal V tract. Here they turn and take a longitudinal direction, most turning cephalad and constituting the ascending secondary gustatory tract ("sekundäre Vagusbahn," MAYSER), but some caudad. The latter are derived chiefly from the more lateral part of the vagal lobe and more probably should be relegated to the cells of the more lateral group of neurones. The relations of the ascending fibers from the vagal lobe and both the ascending and the descending fibers from the facial lobe are indicated in Fig. 37.

The relations of the cells of the intermediary nucleus of the vagal lobe are not very clearly brought out in my preparations. Figs. 29 and 34 show their dendrites in relation with the neurites of type II cells of the vagal lobe. Some preparations suggest that the neurites of these cells end in relation with cells of the nucleus ambiguus. Other preparations show their neurites extending out into the substantia reticularis (right side of Fig. 34), and still others show their neurites passing into the decussating tract for the ventral commissure, probably for the substantia reticularis of the opposite side. Completely impregnated neurones of the latter type are figured by VAN GEHUCHTEN ('94, Plate I, Fig. 13) for the trout. Some of these neurites reach the level of the commissura infima Halleri and arborize among the cells of the commissural nucleus of CAJAL. In

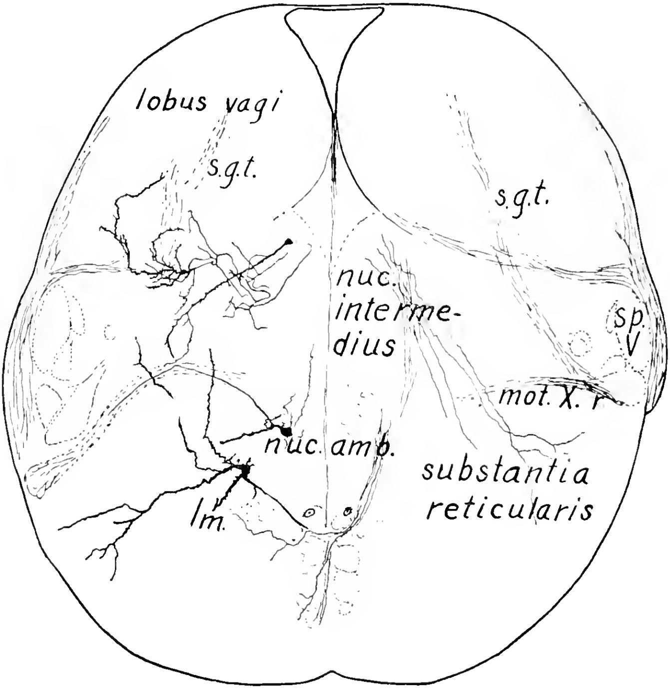

Fig. 34. Transection through the vagal lobes of *Ameiurus melas.* GOLGI method. × 50.

The figure shows on the left an intrinsic neurone whose neurite (of type II) arborizes in the nucleus intermedius. One neurone of the latter nucleus is impregnated, though only the proximal part of the neurite is shown. On the opposite side similar neurites are seen to enter the substantia reticularis grisea and the tract for the ventral commissure.

this way are provided extensive pathways for vagus reflexes both of the gustatory and unspecialized visceral type. This layer of intermediary neurones extends caudad from the vagal lobes directly into the commissural nucleus and the latter is probably in part a differentiation from it. The motor layer of the vagal lobe of cyprinoids occupies the position corresponding to these intermediary neurones, but the structures are not exactly equivalent. These cells are probably represented in the carp by intrinsic neurones which send their neurites into the substantia reticularis. I have no preparations of Ameiurus showing motor root fibers springing from this nucleus, such as arise from the motor layer of the vagal lobe of the carp. Here, as in the cyprinoids, there is no direct path between the termini of the primary gustatory root fibers and the motor nuclei of the oblongata. The most direct return reflex path is by way of the nucleus ambiguus whose neurites pass directly out to the striated branchial musculature. But the dendrites of these cells in no case come into relation with the termini of sensory root fibers. On the other hand, they ramify in the substantia reticularis (Fig. 30) and at least one neurone is always intercallated between them and the sensory root fibers. A similar relation prevails for the connections with the other motor nuclei.

The *facial lobes* of Ameiurus are considerably larger than the vagal lobes and each is incompletely divided into mesial and lateral lobules by a shallow fissure. Both lobules receive the terminals of the very large communis root of the facial nerve, this root entering the lobus from in front at its ventrolateral border and spreading out in many strands which pass upward through the lobe to reach its exposed surfaces. The internal structure is in general similar to that of the vagal lobes. There are numerous very small intrinsic neurones and larger secondary neurones bordering the surface, which differ somewhat in form from those of the vagal lobe.

Fig. 35 shows some of the simpler types of endings of the root fibers. The interior of the lobe in occupied by intrinsic neurones of type II which are similar to those of the vagal lobe (Fig. 35 *in.*). The secondary connections are likewise essentially similar. The large tract of descending neurites shown in Fig. 37 passing from the facial lobe arises from the lateral part of the lobe, while the ascending secondary tract, or central gustotory path, takes its origin from the more mesial portion of the dorsal surface. These chief gustatory neurones of the facial lobe are like those of the vagal lobe in staining reaction, position and general relations. They are, however, smaller with more slender dendrites. One of them is shown in the dorsal

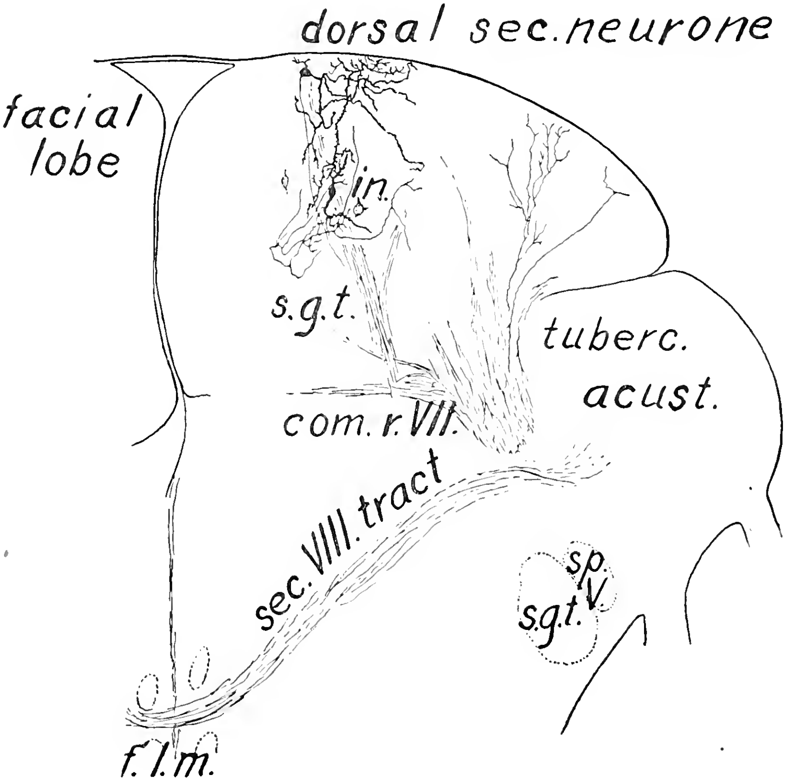

Fig. 35. Portion of a transection though the cephalic end of the right facial lobe of *Ameiurus nebulosus*. GOLGI method. × 60.

The communis (gustatory) root of the facialis (*com.r. VII.*) enters from below. Dorsally is a single impregnated chief secondary neurone whose neurite enters the secondary gustatory tract (*s.g.t.*), and below it is an intrinsic neurone of type II (*in.*).

part of Fig. 35 and another as seen from above in horizontal section in Fig. 36. Ventro-mesially of the facial lobe, especially its caudal part, is a region of sparse cells which extends caudad to join the intermediate nucleus of the vagal lobe. It will be termed the intermediate nucleus of the facial lobe and is strictly comparable with the corresponding region of cyprinoids.

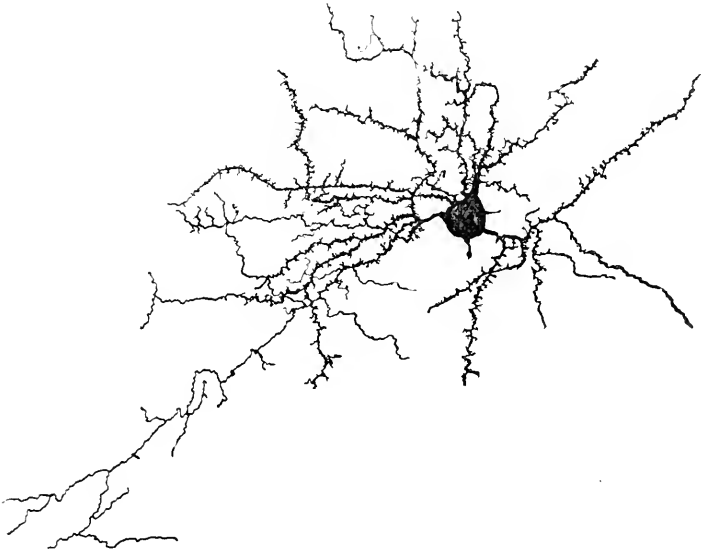

Fig. 36. A secondary neurone of the dorsal part of the facial lobe of Ameiurus as seen from above. GOLGI method. × 500.

Drawn from a horizontal longitudinal section passing through the extreme dorsal part of the facial lobe. The neurite extends ventrally at right angles to the plane of the section (cf. Fig. 35) and hence of course does not appear in this preparation.

The greater part of the chief gustatory neurones of the vagal and facial lobes, as we have seen, send their neurites into the ascending secondary gustatory tract, or central gustatory path (secondary vagus bundle of MAYSER). This ascending tract terminates in the secondary gustatory nuclei under the cerebellum, partly on the same side and in smaller numbers on the opposite side. These nuclei lie in the isthmus close under the cerebellum at the point where the body of this organ is joined by the valvula cerebelli. The two nuclei are connected by a broad dorsal commissure, above which is a commissure of the acustico-lateralis centers lying under the lateral extensions of the cerebellum. They are enveloped on all sides by tracts of fibers running vertically between the cerebellum and the regions in the brain stem below and cephalad of the nuclei, the cerebellar tracts forming a sort of capsule around the grey nuclei, these relations being the same as already described for cyprinoids. The relations of this nucleus and its tracts are shown in Fig. 37.

The intrinsic neurones of these nuclei are rarely well impregnated in my GOLGI preparations. The fibers of the central gustatory path end for the most part in free arborizations among these cells without crossing. But some of the tract fibers are clearly seen to cross to the opposite nucleus through the commissure of the secondary gustatory nuclei, as MAYSER has stated.

The tertiary tract arises from the chief cells in the cortical portions of the nucleus. These are frequently impregnated

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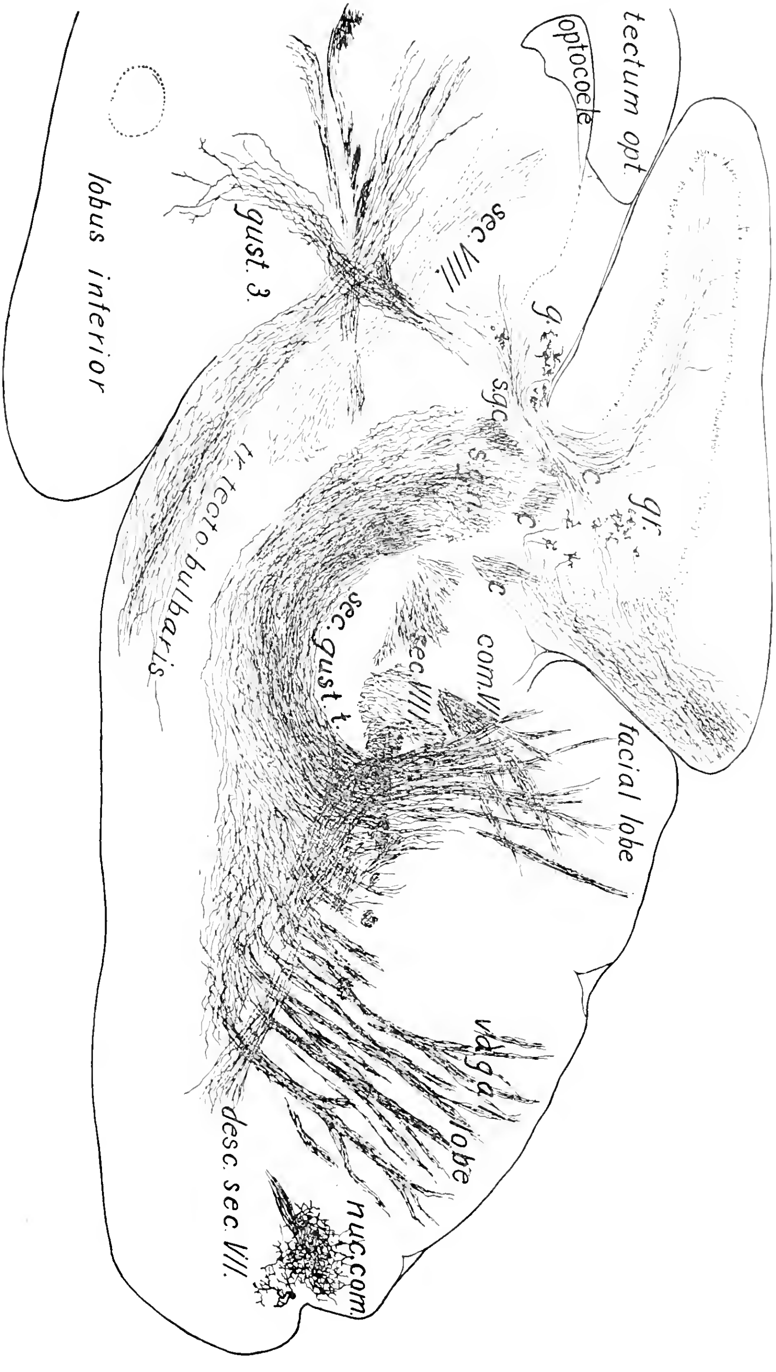
Fig. 37. A parasagittal section taken through the brain of *Ameiurus nebulosus* so cut as to pass through about the middle of one vagal and one facial lobe and the lateral part of the cerebellum (cf. Figs. 5 and 20). Drawn from a single GOLGI preparation. × 45.

The section shows nearly the whole course of the central gustatory path (*sec.gust.t.*), composed of neurites of the chief secondary gustatory neurones of the vagal and facial lobes which terminate in the secondary gustatory nucleus (*s.g.n.*) under the cerebellum. The origin of the facial portion of the descending secondary gustatory tract (*desc.sec. VII.*) is seen in the facial lobe. In the facial lobe there is also seen a portion of the lateral part of the communis root of the facial nerve (*com. VII*) passing up to arborize within the lobe. The neurones of the vagal and facial lobes, which were richly impregnated in the preparation, are omitted from the drawing for the sake of simplicity. Along the cephalic border of the secondary gustatory nucleus is the beginning of the secondary gustatory commissure (*s.g.c.*). The origin of the tertiary gustatory tract from the secondary nucleus is not shown, but the terminations of these fibers (*gust.3*) are illustrated in the inferior lobe.

Bundles of fibers from the tuberculum acusticum are seen under the facial lobe, where they decussate, and their termini in the nucleus lateralis mesencephali (torus semicircularis or colliculus) are also shown (*sec. VIII*). Under the cerebellum are the cerebellar tracts which envelop the secondary gustatory nucleus (*c*). Granules of the cerebellum are marked *gr.*; those of the valvula, *g*. The bodies of the Purkinje cells of the cerebellum are indicated by dotted outlines. *nuc.com.*, is the commissural nucleus of CAJAL.


tectum opt.
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facial lobe
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and are of the same type as in cyprinoids. Their neurites, mingling with the tractus lobo-cerebellaris, pass down to end in the inferior lobe of the same side, essentially as already described for the carp. The ventral portion of this tract and its terminal arborizations are seen in Fig. 37.

The return path in the oblongata by way of the tractus lobo-bulbaris is also essentially as described for the carp.

SECTION V. SUMMARY AND GENERAL CONCLUSIONS.

In this section a brief summary of the facts as described in the preceding pages is followed by a discussion of some of the morphological considerations growing out of them.

The teleostean fishes generally possess taste buds freely scattered over the mucous surfaces of the mouth, gills and lips. The group of Ostariophysi is characterized by a very great development of this system of sense organs—in the siluroids in the outer skin and barblets and in the cyprinoids both in the outer skin and in still greater degree in the palatal organ within the mouth.

It has previously been shown experimentally that these fishes do in reality taste with their cutaneous taste buds, which are often called terminal buds and which have no relationship whatever with any variety of lateral line organs. Furthermore, while pure cutaneous gustatory stimuli can be localized by the fish, ordinarily both gustatory and tactile stimuli cooperate in the discrimination and localization of food objects.

The distribution and innervation of the organs of taste have been accurately determined for the siluroid fish, Ameiurus, all of them being innervated by the communis system of peripheral nerves. The nerves from the buds in the outer skin enter the brain exclusively by the facialis root ; those from within the mouth by the facialis, glossopharyngeus and vagus roots, chiefly the latter. A special tuberosity of the brain, the lobus vagi, serves in fishes generally as the primary cerebral center for all gustatory nerves. This is greatly enlarged in some cyprinoids to provide for the taste buds in the palatal organ, and in both cyprinoids and siluroids there is another tuberosity developed, the lobus facialis, which receives all the gustatory nerves from the outer skin.

The purpose of this study is to trace the farther course of these gustatory pathways within the brain and in particular to map out the reflex paths for the various types of gustatory reaction which have been actually observed in the feeding activities of these fishes.

Peripheral gustatory nerve fibers (especially those of the X and IX nerves) enter the brain in company with unspecialized visceral sensory fibers from which they can be distinguished within the brain only with difficulty. This mixed system is spoken of as the communis system of nerves and centers. It is probable that the complete analysis of this complex can be made only by the degeneration method. But the comparative method has enabled us to determine with great probability the chief secondary connections of both types of fibers and so to prepare the way for an accurate determination of the gustatory pathways in the human brain, which are at present almost wholly unknown.

In the cyprinoids and siluroids the primary gustatory centers possess in both the facial and the vagal lobes two types of secondary neurones; (1) small intrinsic neurones (largely of GOLGI's type II) filling the interior of the lobe, and (2) larger and very highly specialized neurones superficially arranged over the lobes—the chief secondary gustatory neurones.

The intrinsic neurones serve to diffuse incoming stimuli throughout the substance of the lobes and those with longer neurites effect connections with adjacent motor areas, chiefly by way of the substantia reticularis grisea. These connections are probably very largely for unspecialized visceral sensory reflexes, as well as for direct response of the mandibular branchial and palatal musculature (muscles of the visceral system) to gustatory stimulation, and are probably substantially similar in all vertebrates.

The chief gustatory neurones of both vagal and facial lobes give rise to the long paths of secondary connection for distant parts of the brain. Their dendrites receive directly the peripheral gustatory terminals of the first order and their neurites either descend to the inferior secondary gustatory nucleus in the region of the funicular nuclei or ascend to the superior secondary gustatory nucleus in the isthmus. In both cases the path is mainly and perhaps exclusively gustatory in function.

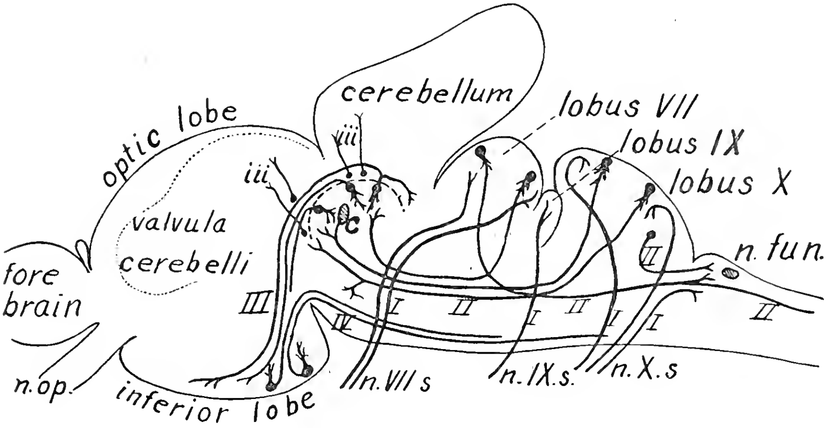

Fig. 38. Diagram of the gustatory paths in the brain of the carp as seen from the side. Only the long paths are shown in this diagram (cf. Fig. 39).

n. VII.s., n. IX.s., and n. X.s., represent the sensory root fibers of the facialis, glossopharyngeus and vagus respectively, or gustatory neurones of the first order (*I*). The secondary tracts, both ascending and descending, are marked *II*. The tertiary path to the inferior lobe is marked *III*; the path to the cerebellum and valvula, *iii*. The return path from the inferior lobe to the motor nuclei of the oblongata (tractus lobo-bulbaris) is marked *IV*. The commissures of the inferior and superior secondary nuclei are indicated by shaded areas (the latter marked *c*). *n.op.*, the optic nerve. The area marked *n.fun.* includes the funicular nucleus and the inferior secondary gustatory nucleus.

In cyprinoids the gustatory neurones of the smaller type probably share both this function and that of the intrinsic neurones. In no case does a peripheral gustatory neurone connect directly with a peripheral motor neurone. There is always at least one intermediate neurone between them.

The vagal lobes of the larger cyprinoids differ from those of the siluroids, in addition to the points already mentioned, in the following respects: (1) The chief secondary neurones, being exceedingly numerous and crowded in a narrow peripheral layer, thrust their dendrites inward in a radial direction and there engage the termini of the peripheral neurones of the first order instead of spreading out tangentially among these termini, and the neurite arises from the tip of the dendrite. This ar-

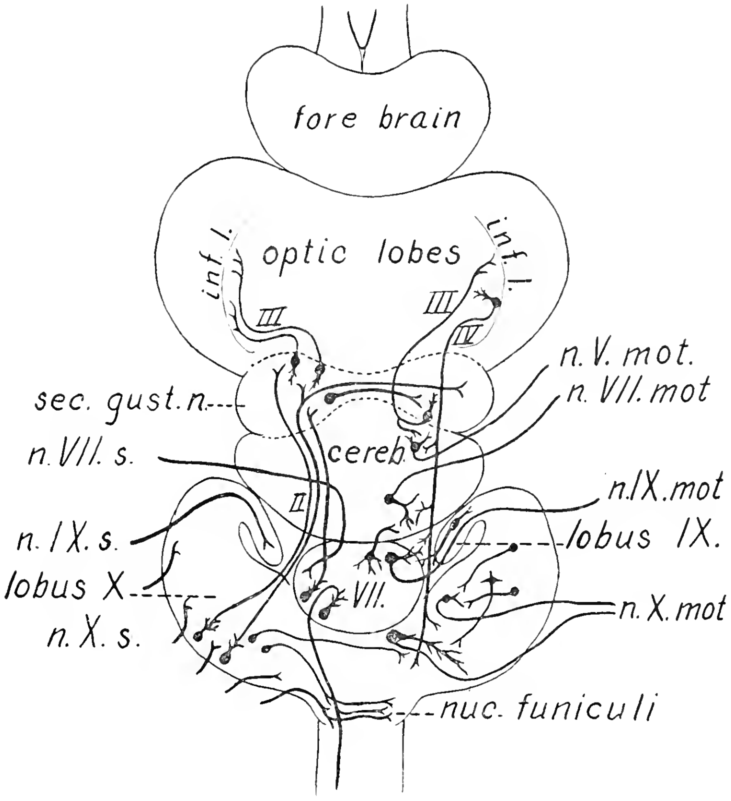

Fig. 39. Diagram of the gustatory paths in the brain of the carp as seen from above. Designations in general as in Fig. 38.

The sensory root fibers and long sensory tracts are indicated on the left side; the short paths, return path from the inferior lobe and motor root fibers, on the right side. The lines, *inf.l.*, designate the outer margins of the inferior lobes. The dendrites of all the motor nuclei ramify in the substantia reticularis grisea. Two types of motor fibers are indicated in the vagus root (*n.X.mot.*), (1) those from the motor layer of the vagal lobe (above), and (2) those from the nucleus ambiguus (below). The facial lobe is designated, *VII*; the superior secondary gustatory nucleus, *sec.gust.n.* The area designated *nuc.funiculi* contains also the inferior secondary gustatory nucleus.

rangement is probably merely a device for economy of space (cf. Figs. 10 and 30). (2) The deepest cells of the vagal lobe are motor neurones (probably derived phylogenetically from the underlying nucleus ambiguus and related to the dorsal motor nucleus of the vagus of FOREL *et al.*) which supply directly the intrinsic muscles of the palatal organ. These motor cells are not present in recognizable numbers in siluroids or other teleosts—correlated with the absence of the palatal organ. (3) A large proportion of the intrinsic neurones serve as intermediaries between the peripheral termini and the motor layer of the vagal lobe, thus providing for a reflex connection within the lobe between the taste buds on the palatal organ and the intrinsic muscles of that organ.

The main paths of gustatory conduction in these fishes may be summarized as follows (cf. the accompanying schemata, Figs. 38 and 39.)

A. Short Paths.

1. Impulses originating in taste buds on the palatal organ pass by way of the X and IX nerves to the vagal lobe; then through the intrinsic neurones to the motor layer and the intrinsic muscles of the palatal organ (in cyprinoids only).

2. From peripheral termini in both the vagal and facial lobes to the substantia reticularis of the same side via intrinsic neurones, the smaller type of marginal neurones (in cyprinoids) and collaterals of the chief neurones. These neurones of the second order, either directly or through the mediation of tertiary neurones of the substantia reticularis grisea, reach the dendrites of the visceral motor nuclei of the medulla oblongata. This provides a pathway for reflex movements of the lips, barbels, tongue, jaws, gills and pharynx in response to gustatory stimulation.

3. Some of the chief gustatory neurones send their neurites directly across the raphé, probably to end in the substantia reticularis of the opposite side of the oblongata. There is also, of course, indirect connection between the substantia reticularis of the two sides of the body, thus providing for coordinated action of the muscles of both sides.

4. The nucleus intermedius of the vagal lobes and the associated substantia reticularis extend caudad from their lobes to fuse directly with important gustatory centers lying mesially of the funicular nuclei—the inferior secondary gustatory nuclei. These nuclei are connected by the commissura infima HALLERI and the commissural nucleus of CAJAL is a specialized part of this gustatory center. These nuclei are very intimately related to the funicular nuclei and thus afford a mechanism of correlation between gustatory and tactile impressions.

B. Long Paths.

5. The descending secondary gustatory tract arises from the chief gustatory cells of the facial lobe mainly and terminates partly in the inferior secondary gustatory nucleus and a smaller part lower down in the spinal cord. This puts the taste buds in the outer skin into very direct relations with the trunk musculature and so provides for the body movements necessary to turn and seize food after its detection by contact with cutaneous taste buds. This inferior nucleus, as stated above, is connected by a rich fibrous plexus with the funicular nucleus, which is the primary tactile coordination center for the skin of the head and trunk. Thus the cutaneous gustatory and tactile impressions may be brought into relation, as required by the physiological evidence that these senses cooperate in the localization of food objects.

6. The ascending secondary gustatory tract arises from the chief secondary neurones of both vagal and facial lobes and terminates in the superior secondary gustatory nucleus located in the lateral wall of the isthmus (the "Rindenknoten" of MAYSER). It ends chiefly on the same side, but a part of its fibers cross through the commissure of the secondary nuclei to end in the opposite nucleus.

The superior and inferior secondary gustatory nuclei are both specializations of the substantia reticularis grisea. The superior nucleus is especially intimately connected with the motor V nucleus, partly directly and partly through another specialized area termed the substantia reticularis grisea trigemini. It also has connections cephalad with the region of the eye-muscle nuclei and the nucleus of the fasciculus longitudinalis medialis, thus putting the gustatory system into physiological relation with the somatic motor centers. There is also probably an important connection between the superior nucleus and the cerebellum and valvula cerebelli by way of the nucleus lateralis valvulae. These important mesencephalic and cerebellar connections merit much more thorough study.

7. The chief tertiary gustatory tract arises from cells in the cortical layer of the secondary nucleus, whose dendrites receive the terminal arborizations of the secondary fibers. This tract is heavily medullated and mingles with the tractus lobo-cerebellaris (EDINGER) and other vertical tracts connecting with the cerebellum, so that it is difficult to follow it separately. GOLGI impregnations show that its fibers pass ventrad and slightly cephalad to arborize widely throughout the lateral lobule of the inferior lobe (hypoaria, C. L. HERRICK) along with others from the forebrain, tectum, etc. This appears to be the chief center for the correlation of olfactory and other higher senses.

8. The return path for all of these sensory activities of the inferior lobe is the tractus lobo-bulbaris, the dendrites of whose cells of origin ramify widely among the gustatory and other terminals just mentioned. This tract (MAYSER'S "Nervenfaser-bundel x") passes into the oblongata mesially of and partly enclosed by the ascending secondary gustatory tract and along the lateral border of the substantia reticularis grisea, within which its fibers gradually diffuse themselves. Through the medium of this reticular area the descending impulses from the inferior lobe come into relation with the peripheral motor neurones of the oblongata and probably also of the spinal cord, thus providing for the most complex reflexes of which the fish is capable.

TABLE OF THE GUSTATORY PATHS IN FISHES.

A. PERIPHERAL NEURONES—GUSTATORY NEURONES OF THE FIRST ORDER.
  I. Radix communis facialis.
  II. Radix communis glossopharyngei.
  III. Radix communis vagi.

These radices contain unspecialized splanchnic fibers in addition to gustatory fibers. In their intra-medullary courses they unite to form the fasciculus communis of the Ichthyopsida, or the fasciculus solitarius of birds and mammals. In some animals the secondary gustatory fibers are also in part represented in this tract.

B. NUCLEUS GUSTUS PRIMUS.

The communis roots terminate in a medullary center which may be termed the primary communis center. That portion of this center which receives the gustatory component of these roots is the primary gustatory nucleus. It may be single, but in the fishes described in this paper is double.

  I. Lobus Vagi.
    1. Layer of root fibers.
    2. Layer of secondary neurones.
      1) Chief secondary neurones.
      2) Intrinsic secondary neurones.
    3. Layer of secondary gustatory tracts.
    4. Layer of motor neurones.
    5. Ependyma.

These layers occur as above only in some cyprinoids. In place of the 4th layer in siluroids is the nucleus intermedlus vagi, and in these fishes the chief gustatory neurones are arranged in dorsal and lateral groups with somewhat different secondary connections.

  II. Lobus facialis (=tuberculum impar=lobus trigemini, MAYSER).
    1. Chief secondary neurones.
    2. Intrinsic secondary neurones.
    3. Nucleus intermedius facialis.
  III. Lobus glossopharyngei (in cyprinoids only).

C. TRACTUS GUSTUS SECUNDUS DESCENDENS.
  1. Pars facialis (distinct only in cyprinoids and siluroids).
  2. Pars vagi (part of the spinal portion of the fasciculus solitarius in mammals).

D. TRACTUS GUSTUS SECUNDUS ASCENDENS (central gustatory tract = "sekundäre Vagus-Trigeminusbahn," MAYSER).
  1. Pars facialis (in cyprinoids and siluroids only).
  2. Pars vagi.

E. NUCLEUS GUSTUS SECUNDUS INFERIOR.

F. NUCLEUS GUSTUS SECUNDUS SUPERIOR (central gustatory nucleus = "Rindenknoten," MAYSER=secondary vagus nucleus, JOHNSTON).
  1. Commissure of secondary gustatory nuclei.
  2. Intrinsic neurones (mainly commissural ?).

3. Chief tertiary gustatory neurones.

G. TRACTUS GUSTUS TERTIUS.
  1. Ad lobum inferiorem.
  2. Ad cerebellum.
  3. Ad mesencephalon.
  4. Ad substantiam reticularem.

A detailed discussion of the *mammalion homologies* of the tracts and nuclei enumerated in the preceding table is as yet premature. Much further work on the intermediate types remains to be done before such comparisons can have much value except as suggestions for further research.

In the human body the lingual branch of the glossopharyngeal nerve (from taste buds at the base of the tongue) undoubtedly corresponds to a portion of the pre-trematic branch of the same nerve in fishes. The course of the peripheral gustatory nerve from the taste buds at the tip of the tongue is still disputed, though the evidence is rapidly accumulating that this course is via the lingual nerve, chorda tympani and portio intermedia of WRISBERG into the fasciculus solitarius. The homologies of the chorda tympani have given comparative anatomists a world of trouble. If the gustatory component of the chorda in man supplies taste buds on the tip of the tongue, it is obvious that in the fishes there can be no strictly homologous nerve, for there is no fleshy tongue in fishes. From what branch of the piscine facial nerve the mammalian chorda tympani has been specialized is uncertain—possibly from none of them.

The identification of the fasciculus communis of amphibia with the fasciculus solitarius of mammals was a very important step in advance. In the teleosts the case is much more complicated and difficult of correlation. But the descriptions of CAJAL ('96, p. 43) permit comparisons which are very close in all fundamental respects. In the new-born mouse there is a single sensory root for the vagus and glossopharyngeus and a single terminal nucleus which is the grey substance associated with the fasciculus solitarius. In addition to the dorsal nucleus of KÖLLIKER, which is a specialized portion of this substance, there is another and more important specialization from it in the region of the funicular nuclei. Here is a commissure which corresponds to the commissura infima HALLERI of teleosts and a commissural nucleus which is also present in fishes and which is closely related to the inferior secondary gustatory nucleus of my descriptions. In the mouse the greater part of the primary sensory root fibers of the IX and X nerves appears to end in this nucleus; in the fishes a very small part, while the greater part of the fibers end in the vagal lobe whose sensory portion is homologous with the dorsal sensory nucleus of KÖLLIKER. The commissural nucleus of CAJAL, as a primary end-station for the spinal root of the vagus, is homologous with the terminal nucleus of the descending vagus root fibers associated with the inferior secondary gustatory nucleus. The latter nucleus is not represented in CAJAL's descriptions, though I venture the prediction that further study of the mammals will show that it too is represented in the commissural nucleus. CAJAL finds that the neurites of the cells of the commissural nucleus enter the lemniscus along with secondary tracts from the funicular nuclei (secondary tactile path), and here again the teleostean and mammalian relations are closely parallel.

HIS has shown that the fasciculus solitarius, when first apparent in the human embryo, lies, like the spinal V, superficially on the lateral border of the oblongata and its deeper adult position is due to the overgrowth of structures from the "Rautenlippe." In teleosts it lies still deeper, as close to the median line as possible. This may be explained by the fact that the fasciculus solitarius as a visceral sensory tract is more ancient than the specialized somatic sensory enlargement (tuberculum acusticum) of this part of the oblongata. The communis VII + IX (= fasc. communis) was therefore passively crowded inward from the primitive superficial position by the over-growth of the tuberculum acusticum (and later by the "Rautenlippe" for the olive) and prevented from passing ventrally by the great ventro-lateral tracts and the secondary mechanism for the tuberculum acusticum. The spinal V tract, however, being organically connected with the somatic sensory centers here developed, retained its superficial position with reference to them. In passing from the fishes to the mammals the fasciculus solitarius has been crowded again somewhat laterally on account of the further development of median structures.

The short gustatory paths between the primary centers and the motor nuclei of the oblongata by way of the substantia reticularis are essentially the same in the fishes and mammals.

The homology of the nucleus ambiguus of fishes and mammals is not open to question. FOREL in 1891 showed that the so-called chief or dorsal sensory nucleus of the IX and X nerves of mammals is in reality a motor nucleus of origin for these nerves and much evidence in confirmation of this view has since been published. The motor layer of the vagal lobe of cyprinoids corresponds in position exactly with this nucleus and is probably in a broad way homologous with it, though of course the homology is not exact.

The long ascending secondary tracts from the vagal and facial lobes (central gustatory path, or tractus secundus ascendens) has not been identfied in any vertebrates save the fishes, though it has long been in the minds of several neurologists that the homologies of this tract are to be sought in the lateral cerebellar tract of FLECHSIG (tractus spino-cerebellaris dorsalis, EDINGER). These fibers are known to arise from the cells of CLARKE'S column (supposed to be a visceral sensory center) and to enter the vermis cerebelli by way of the restiform body of the same side. Dorsally of the ventricle they cross to the opposite side and the whole arrangement strongly suggests a survival of a primitive secondary tract from the visceral sensory center of the spinal cord to the isthmus, to which in fishes the strong secondary gustatory tracts arising in the oblongata are added. This suggestion, however, cannot be taken seriously until we have much more exact knowledge of the superior connections of these fibers in the mammals and of the comparative anatomy of the structures at the base of the vermis cerebelli.

The morphological relations of the secondary gustatory tract and nucleus are clearly defined. The tract represents a specialization of the substantia reticularis alba and the nucleus a similar derivative of the substantia reticularis grisea. The lemniscus (fasciculus lateralis) of these fishes represents a similar specialized somatic sensory path from the primary tactile and acustico-lateral centers to the nucleus lateralis mesencephali (torus semicircularis, or colliculus), whose fibers cross in the ventral commissure of the oblongata. This special splanchnic (gustatory) path appears to have been differentiated later in the phylogeny than the secondary somatic path. Hence its superficial position, coenogenetic structures of the brain being generally added external to palingenetic structures. The crossing of the visceral path within its terminal nucleus instead of at its origin in the oblongata is perhaps due to the same cause, the primitive undifferentiated visceral path having been uncrossed or diffusely crossed because these sensations are not localized ordinarily. The *unspecialized* secondary visceral path doubtless is as primitive as the unspecialized somatic path and probably was originally a diffuse connection by short fibers in the substantia reticularis (crossed or uncrossed). But the ascending gustatory tract (specialized visceral) as a well defined conduction path is quite certainly more recent. This does not affect the conclusion to which we were led above that the visceral root fibers (fasciculus communis) are older than the *special* somatic centers in the tuberculum acusticum.

The topography of the oblongata suggests that upon the basis of the unspecialized centers the ascending secondary paths for the specialized systems were added in the following order,—first, the somatic sensory, or lateralis system for orientation and equilibrium, and, second, the gustatory. The latter is a strictly visceral system except that in some fishes important somatic secondary connections appear sporadically in correlation with the appearance of taste buds in the outer skin.

The mammalian homologies of the superior secondary gustatory nucleus cannot be determined until its relations to neighboring structures are much more fully known. STIEDA's original designation, "Uebergangsganglion," apparently included much more than the secondary gustatory center, which is probably coextensive with MAYSER's narrower term, "Rindenknoten." Mayser ('82, p. 334) identifies the "Uebergangsganglion" with the corpus quadrigeminum posterius of Fritsch ('78). From the latter's figures, I infer that he included under this term the structures adjacent to the secondary gustatory nucleus as far as cephalad as my nucleus lateralis valvulae. The latter nucleus is apparently included in the "cells of the superior and internal regions of the torus semicircularis" of Catois ('01, p. 133). Catois' "cells of the external region of the torus" constitute the nucleus lateralis mesencephali of Edinger. Edinger states that the "Uebergangsganglion" of Stieda (sekundäre Vaguskern) is homologous with his ganglion isthmi ('96, p. 94 and '03, p. 75). He also identifies ('04, p. 194) the ganglion isthmi with the nucleus tegmenti dorsalis of von Gudden and thinks it probably is the same as Bechterew's corpus parabigeminum. Edinger adds ('04, p. 267) that the ganglion isthmi of lower vertebrates receives the median root of the optic nerve and gives rise to centrifugal fibers for the retina. His account make it probable that his ganglion isthmi sould be identified with my nucleus lateralis valvulae rather than with the "Uebergangsganglion" as a whole. Though I have not traced the fibers of the mesial optic root so far caudad as this, yet the connection with the post-optic commissure, referred to by Edinger, is very plain, and the tract running from the cephalic end of the n. lateralis valvulae to the oculomotor nuclei lends probability to the belief that the n. lateralis valvulae is in part a path for oculo-motor reflexes and probably also somatic motor reflexes via the fasciculus longtitudinalis, of optic, gustatory and perhaps olfactory origin. My n. lateralis valvulae is apparently included in the "ganglio subcerebelloso" described ('94, p. 96) and figured ('94 a, Fig. 4, p. 203) by Cajal. His figure shows the cells provided with a single thick unbranched dendrite which comes into relation with collaterals from the ventral longitudinal tracts of the mid-brain.

The only conclusion at present possible is that the "Uebergangsganglion" is a very complex structure, devoted largely to gustatory reflexes and coordinations of several sorts, and doubtless with other important connections as yet imperfectly known.

While these pages are passing through the press the excellent paper by GOLDSTEIN (Untersuchungen über das Vorderhirn und Zwischenhirn einiger Knochenfische, nebst einigen Beiträgen über Mittlehirn und Kleinhirn derselben. *Arch. f. mikr. Anat.*, LXVI, 2, 1905, pp. 135-220), on the brains of teleosts has come to hand. While GOLDSTEIN's detailed examination did not extend back into the region of the gustatory centers, yet I am pleased to note that he found and figured the tertiary path to the inferior lobes, though naturally without being able to give its functional interpretation. It has been assumed by some authors that the ganglion isthmi of EDINGER is the same as the "Rindenknoten" of MAYSER (my nucleus gustus secundus superior). GOLDSTEIN, however, terms the latter "nucleus lateralis cerebelli" and the cells which he designates as ganglion isthmi are clearly shown by his figures to be the cortical layer of tertiary gustatory neurones surroung the "Rindenknoten" as I have described them in the preceding pages. GOLDSTEIN's tractus isthmo-hypothalamicus, then, is my tertiary gustatory path to the inferior lobe. It is apparently another portion of this tertiary gustatory path which he shows in text-figure 21 (p. 206) entering the tr. cerebello-thalami from the dorsal part of the nucleus lateralis cerebelli.

There remain to be considered the *morphological relations of the gustatory system* as a whole to the other functional systems of the brain. The intimate association of gustatory fibers with those of general visceral sensation, both in the peripheral and the central nervous system, strongly suggests that the gustatory system has been specialized from this primitive source; but it must be admitted that the evidence thus far produced, while very suggestive, can hardly be called demonstrative. A comparison of the gustatory system with the "visceral sensory system" cannot be expected to yield very important results so long as the latter system remains so imperfectly understood. There is a strong demand for an analysis of the visceral nerves and for a clear understanding of the relations (both anatomical and physiological) of their various kinds with certain systems commonly classified with the somatic sensory group, such as the nerves of muscle and joint, thermal and pain (?) sensations.

Whatever the phylogenetic origin of the gustatory system, it is clear that it is confined to the cranial nerves and that in the lowliest vertebrates it is represented in at least three of these nerves. The primary terminal center does not correspond topographically with the dorsal horn of the spinal cord, but with the region of CLARKE's column. In the present state of our knowledge, no precise comparisons are possible between the gustatory secondary connections and those of the visceral centers of the spinal cord. And in the brain, where our knowledge of the connections of the nerves is more exact, there is no close resemblance between the secondary gustatory and any other secondary sensory system.

The acustico-lateral and tactile systems have been shown to be intimately related and their secondary tracts in fishes are, in a general way at least, known, crossing immediately in the ventral commissure and ascending in the lemniscus (fasciculus lateralis) to the opposite mesencephalon. Clearly there is no close resemblance here with the gustatory connections and it is difficult to conceive how either form could have been derived from the other.

Given a primitive elongated gustatory center in the oblongata, like that associated with the fasciculus communis of the amphibia, and the development of all types of primary gustatory centers known among fishes can be easily understood by simple hypertrophy of different parts of the system. We have seen in the preceding descriptions that the secondary gustatory connections are in almost all cases through the substantia reticularis grisea or derivatives from it. This applies both to the short connections and to those by way of the superior and inferior secondary nuclei. In the two latter cases the connection is partly on the same side and partly on the opposite side through a commissure.

The superior secondary nucleus is clearly adapted to serve the higher gustatory reflexes, and various coordinations, chiefly with smell and sight. The connection with the valvula cerebelli and cerebellum is very perplexing. There is a suggestion in certain comparative anatomical facts that the valvula cerebelli of teleosts (or at least its lateral lobes which are broadly confluent with the nucleus lateralis) has been differentiated in connection with the secondary gustatory nucleus. The valvula is largest in those teleosts which have the most highly developed gustatory systems, and it was noticed by MAYSER ('82, p. 325) that the cephalic part of the "Uebergangsganglion" (including my nucleus lateralis valvulae) varies in size with the valvula cerebelli, while the caudal part (which corresponds in part with our substantia reticularis grisea trigemini) varies with the size of the secondary gustatory tracts. In Mormyrus, where the lateral lobes of the valvula attain so enormous size as to expand upwards and laterally in mushroom shape and overlap the whole brain, SANDERS ('83) describes also a considerably enlarged and modified tuberculum impar and vagal lobes. Since the other parts of this brain are of the typical teleostean type, save for the reduction of the visual apparatus and inferior lobes, it appears probable that the lateral lobes of the valvula are related with the gustatory reflexes.

The chief connections of the cerebellum are with centers commonly regarded as of the somatic sensory type—tactile, acustico-lateral, visual. This strengthens the current view that this organ is concerned with the regulation of somatic movements, or reactions of the body to external stimuli as distinguished from visceral reactions to internal stimuli. A gustatory cerebellar connection would seem, therefore, very anomalous. And so it would be in an ordinary vertebrate, if our present functional analysis is proceeding along true lines. But we have seen above that the fishes here under consideration, unlike most other vertebrates, make somatic movements in response to cutaneous gustatory stimulation in their ordinary feeding reactions. This feature gives an abundant explanation for the cerebellar connections of the secondary gustatory nucleus, by way of the nucleus lateralis valvulae, as well as a possible clue to the morphology and phylogeny of the valvula.

The problem of the relation of taste and smell is of major importance from the points of view of comparative physiology, of phylogeny and of morphology. Why the single chemical sense of some invertebrates should have given rise in the vertebrates to two systems so distinct morphologically as the olfactory and gustatory apparatus has not been explained. A suggestion of a possible genetic connection is manifest in the accompanying diagram (Fig. 40) of the morphological relations.

Remembering that the secondary gustatory connections are differentiations from the substantia reticularis grisea (the anomalous position of the superior secondary nucleus being easily explained on mechanical grounds), we find here a natural explanation of the further (tertiary) path to the inferior lobe, for this is also a derivative of the substantia reticularis, crowded for mechanical reasons in the opposite direction from that taken by the secondary gustatory nucleus (cf. Johnston '02 a, p. 100). Turning now to the secondary olfactory connections, the resemblance to those of the sense of taste is striking in fundamentals, in spite of great difference in detail.

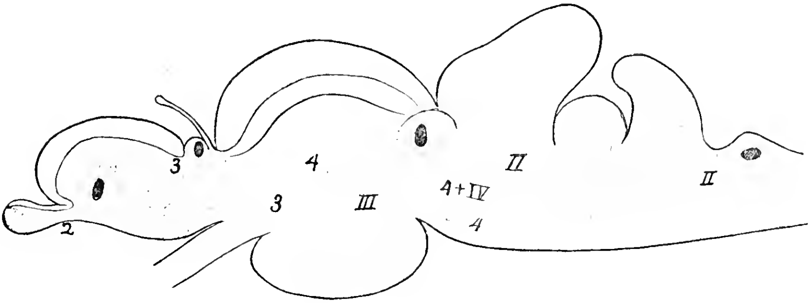

Fig. 40. Diagram showing the relations of the gustatory and olfactory centers in teleosts, as represented by the shaded areas. The black spots represent the position of commissures of secondary or tertiary fibers. 2, 3 and 4 represent the olfactory conduction paths of the second, third and fourth orders respectively. II, III, IV represent the gustatory conduction paths of the second, third and fourth orders respectively. Compare Figs. 38 and 39.

The olfactory bulb, like the vagal lobe, contains a marginal zone of large secondary cells, the mitral cells, with long neurites and with dendrites which receive the endings of the peripheral neurones. The interior of the bulb is filled with minute intrinsic neurones. The secondary center is the area olfactoria of the fore-brain, whose commissure bears the same relation to the secondary tracts as do those of the secondary gustatory nuclei. The main tertiary tract passes, as before, to the inferior lobe, which is, in fishes, the central correlation station for all sensory impressions. The return path from the inferior lobe to the epistriatum in teleosts is a prophesy of the evolution of the cortex cerebri in the later phylogeny. The olfactory and gustatory tertiary tracts end together throughout the inferior lobe and they have a common descending conduction path, the tractus lobo-bulbaris. In addition to this ventral olfactory path, there is the dorsal tertiary tract from the fore-brain to the habenula and its descending path of the fourth order, MEYNERT's fasciculus retroflexus. This path offers opportunity for somatic sensory (including optic) and somatic motor connections analogous to those provided for the sense of taste in the inferior secondary nucleus.

If the olfacto-gustatory connections of the human body are at all similar to these of fishes, this relation offers a possible anatomical correlate of the familiar fact of experience that subjectively we distriminate tastes and smells only imperfectly, in many cases not at all, without the aid of collateral physiological experimentation to determine which organ receives the stimulus.

It is freely granted that these comparisons are, in the present state of our knowledge, rather fanciful. They are offered merely as the first practicable working hypothesis for a correlation of the olfactory with the other sensory mechanisms. If the anterior end of the primary nerve tube lies in the region of the preoptic recess, as seems to be now commonly assumed, the peculiar relations of the rhinencephalon are to be explained as due to the suppression of the most anterior sensory and motor centers of other systems, leaving the olfactory apparatus free to develop without constraint.

The most striking difference noticeable in the diagram between the centers for taste and smell is the apparently ventral position of the primary and secondary olfactory centers as contrasted with the dorsal centers for taste. But if the anterior end of the brain tube lies near the preoptic recess in the lamina terminalis, this difficulty disappears; for all structures in front of this point must have been developed from the dorsal wall of the brain tube. That is, the secondary fore-brain, including the entire rhinencephalon, is a dorsal structure.

Our conclusion, then, is that the morphological relations expressed in Fig. 40 strongly suggest that the central reflex mechanisms of taste and smell have had a common phylogenetic origin and that they have been from the first quite independent of the so-called somatic sensory centers.

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Volume XIII.

ARTICLE III.
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BULLETIN
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CLARK W. CHAMBERLAIN,
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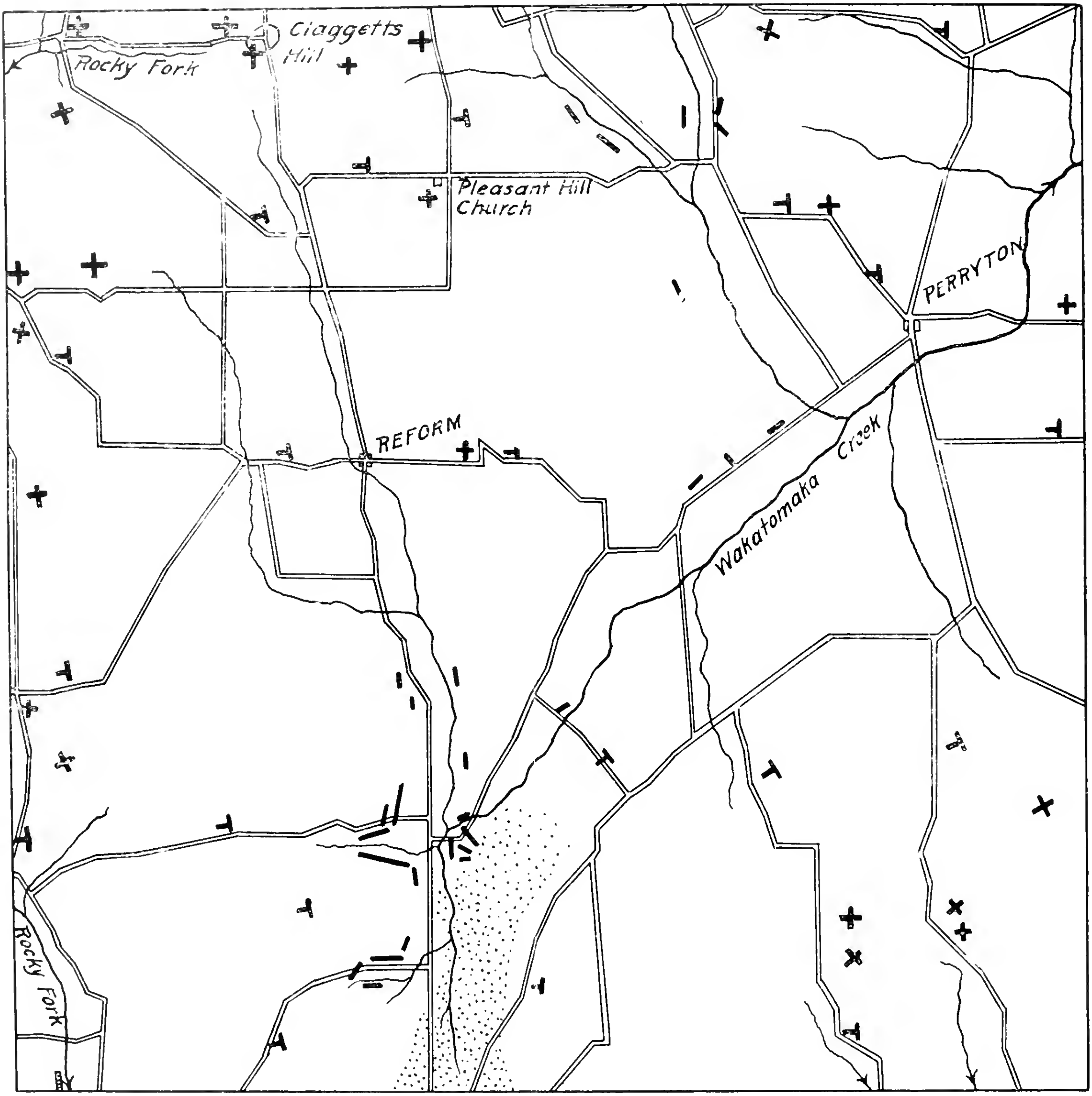
THE GEOLOGY OF PERRY TOWNSHIP, LICKING CO., OHIO.

By F. CARNEY.

Granville, Ohio, June, 1906.



PERRY TOWNSHIP,
LICKING COUNTY, OHIO.

0 ½ 1 MILE

PLATE I.

▬ BLACK HAND CONGLOMERATE
░ DRIFT AREA
+ SHARON CONGLOMERATE
┤ LOGAN FORMATION
▭ CUYAHOGA FORMATION

BULLETIN OF THE SCIENTIFIC LABORATORIES OF DENISON UNIVERSITY.
Vol. XIII. Article III. June, 1906.

THE GEOLOGY OF PERRY TOWNSHIP, LICKING CO., OHIO.

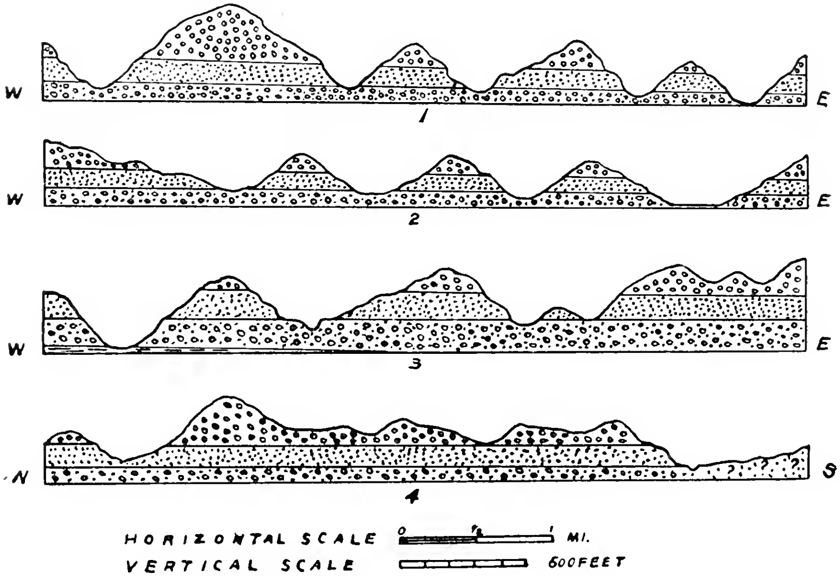
By F. CARNEY.

OUTLINE.

- I. STRATIGRAPHY
  - 1. Cuyahoga formation.
  - 2. Black Hand formation.
  - 3. Logan formation.
  - 4. Pottsville formation.
- II. TOPOGRAPAY
  - 1. Weathering.
  - 2. Water table.
  - 3. Surface slopes and rock structure.
  - 4. Present streams.
- III. GLACIATION
  - 1. Little evidence of glaciation.
  - 2. The Hanover drift.
- IV. DRAINAGE
  - 1. The Wakatomaka and tributaries.
  - 2. Well borings south of Reform.
  - 3. Extension of the Hanover Dam.
  - 4. Reversal of Drainage.
  - 5. Relation of stratigraphical structure and drainage development.

STRATIGRAPHY.

In Perry township but one stream, Rocky Fork, is flowing on rock; and this is rock-floored for less than a mile, presenting at no point a vertical rock section of more than fifteen feet. In the south central part of the township a small tributary of the Wakatomaka creek cascades across the Black Hand conglomerate at a sharp grade exposing only a portion of the formation. Scattered elsewhere we find ledges of the Black Hand, the lower part of the formation being frequently covered by talus slopes or by flood-plain deposits, while its contact with the overlying Logan is generally hidden by products of weathering. In a few places the highways crossing sharp elevations have so directed the run-off water of showers as to reveal the strata, but seldom forming a section that will admit of precise measurement. In general the uplands and slopes have a coating of residual material, while aggraded valleys prevail elsewhere. These conditions therefore have precluded any great



1. W-E SECTION THROUGH NORTH END OF TOWNSHIP
2 W-E SECTION THROUGH REFORM
3 W-E SECTION THROUGH SOUTH END OF TOWNSHIP
4 N-S SECTION THROUGH PLEASANT HILL CHURCH

PLATE 2

accuracy in obtaining vertical sections of rock structure. Nevertheless we feel that the data obtained adds something to published reports on the stratigraphy of the immediate region.[1]

The thickness of the formations, as well as the vertical range of dissection, was established by the barometer, the var-

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[1] Rep. Geol. Surv. Ohio, vol. iii, Pt. I, 1874. pp. 349, 352.

iations of which were checked up by another instrument kept at a given base in the area being worked and read hourly or oftener; that the two aneroids when kept together varied alike had been ascertained previously.

The following formations occur in the township:

(4) Sharon conglomerate.	(2) Black Hand formation.
(3) Logan formation.	(1) Cuyahoga formation.

In most cases the lithological distinction of the formations is sufficiently marked to establish lines of contact; whenever doubt arose the question was further investigated by seeking characteristic fauna.

1. CUYAHOGA FORMATION. The Rocky Fork crosses the northwest corner of Perry township, flowing southward through Mary Ann township till within a mile of the southern boundary where it swings eastward cutting the southwest corner of Perry. Only in this latter part of its course does the stream flow on rock, which is the Cuyahoga. At several points along the bed are ripple marks, the best illustrations being just south of the swing foot-bridge over the stream near the point of its turn westward into Mary Ann township. The lower three feet of section shown in Fig. 1, consisting of blue shale and thin sandy layers, belongs to the Cuyahoga.

The broad valley in which Perryton lies, (Fig. 2), and the valley extending south from Reform, evidently are floored in the Cuyahoga. The relative great width of the former valley in the region referred to is due in part to another cause considered later.

2. BLACK HAND FORMATION. In the area studied the maximum thickness of the Black Hand is 110 to 115 feet; this is attained in the southern part of the township; the formation apparently thins northward. At Haven's quarry and down Quarry run southeast of Newark Professor Prosser measured 100 1-2 feet of Black Hand[1]; one-half mile east of Claylick Professor C. L. Herrick reported "about 100 feet of alternating

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[1] The Am. Geologist, vol. xxxiv. 1904, p. 359.

conglomerate and coarse sandstone of prevailingly red color,"[1] a description which closely characterizes the formation as it appears in Perry township, and a thickness which Professor Prosser verified in the vicinity of Claylick[2].

From the highways of Perry township the coarse conglomerate horizon of this Black Hand formation is the most striking lithological feature. Along the "Newark Road" (Fig. 3) from Perryton towards Hanover, and along the roads bearing northward to Fallsburg and Reform it stands out in cliffs revealed by lateral planation of the older drainage lines.

Both above and below this conglomerate horizon we find thiner bedded buff sandy layers, which weather into gentle slopes in accord with the overlying Logan slopes (Fig. 2). But wherever the Black Hand contains 10 feet or more of the conglomerate phase, a break is noticed in this slope.

In the central part of Licking county Professor Herrick[3] found that this formation dips to the south about 14 feet, and to the east about 18 feet per mile. In determining the eastern dip he made his computations from a line of precise levels, using as a base Conglomerate I[4]. The work in Perry township done with two barometers is not so exact; our readings give an eastern dip of nearly 13 feet, and a southern dip of about 18 feet per mile.

In the eastern part of the county, Conglomerate I, which Professor Herrick used as a base is not constant in texture as in the central part; it is not sharply marked because the whole formation is often largely conglomerate. Therefore in ascer-

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[1] Bull. Sci. Lab. Denison Univ., vol. ii, 1887, p. 15.

[2] *Loc. cit.*, pp. 360, 361.

[3] Bull. Sci. Lab. Denison Univ., vol. iii, p. 24.

[4] Herrick considered Conglomerate I as the base of the Black Hand. In speaking of the section exposed in Quarry run and on Stasel Cliff east of Newark, Prosser says: "coarse grained buff sandstones extend for about sixty feet below the base of Conglomerate I, at which horizon is the most marked lithologic change in the rocks, and the base of these sandstones has been selected as the line of division between the Black Hand and Cuyahoga formations." (The Am. Geologist, vol. xxxiv, 1904. pp. 359-360).

taining dip we were guided usually by the contact with overlying Logan. The eastern dip which is lower in Perry township than a few miles west may be due to proximity to the axis of the Claylick anticline.[1]

3. LOGAN FORMATION. The greatest thickness of the Logan, measured in the southern part of the township, is about 120 feet; this formation also appears to thin northward. In texture the Logan here accords with the descriptions found in the literature.[2] It was noted, however, that in the upper layers many ironstone concretions appear; in two localities thin beds of ferruginous shale outcrop.

When the overlying Pottsville does not appear in the usual coarse conglomerate phase, its contact with the Logan is not sharp. In ascending a section of the Logan, the presence of nodulary iron masses denotes proximity to the Sharon member of the Pottsville.

On the hill road running northwest from Perryton is found perhaps the most accessible section of the Logan in the township. Here it is 79 feet thick, aneroid measurement, the top of the Black Hand being found at the first house to the north after descending the west slope No stream-made section of the Logan was noted; but it is surface rock along nearly all highways leading away from the Wakatomaka valley.

4. POTTSVILLE FORMATION. Commencing with the Sharon conglomerate overlying the Logan, we have measured 225 feet of Pottsville. In ascending order the formation may be described thus: A conglomerate, locally called "peanut stone," with quartzite and other pebbles sometimes very coarse; in northwest part of the township near the Rocky Fork, conglomerate units weighing about two and one-half pounds were found. Fire clay overlain by shale beds frequently carbonaceous follows; then come sand and shale layers with iron nodules followed often by white micaceous sandstone. In one place, on the farm

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[1] Bull. Sci. Lab. Denison Univ., vol. iii, p. 24.

[2] Prosser. Jour. Geol. vol. ix, 1901, pp. 230-231.
Andrews. Geol. Surv. Ohio, Rept. Prog. (1869), Part II. p. 76.

of Samuel Wise, a little east of Claggett's Hill, was noted a fourteen inch seam of coal which has been worked some; succeeding this in vertical section are fire clay, thin bedded sandy layers, and, 25 feet above the coal seam, in Mr. Wise's cellar (a house just constructed) a "coal blossom." On elevations above this point conspicuous conglomerate strata, but not so coarse as much of the Sharon, again appear; this second horizon of conglomerate, if not too local in distribution, might mark one boundary of another member of the Pottsville formation, to the upper part of which the Ohio Survey has not given final classification[1].

In the hill region south of Perryton carbonaceous shales were also noted below the Sharon conglomerate, which in this locality forms a pronounced escarpment (Fig. 4).

The maximum thickness of the Pottsville in Perry township is about 225 feet. The highest and lowest beds of the formation are conglomerate; the succession of intervening layers is not constant.

SUMMARY. In character the rocks of this township are prevailingly coarse. Streams from the Logan areas deposit some clay, but sandy highways are the rule. The two marked conglomerate phases, the Black Hand and the Sharon, stand out as shoulders in the degraded slopes.

Careful search was made for any trace of the Maxville limestone. In a few places a hard, fine-textured rock, light in color, was found at the proper horizon for the Maxville; but in most cases the rock gave no response to a lime test; in only two instances was there even a slight effervescence.

TOPOGRAPHY.

The region is maturely dissected; nowhere can one find a mile of unbroken divide. For the most part the surface is cut up into contiguous inverted bowl-like topography. The method of degradation which has produced this result is probably complex; the same weathering agents at work elsewhere in a

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[1] Prosser. Bull. Geol. Surv. Ohio, Fourth Series, No. 7 (1905) p. 13.

similar climate have not always given like surface features. The stratigraphy of the area has been the important control in the topographic effects of weathering.

In the rocks of this area chemical weathering evidently has been active ever since the appearance of vegetation to decay. Silica is the only cement noted in the sandstones and conglomerates. Along the outcrops of the Black Hand and Sharon, "honey combed"[1] surfaces (Fig. 5), and pronounced reentrant angles in lines of major joints, show the corrosive work that is being done today. In the Black Hand one mile south of Reform, and in the Sharon three miles south of Perryton, masses of rock thirty to forty feet in maximum length and ten feet or more in width have been detached and are working down the slopes because of the widening of major joint planes slightly oblique and parallel to face of cliff, the exposed surface becoming the face of the new escarpment (Fig. 6).

Since sandstone is so common, and so irregular in its bedding, there is no uniformity in position of the water table. Springs appear on the surface with little system. These springs have rendered the slopes quite uneven ; apparently they have had an important part in bringing about the prevailingly crenate form of divide.

The angle of surface slopes generally reveals the rock formation present. The Logan slope is typical ; while the sharper declines mark position of the coarser rock structures. The gentler slopes of the former (Fig. 7) are often dotted with blocks of the latter which are slowly weathering as they creep down the grade.

The major valley of the township is occupied by the Wakatomaka Creek which flows from the south central part northward, then at an angle of some forty degrees east of north continues past Perryton entering Muskingum county. Two tributary valleys from the north enter this valley, one heading in the Claggett's hill area, locally called the "Highlands," the other reaching into Fallsbury township. The valley of the

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[1] Andrews. Loc. cit. p. 76.

Rocky Fork, crossing the township twice, has already been alluded to. A tributary stream comes from the south joining the major valley near Perryton.

These valleys are not uniformly concordant, a condition discussed under Drainage. We do not know the exact depth to which they have been incised. An altitude of about 400 feet was measured between the greatest elevation, Claggett's Hill, and the lowest flood-plain, the point where the Wakatomaka leaves the township. But the present vertical range in altitude falls much short of representing the maximum work done by erosional factors. We have no borings giving complete cross-sections of the drainage lines, therefore the exact depth of their aggraded materials cannot be stated.

Weathering and degradation have proceeded so far that we have no long ridges or divides. Conditions inherent in the stratigraphy, important among which is the variation in rock texture along both vertical and horizontal lines, have aided in accomplishing the topographic features described.

GLACIATION.

All evidence found points to the conclusin that ice never moved into this township from the west, north, or east. We find columnar remnants (Fig. 8) of once continuous escarpments that could not have withstood the over-riding of ice. Residual soil in place is constant on slopes exposed to ice moving in from any of these directions (Fig. 9). We find no foreign boulders that could have been brought in by ice, except in southwest corner of the township in the flood-plain material along the Rocky Fork. Furthermore the valley filling of the streams is local.

In the south central part of the township is glacial-carried deposit; this accumulation is continuons with the drift about Hanover. Towards its northern margin this drift area is made up of assorted materials as if deposited by water moving rather freely in the direction of Perryton; in this marginal section we do not find any immediately ice-front drift, or till; and the drift thickens as we go southward in the direction of Hanover. The evidence points to the existence of a tongue of ice extending from the vicinity of Hanover northward, reaching possibly a mile into Perry township. Furthermore there is evidence of one, and possibly two halts of this ice-tongue.

DRAINAGE.

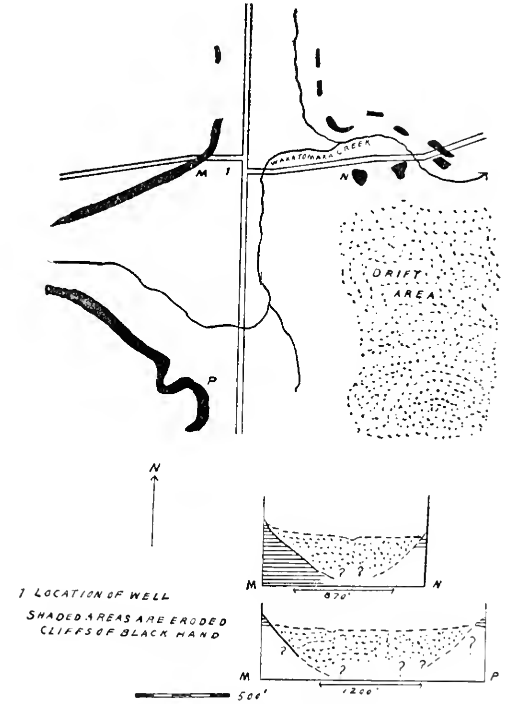
Since drainage problems are seldom localized, little can be accomplished in considering the drainage of a restricted area. But in this region of about 25 square miles we find one or two points that will be of use in investigations including adjacent territory.

The major stream of the township, the Wakatomaka, rises in the drift just considered; its headward work is slight save that accomplished through heavy rains and at flood seasons. At two places only is it on or near rock (Plates 3 and 4). It occupies a valley cut down possibly into the Cuyahoga; this valley is irregular in width; for about a mile either way from Perryton it is very mature, being constantly a mile and sometimes one and a half miles wide. Northeast of Perryton the valley, swinging into Muskingum county, narrows. Near the county line this branch of the Wakatomaka joins another arm which rises near Bladensburg, Knox Co. The Wakatomaka is a tributary of the Muskingum river, uniting with it at Dresden.

From the north the Perry township arm of the Wakatomaka receives several tributaries; the largest of these flows from the central part of Fallsburg township, another rises north of Reform. Both the major stream and these tributaries have flood-plains, and present other evidences of an advanced stage in the erosion cycle.

Plate 3 gives a detail of drainage about one mile south of Reform. The Black Hand cliffs exposed attain a maximum height of 32 feet; we have here the coarse conglomerate phase of the formation. From all evidence available these cliffs, produced by steam work, weather slowly. North of the highway on the east, the patched appearance of this outcrop is due in part to talus from the overlying Logan; while the two isolated rock areas just south of this road evidently are remnants from stream erosion.

A recent well boring at 1, on the farm of C. E. Smith, throws much light on the shape of the valley floor here. This boring passed through 198 feet 10 inches of stream gravels (as reported by the owner) before reaching rock; it stands 296 feet from the cliff M, and is 574 feet from the rock remnant, N. The upper cross-section through M-N is drawn according to these figures; while the lower cross-section is drawn through M-P, the mouth of the tributary valley from the west.

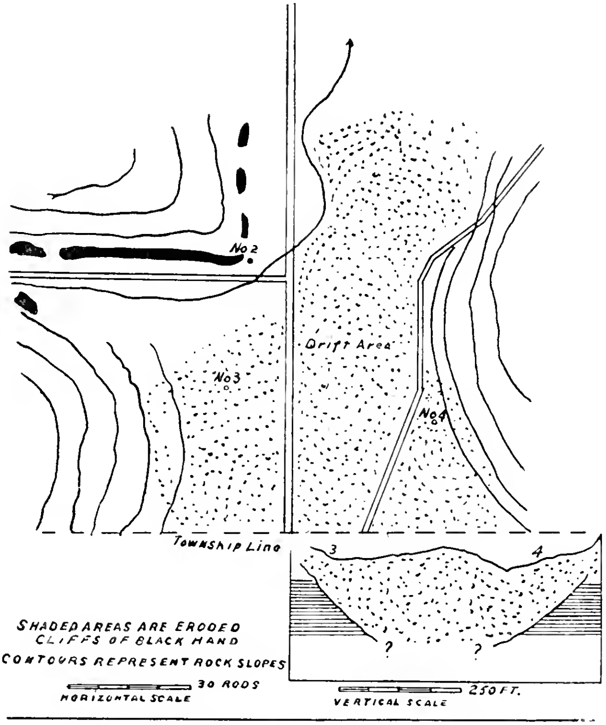


DETAIL OF DRAINAGE 2 MI S OF REFORM

PLATE 3

Cliffs of the Black Hand conglomerate, in one place on west side of valley 40 feet high, appear in patches on the way north to Reform. But these lines of cliffs do not converge regularly northward ;this valley swells and contracts as already noted in the major valley.

Cliffs of the same formation lie just west of the road leading south towards Hanover. Proceeding in this direction, at the next highway which turns west, we find a repetition of the conditions recorded west of the north-south road in Plate 3. But here the valley coming from the west is not so mature ; its eastward flaring cliffs of conglomerate, while not so far apart, are as high as in the case above ; and within one-half mile of the north-south road the brook which now occupies this valley cascades, marking the limit of dissection of the Black Hand in this direction. We have here also, in a position corresponding to the location of the well in Plate 3, on the farm of Z. H. Mc-



DETAIL OF DRAINAGE JUST SOUTH OF PLATE 3

PLATE 4.

Knight a well (No. 2 in Plate 4), standing about 50 feet east of the cliff, which reaches rock after passing through 81 feet of aggraded materials. It is evident that the rock wall here drops off rather sharply, a repetition of the gorge characteristics illustrated in the cross-sections of Plate 3.

At the second house south of well No. 2, Mr. McKnight has driven another well which reaches rock at 78 feet; this well, marked No. 3 on Plate 4, stands a few rods farther west than does No. 2. On the next highway east is well No. 4, nearly in an east-west line with No. 3, on the property of H. S. Montgomery. After going through 129 feet of gravel, sand, and clay this well reaches rock.

The curb of No. 2 is 65 feet below the crest of the drift to the east; that of No. 3 is 35 feet below, while No. 4 stands about 18 feet lower than the top of the drift. Plate 4 gives a cross-section of the valley passing through wells 3 and 4, showing the probable outline of the valley floor. The great mass of drift here shown is a continuation of Leverett's Hanover Dam.[1] In the valley included in the region of these wells, stream erosion has exposed in the drift a measurable thickness of 90 feet; this depth with the record of No. 4 gives the drift an established thickness of 147 feet. But the drift here is presumably much thicker since it occupies a valley the rock walls of which, at this point 240 rods apart, flare southward into a wider valley, an old drainage line which Tight[2], in his work on restored drainage, connects with the Scioto basin.

We have here, then, an obvious instance of drainage re-

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[1] U. S. Geol. Surv., Monograph xli, p. 260, and p. 286.

[2] Bull. Sci. Lab. Denison Univ., vol. viii., part II, p. 47.

Speaking of the old east-west valley Tight says, on page 43: "The line of Waverly hills . . . . , which form the northern wall of this broad valley, ... , can be traced as an unbroken ridge to the east. . . . . It is divided north of Hanover by Rock Fork Creek and north of Frazersburg by Wakalomaka Creek, both small streams with narrow V shaped valleys." No mention is made of the broad buried valley from Perryton coming into "this pre-Glacial stream, for which the name Newark River is suggested." (This last quotation is also from Tight, Professional Paper, No. 13, U. S. G. S., p. 18.)

versal; and an equally obvious cause for the reversal is suggested in the glacial dam.[1] Although the drift deposits completely fill the valley at the point of its debouchure into the broader east-west valley, thus affording the requisite conditions for a ponded water body that would rise to a spill-way somewhere about its rim, yet a field study of the basin that must have been involved in such a static body suggests the advisability of considering other causes that might produce the same reversed drainage.

The tributary valleys of this hypothecated lake-basin were favorable to the formation of deltas; but no deltas exist anywhere about the basin. The irregularly dissected shores furnish numerous profiles to register wave work in the formation of cliffs and bars; but we find neither. The absence of clays suggests that a lake could have existed here but a short time, if at all. Furthermore the valley-train frontal appearance of the drift area, which constitutes the glacial dam, is evidence pointing to the same conclusion as does this absence of shore phenomena.

Whatever cause has effected the reversal, the stratigraphy of the area has been an important control in the working out of that cause. The original horizontal beds in this part of the State are undisturbed save for broad low folds decreasingly characteristic as we come westward from the axis of the Appalachian movement. In vertical section, however, (Plate 2,) the formations in eastern Licking county at least are sharply different in texture, hence in capacity to resist denudation.

The Sharon conglomerate apparently marks the limit of down-cutting reached in the Cretaceous base-level cycle. This formation is underlain by the thin bedded sands and sandy shales of the Logan. Stream erosion was held up by the coarse silica-cemented Sharon, but after this conglomerate horizon had been incised, erosion proceeded more easily in the Logan; and through planation the Sharon cliffs were undercut thus widen-

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[1] Clark, W. B. Bull. Sci. Lab. Denison Univ. vol. xii, p. 8.

ing the stream valleys. Further cutting in the Logan developed easy slopes down which Sharon blocks are still creeping.

And erosion was again retarded whenever encountering the coarse phase of the Black Hand conglomerate, the phase that predominates in Perry township.[1]

Still another factor has had much to do, as already intimated, in producing the present drainage topography: These conglomerate and coarse sandstone horizons lack homogeneity in both vertical and horizontal sections. Since the maximum thickness of either formation is not over 225 feet, the vertical changes in texture are not of controlling importance; but the variations in horizontal extension is important. This control is manifest in the short and disproportionately wide tributaries, in the contraction and expansion of valleys, in the distinct variations in angle of slopes, and in the crenate form of divide.

Therefore the fact that a tributary is as wide or even wider than the major valley, and that a stream is flowing through a narrow reach in a valley which broadens both up and down stream, may or may not be evidence of drainage reversal. Such a relationship of valleys, or of streams to their valleys, may be the normal result of drainage development in the lower Carboniferous.

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[1] In the central and western parts of Licking county the Black Hand formation is finer in texture and contains more thin layers; this condition is noted in quarries about Newark and Granville.

Volume XIII

ARTICLES IV, V, VI
P 130—168

BULLETIN
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EDITED BY
CLARK W. CHAMBERLAIN,
Permanent Secretary Denison Scientific Association.

VALLEY DEPENDENCIES OF THE SCIOTO ILLINOIAN LOBE IN LICKING COUNTY, OHIO.

THE GLACIAL DAM AT HANOVER, OHIO.

By FRANK CARNEY.

THE ORIGIN OF SPRING VALLEY GORGE,

By EARL R. SCHEFFEL.

Granville, Ohio, September, 1907.

Bulletin of the Scientific Laboratories of Denison University.
Vol. XIII. Article IV. September, 1907.

VALLEY DEPENDENCIES OF THE SCIOTO ILLINOIAN LOBE IN LICKING COUNTY, OHIO.[1]

FRANK CARNEY.

Leverett classifies the drift of eastern Licking County as Illinoian. He says: The Illinoian deposits are much heavier in valleys than on uplands, and there is a marked sinuosity of margin to conform to the topographic conditions.[2] The observations described in this paper were undertaken in part to give closer definition to the extent of the topographic control to which Leverett refers. The paper attempts to show that the Scioto lobe on this part of its eastern margin, where it reached out over the more rugged topography of the coarser Mississippian and Pennsylvanian formations, was affected by valley dependencies. It is felt that a detailed study of the marginal areas may add to our knowledge of the exact shape of the ice-front at the time of its maximum extension.

MARGIN OF THE ILLINOIAN DRIFT.

In central Ohio.—The general location of the Illinoian sheet, according to Leverett,[3] reflects the influence of great basins in the topography farther north, the Huron-Erie basin probably controlling its extension into the tract now drained by the Scioto River. That the extreme reach of the Illinoian ice in the southern part of the state—i. e., where it crosses the Ohio River in Brown County—is due to a combination of controls, seems likely.

Fig. 1 gives the results of Leverett's mapping of the Illinoian ice in Ohio. It appears that in one general locality on the eastern side of the Scioto lowland the ice manifested a tendency to protrude, as is shown by the curve southwest of Muskingum County; another evidence of this impulse is seen (Fig. 2), just north of this convexity, in the valley dependencies reaching beyond the body of the ice-field, described in the present paper. This later

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[1] Reprinted from the *Journal of Geology*, Vol. XV, No. 5, July-August, 1907.

[2] *Glacial Formations of the Erie and Ohio Basins:* XLI Monograph, U. S. Geological Survey (1902), p. 222.

[3] *Ibid.*, p. 226.

and more leisurely field-study gives greater prominence and exactness to this curve of local lobation first examined by Leverett.

In Licking County.—Save in the valleys, the Illinoian drift near its front is so attenuated that mapping it is a problem of elimination, or the careful study of the rather maturely dissected divide areas. The lesser details of topography in the marginal zone appear to have had slight influence on the outline of the ice-front, while obviously exercising a considerable control over the duration of the ice in its position of maximum reach. This latter fact necessitates patient observation, particularly where the stratigraphy did not encourage differential-weathering effects previous to glaciation; it is evident that on slopes of heterogeneous rock structure facing the direction of ice-movement, benches of the more resistant formations, weathered into semi-detached spires and blocks,[1] would have suffered some from ice-work, even though the products of residual decay did not receive a noticeable admixture of glacial drift. But among the hills, where the rock structure is more uniform, and the weathered slopes correspondingly even, the absence of foreign material must be established before drawing the drift-line; and in these higher areas an unexpected localization of erratics surrounded completely by territory in which the most diligent search has not revealed any evidence of glaciation is somewhat puzzling, but very convincing of the fact that the final demarkation of the glacial boundary is a problem of time.

In establishing the relationship of these valley dependencies of the Illinoian ice-sheet to the Scioto lobe, and in determining whether they are tongue-like extensions of the ice-mass at its period of greatest development, or at a later retreatal stage, three townships, Perry, Hanover, and Mary Ann, of Licking County, have been carefully studied, while like attention has been given to portions of adjacent townships. In valleys trending in general with the direction of ice-movement, the problem is one of distinguishing the unmodified drift from the deposits of entirely extra-glacial waters, and of determining the drift-covered portion of the valley walls.

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[1] F. Carney, *Bulletins of Denison University*, Vol. XIII (1906), p. 124.

It has been established that ice did not enter Perry township (Fig. 2) from the north or west,[1] and that the township was not glaciated save for the presence of a lateral tongue reaching northward from the valley lobe that extended eastward into Muskingum County (Fig. 3).[2] Less than one-half of the next township west, Mary Ann, was covered by ice; this ice had a very irregular front. The conspicuous drift knolls at Wilkins Run are alluded to by Wright,[3] and by Leverett.[4] One of the most typical valley trains of this region was built into the mature valley southwest of Wilkins Run.

The southeast corner of Eden Township was not glaciated; but the front of the ice has not been traced in detail through this township, nor into Fallsburg. A small portion of the northeast corner of Madison Township was not covered by ice. The outline of the drift in Hanover Township is considered in the following section. Southward into Hopewell Township the margin of the ice has been traced in detail for only a short distance.

VALLEY DEPENDENCIES.

At Wilkins Run.—A tongue of ice about one and seven-tenths miles long reached eastward from Wilkins Run. This village lies at one side of a mature valley which once embraced in its drainage the area east and north, the region now constituting the headwaters of the Rocky Fork; this defunct valley opened westward

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[1] F. Carney, *loc. cit.*, p. 124.

[2] Since the government has not issued a map of this area, the writer, appreciating the difficulty that one not acquainted with the region would have in visualizing the topography described in the paper, has attempted to represent in contours the relief of the section about Hanover. No traverse work was done; county surveyor's maps were used for the highways and horizontal distances, an attempt being made to correct the grosser errors. It is felt, however, that the altitudes in reference to the arbitrary bench mark selected have been established with greater accuracy. For this purpose two aneroids were used; these instruments are of the same make, and for over a year have shown the same variation when together. During the progress of the fieldwork the aneroids were set the same at the bench each morning; the one kept at the bench was read every thirty minutes. The time at which readings were made on the other instrument in the field was recorded; the watches were also set alike each morning. At night the field readings were corrected for the variations shown by the bench aneroid. Many critical points were checked several times.

[3] *The Glacial Boundary of Ohio*, Geological Survey of Ohio, Vol. V (1884), p. 755.

[4] *Loc. cit.*, p. 260.

into the valley of the North Fork of the Licking River, and belonged to the ancient Newark River.[1]

This tongue-like extension of the ice pushed eastward to the point where the valley turns to the north; a tributary from the east which joins the major at its bend to the north, being in line with the feeding ice, was blocked also. The ice reached northward but a short distance beyond this angle; a few drift knolls mark this brief position. A halt of considerable duration was made after the ice had retreated to a position bringing the north side of the valley tongue directly across the valley; here it built a marginal ridge averaging 90 to 95 feet high, at no point lower than 70 feet, and about 500 feet broad at the base (Fig. 4). A terrace of similar development marks the outline of the ice against the walls of the valley elsewhere, except in front of the tributary valley, mentioned above, through which most of the drainage from the ice was led east to the Rocky Fork valley. It is evident that the Rocky Fork drainage had gained control of the mature valley long previous to its being occupied by this ice.

These moraine terraces, best developed on the south side of the valley, are very conspicuous. Commencing across the valley from the hills mentioned by Wright,[2] a terrace of the aggradation type reaches half-way up the valley wall; it gradually descends eastward, where it becomes more irregular both because of initial distribution and of subsequent weathering. The line of demarkation between this drift and the upward slope is sharp.

The main body of ice, while the tongue reached eastward, maintained a position nearly north-south for a few miles each way from Wilkins Run. North of this place, so far as Mary Ann Township is concerned, the retreat of the ice-front appears to have been rapid, and there is no evidence that the valley lobe maintained intermediate positions; but the old valley becoming broader southwest of Wilkins Run encouraged a tongue-like extension of ice at the next halt of the ice-field; the well-developed valley train already mentioned was formed at this time.

At Hanover.—Here we have a much wider valley than the case

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[1] W. G. Tight, *Professional Paper No. 13*, U. S. Geological Survey (1903), p. 18.

[2] *Loc. cit.*, p. 755.

just cited. The tongue of the ice reached about six miles eastward from the main body of ice. The maximum position of this valley dependency is marked by typical morainic topography (Fig. 5), with a contemporaneous deposition of drift against the side walls of the valley, which above the glacial débris are veneered with rock decay *in situ*. The line of demarkation between this drift and the valley wall is shown very conspicuously on the Hagerty farm southeast of the 216-foot well (Fig. 3). The drift, judged from surface appearance, especially east of the Muskingum County line, is rather bowldry; no very large bowlders were noted, but their fewness may be accounted for by the fact that the area has long been under cultivation.

This tongue-like extension of the ice maintained its distal position for some time, but in comparison with the duration of retreatal positions the period was proportionately brief. At the second halt the alignment of the drift suggests a tapering of the ice-tongue; this form, however, is not seen in the other halts (Fig. 3, *H*. 3, 4, etc.), because of the contraction that exists in the valley in the vicinity of Hanover. So long as the ice fed actively through this narrow part it broadened some in the wider segment of the valley beyond; only in this latter area should we expect to find evidence of tapering as the ice-movement weakened.

Moreover, it should be noted that the distribution of the drift in this valley does not conform to the pattern usually normal to valleys[1] which encourage tongue-like extensions from the ice border in line with the direction of the deploying ice. The east-west valley passing Hanover is unusual in that it has a composite history, the most obvious feature of which, that it was formerly the course of a west-flowing stream, has been published.[2] The continuity of the south wall of the valley is broken by gaps at *A*, *B*, and *C* (Fig. 3), representing a change in the drainage-control of the region; the presence of these openings allowed free drainage, particularly in the case of *A* and *C*, from the southern side of the ice-tongue, thus removing much glacial rubbish that otherwise would have remained as a lateral terrace or ridge.

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[1] R. S. Tarr, *Bulletins of the Geological Society of America*, Vol. XVI (1905), pp. 218, 219.

[2] F. Leverett, *loc. cit.*, p. 155; W. G. Tight, *Bulletins of Denison University*, Vol. VIII (1894), p. 47.

Furthermore, westward from Hanover the valley grows broader; at Newark, a distance of seven miles, it is about two miles between the rock walls. Consequently as the margin of the eastern side of the Scioto lobe assumed new positions in its decline—a long halt has been noted in the vicinity of Newark[1]—this valley dependency persisted.

The details of the drift south and southwest of Claylick have been studied for two miles, showing that the retreat of the main body of the ice was gradual, and apparently maintaining positions parallel to the convex margin mapped by Leverett.

SUMMARY.

A study of the Illinoian drift in this broken topography of the coarser-textured and more resistant formations of the Mississippian and Pennsylvanian periods establishes the existence of tongue-like dependencies of the Scioto lobe reaching out into the eastward trending valleys.

Geological Department, Denison University, Granville, O., April, 1906.

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[1] F. Leverett, *loc. cit.*, Plate II.

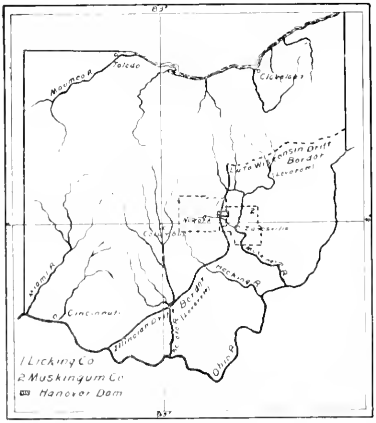


Fig 1

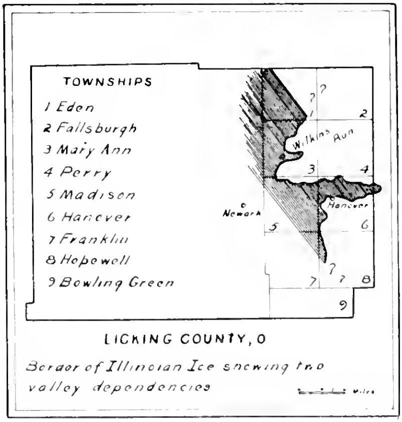
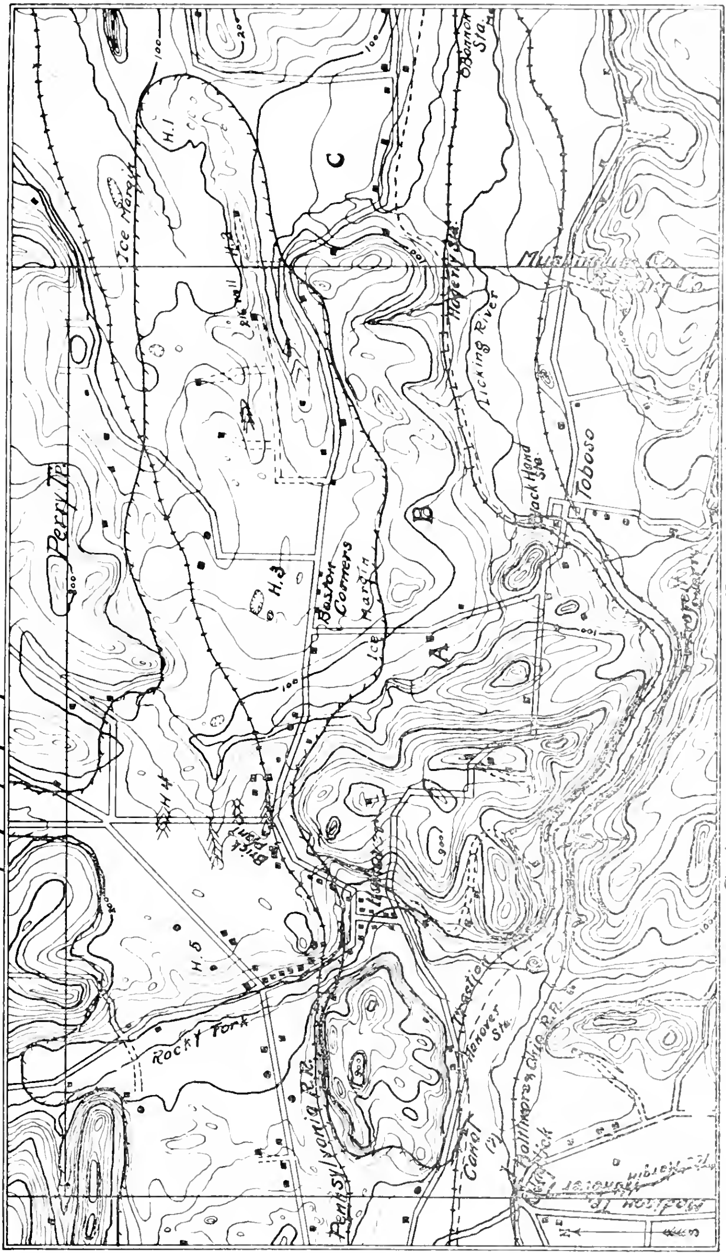


Fig 2

Topography of Hanover Dam Area



Contour interval 20 feet – Datum is arbitrary Bench Mark at M.
>>> Ice front channels – Fig. 5

Fig. 4. Looking south of west. The wooded area on the extreme left is rock, as is also the slope above the buildings on the right. The intervening ridge of drift marks the position of the ice-tongue that extended eastward from Wilkins Run.

Fig. 5. Moraine which marks the terminus of the Hanover valley dependency.

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THE GLACIAL DAM AT HANOVER, OHIO.

FRANK CARNEY.

THESIS: The glacial dam at Hanover consists of peculiarly tied-together drift loops made by successive halts of a retreating dependency of the Scioto Illinoian lobe.

INTRODUCTION.

Leverett calls attention to the mass of drift which blocks the east-west valley at Hanover.[1] Other writers in discussing drainage features have alluded to the same phenomenon.[2] Wright does not include this part of Licking County within the drift.[3] Leverett's map (Fig. 1) includes within the drift all the county save a narrow strip, convex towards the ice, along its eastern side.[4]

STRATIGRAPHY.

In this area the Missippian and Pennsylvanian formations from the Cuyahoga to the Sharon of the Pottsville are exposed. The lowest of these formations has been noted in but two localities. In the region under discussion the Black Hand formation was first studied, and named, by Hicks.[5] In east-west extension from Claylick to Toboso, and northward at least through Perry Township,[6] this formation is prevailingly coarse, often conglomeritic; westward about Newark[7] and Granville it is rather coarse in

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[1] Frank Leverett, "*Glacial Formations of the Erie and Ohio Basins,*" XLI Monograph, U. S. Geological Survey (1902), pp. 155, 260, 286.

[2] W. G. Tight, *Bull. Sci. Lab. Denison Univ.*, Vol. VIII (1894), pp. 35-63. W. B. Clark, *Ibid.*, vol. XII (1902), pp. 1-16.

[3] G. F. Wright, "The Glacial Boundary in Ohio," *Geolog. Survey of Ohio*, Vol. V (1884), p. 755.

[4] *Loc. cit.*, plate XIII.

[5] L. E. Hicks, *Am. Journal of Science*, 3d Series, Vol. XVI (1878), pp. 216-217.

[6] F. Carney, "The Geology of Perry Township," *Bull. Sci. Lab. Denison University*, Vol. XIII (1906), p. 120.

[7] C. S. Prosser, *American Geologist*, Vol. XXXIV (1904), p. 359.

patches, and sometimes has conglomerate beds of considerable horizontal extension, yet it does not represent as constant conditions of sedimentation. Consequently in the Hanover area, the topographic control exercised by the Black Hand formation is very important.

The development of the Logan in this region is normal. Professor Prosser has studied an exposure, which is typical, at the Brick Plant (Fig. 3).[1] This formation disintegrates evenly, giving gentle slopes.

No outcrop of Maxville limestone was found, nor was this formation noted in the 25 square miles immediately north of Hanover Township.[2]

The Sharon conglomerate caps nearly every hill reaching an altitude of about 225 feet above the bench mark (Fig. 3). Much diversity in its structure is noted; to this condition is due the fact that we find in close proximity hills that vary 20 to 40 feet in altitude; the regular extension of drainage disintegration would not account for this discrepancy.

With the above arrangement of rock horizons: a conglomerate (Sharon, 250-feet) underlain by thin bedded sandy and shaly layers (Logan, 115-feet) capping a conglomerate (Black Hand, 100-feet) which in turn overlies a shale formation (Cuyahoga), we have a vertical succession that responds irregularly to stream erosion. Furthermore with the horizontal variations characteristic of the two coarse formations we find in the stratigraphy of the Hanover area another factor that has been active in producing its rather unusual rock topography.

PECULIARITIES OF DISSECTION.

The widest and apparently the oldest valley of this section is the one now blocked across by the Hanover Dam. This valley is explained as a "preglacial" west-flowing[3] drainage line, named

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[1] C. S. Prosser, *Journal of Geology*, Vol. IX (1901), pp. 230-231.

[2] F. Carney, *loc. cit.*, p. 122.

[3] F. Leverett, *loc. cit.*, p. 155.
W. G. Tight, *loc. cit.*, p. 47.

"Newark River."[1] The proximity of the two spurs, one from either side of the valley, just east of the Hanover Brick Plant (Fig. 3), and the fact that westward toward Newark and eastward toward Dresden the valley grows uniformly wider, suggests that at some anterior "preglacial" time two streams here headed against each other, the west-flowing one of the pair capturing the other.

This old drainage line controls from the north two tributary valleys, one of which now carries the Rocky Fork, the other being filled for some distance northward by the same drift material that bars the major valley. This latter valley is more mature in general aspect; it now bears a stream to the northeast, probably in reversed course. The Rocky Fork has a drainage basin extending about 15 miles to the north; during the recession of the ice sheet it carried an abnormal amount of water, the work of which is now seen in the terraces of water-laid drift that skirt its course.

From Toboso eastward is a valley whose maturity is strikingly in contrast with the stream it now bears. The aggraded glacial outwash materials that level up the floor of this valley, which widens to the east, have been terraced by the swinging meanders of a stream whose volume is likewise out of harmony with the Licking River which joins the Muskingum at Zanesville.

West from Toboso for two miles the Licking traverses a rock-walled gorge which abruptly expands south of Hanover into a wide valley that heads about two miles farther south. This valley is an arm of the old drainage line already described, passing Hanover westward through Newark.

Connecting these two east-west lines of dissection are four gaps in the rock divide. Three of these gaps cut through or into the Black Hand formation. The village of Hanover lies in the most western; the other three are designated on the topographic map (Fig. 3) by the letters, A, B and C.

The Hanover gap is Y-shaped, one branch extending toward the Brick Plant, the other being traversed by the Rocky Fork.

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[1] W. G. Tight, *Professional Paper No. 13*, U. S. Geological Survey (1903), p. 18.

Gap A is now the valley of a slight stream which rises in Perry Township. This creek is rock bound at a point just southwest of Boston Corners where the ice so abutted the nose of a spur that the drainage was forced across it thus cutting a channel which has held the stream since. From this point southward almost to its intersection with the highway, the creek skirts the conglomerate cliffs of the Black Hand. Throughout most of its course, however, the washings from the ice front have obscured the lower contours of the valley represented by A.

The next gap, B, is not so pronounced in its rock topography as the two cases just described. The hills immediately east and west (Fig. 6) are rock; the area intervening, and to the north, is buried with drift. Even with a moderate thickness of drift—a well at Boston Corners shows 50 feet and no rock—it is obvious that the rock rim of the divide dropping into the filled valley north is very much lower than the row of rock hills which the ice-margin skirts eastward. B then marks a gap of the same kind but not of the same degree as the others.

Fig. 6. Looking a little north of east from the top of the west wall of gap *A*. The curve in the traction line is in front of the southern end of gap *B*. The stream of *A* now enters *B* through a rock channel at foot of the wooded slope in right foreground; the camera stands about 200 feet above this channel, hence the picture does not show the former course of this stream.

C is the widest and presumably the deepest of these gaps. It too is clogged with drift; when viewed from the moraine hills north, the washplain origin of this aggraded deposit is evident. Its southern margin, that is, its line of contact with the flood plain area of the Licking valley, is sharply terraced, thus establishing a neighboring base-level that has encouraged subaerial dissection; as a result the washplain is somewhat roughened by the work of streamlets. This gap, C, represents long-continued lateral planation work of some stream, probably south-flowing; its sides have mature slopes (Fig. 7); its aggraded bed has about the same level as has the outwash plain reaching eastward in the valley of the ancient Newark River.

DISTRIBUTION AND DESCRIPTION OF THE DRIFT.

The area within the broken line, "ice margin," (Fig. 3), includes the deposits of unmodified drift; within this area there is also much washed drift, while outside the line we find only water-laid deposits.

Modified drift is found in all the valleys enumerated under the preceding section of this paper. In portions of these valleys adjacent to the ice front, the drift is of the outwash-plain type.

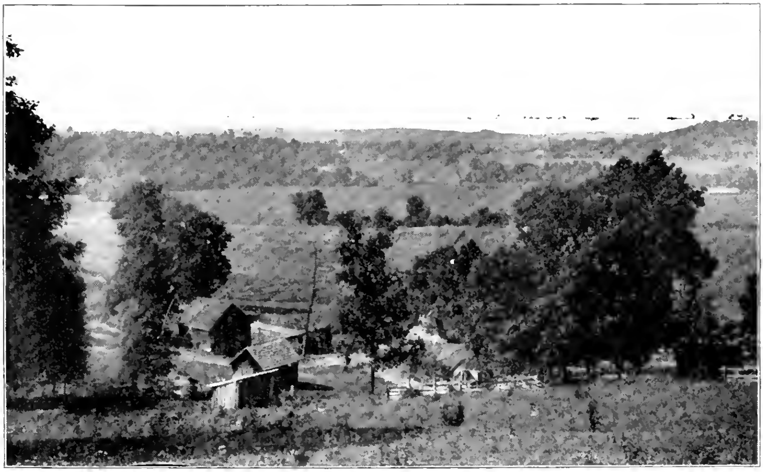

Fig. 7. Looking directly north through gap *C*. Camera stands on south wall of the Licking about 180 feet above the stream. The sky-line of the middle distance is the north wall of the old east-west (Newark) valley.

Elsewhere through these valleys it constitutes their flood plains so far as may be observed in the old terraces, in the erosion of the laterals crossing the flood plains, and in the notch made by the present major streams traversing them. The further distribution of washed drift in this part of the State has been described by Leverett.[1]

In topography the drift of this region presents some interesting features. Near the western edge of the area, just off the map (Fig. 3) in Madison Township, the moraine is quite kame-like. The low place now crossed by the Rocky Fork (Fig. 8) is due in part to the removal of the drift by the augmented drainage from the ice-front north and west; this stream has terraced the drift east of the highway, thus possibly over-steepening the slope there, but the low sag is the result rather of rapid melting of the ice-tongue.

Fig. 8. Looking north of east over the inner slope of halt 5. The steep slope on the right is rock which lies within the Y-shaped gap at Hanover (p.141). The sky line is the north wall of the "Newark River" valley; the stream in the foreground is the Rocky Fork.

Proceeding eastward the highway rises about 100 feet, then crosses a level delta-like stretch of drift. The surface is mildly

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[1] *Loc. cit.*, p. 157.

undulating, rarely having a vertical range of 20 feet. The surface material is rather fine, and as revealed in sections is sometimes water-laid; unassorted sections also appear. The highway leading north from the Brick Plant crosses four distinct channels (Fig. 9), which have neither the form nor the relative location of normal erosion channels; they are interpreted as made by ice-front streams. East of the highway, and about half the distance between the Brick Plant and the first road leading eastward, the drift assumes a sharp morainic aspect. The level-topped area west of the highway continues northward in the valley extending into Perry Township; here too the delta-like appearance blends into more irregular forms of the drift, suggesting intervals of retreating and stationary positions of the lateral tongue which fed into this side valley.

In eastward continuation we have next another interval of descending contours (Fig. 10), denoting a period during which the melting factor was greater than the ice-feeding factor. Here the Pennsylvania railroad swings northward towards the sag between the ice margin and the valley wall. In doing this the railroad has made a cut about one-half mile long and 50 feet in maximum depth. The great amount of clay in the drift has necessitated a wide cut and frequent cribbing. The region of this cut,

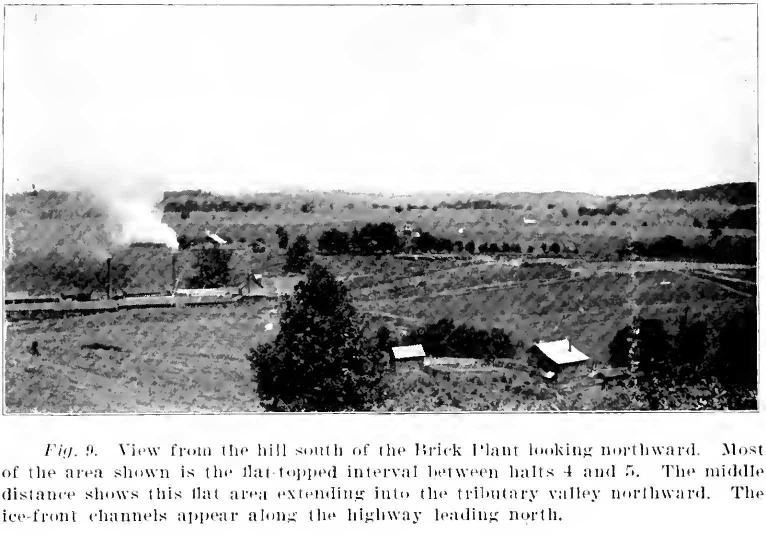

Fig. 9. View from the hill south of the Brick Plant looking northward. Most of the area shown is the flat-topped interval between halts 4 and 5. The middle distance shows this flat area extending into the tributary valley northward. The ice-front channels appear along the highway leading north.

while rather plain-like in surface, is contiguous to morainic topography.

From the vicinity of Boston Corners to the easternmost reach of the ice-tongue we have a recessional period of drift accumulation during which the ratio of the supply to the melting factor was a little less than unity; but in the neighborhood of the 216-foot well (Fig. 3) there is evidence of a stationary condition of the ice. Through this whole distance, kettles are quite common, some of which are designated on the topographic map. Extending eastward from this deep well there is a marked morainic ridge, for a ways simulating in its form an esker, but gradually broadening into the mass of very irregular drift in which the loop terminates (Fig. 5), reaching about one mile into Muskingum County where glacial drift *in situ* has not been previously reported.

To account for this ridge there are two suggestions: The ice-front drainage in the direction of Black Run, which lies just off the northeast corner of the map, may have been sufficiently vigorous to remove most of the débris collected from the melting ice; it will appear in later discussion that there was active drainage in this direction. Or the load of rubbish carried by this valley dependency may have been much greater on its southern side; the rock spur on either side of Hanover offered ample obstruction to the progress of the ice to encourage acquiring a load.

An analogous arrangement of rock spurs is noted on the opposite side of the valley; here, however, it is apparent that the tributary valleys were occupied by laterals from the ice-tongue, thus lessening its power of erosion. The low area in which Hanover lies was not similarly filled with ice for the reason that its approach from the north is an almost continuous wall of rock (Fig. 8), save where the Rocky Fork has incised it. This wall was doubtless considerably lowered by ice-erosion as there is but little Logan sandstone capping it, and apparently some of the Black Hand in places was also carried away. So it seems that the conditions for acquiring a greater load of rubbish were in favor of the south side of the tongue of ice that fed eastward through this valley.

Fig. 10. Looking west from halt 3. The leveled surface of halt 4 shows in the middle distance; camera stands on the west slope of halt 3. Barn on left is in line with the Brick Plant.

THE DELTA-LIKE TOPOGRAPHY OF PARTS OF THIS VALLEY DRIFT.

As one approaches the Hanover Dam area from Newark, he notes the strip of even sky-line, flanked by irregular horizons, blocking the valley (Fig. 8). In ascending the grade just east of the Rocky Fork, gravel is conspicuous in the road gutters. Having reached the summit, it is evident that "the top is nearly plane."[1] And looking eastward the second area of level topography, near Boston Corners, tends to emphasize the resemblance to a delta, or an outwash deposit "from the ice sheet into a body of water held in the valley to the east."[2] This second level strip averages 10 to 15 feet lower than the first, thus the dam "descends gradually eastward."[3] Therefore the topography and the surface materials suggest that "while the dam was accumulating a lake probably occupied the valley to the east."[4]

If this accumulation is outwash material, delta-like in form, then we would anticipate finding other but probably smaller deltas marking the mouths of valleys that were tributary to the area involved by the static body of water extending eastward. During the long interval since these smaller deltas, if any existed, were built they must have suffered much from erosion and solifluction,[5] but not to the extent of being obliterated. We have studied

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[1] F. Leverett, *loc. cit.*, p. 260.

[2] *Ibid.*, p. 260.

[3] *Ibid.*, p. 260.

[4] *Ibid.*, p. 286.

[5] J. G. Anderson, *Journal of Geology*, Vol. XIV (1906), pp. 95-96.

many minor deltas laid down in ponded bodies which filled the short but wide tributaries of the major valleys, so common in these Mississippian-Pennsylvanian horizons, and have been surprised at the little disintegration such slight deposits of sediments have suffered. And the lapse of time since the Illinoian glaciation is perhaps greater than is generally supposed. But concerning the "smaller deltas" of the body of water in question: very diligent search shows that there are no such deltas.

Furthermore a detailed study of the boundaries of the Hanover Dam shows the improbability of a ponded body of water having been confined in the area, at least since long anterior to the earliest glaciation. Gaps, A, B, and C, as shown on the topographic map are low places in the rim of the basin that must have been involved in such a static body.

These gaps are tributary valleys of the drainage line now occupied by the Licking River. They have tended to keep consonant grade with the major valley; proof of this fact, however, is observed only in valley A, the stream of which now flows just east of the isolated rock hill at Black Hand station (Fig. 3); this stream has hardly yet attained the grade of the major stream (Fig. 6), with which it possibly at a former time made its junction just west of this isolated hill. This western outlet was maintained till some progress was made in disintegrating the Black Hand formation; then a tributary of the stream that was at work in valley B, because of variation in the structure of this formation, was led headward into valley A, and captured its drainage. This episode in the evolution of these gaps is mentioned for the purpose of emphasizing their chronology.

The slopes of the rock walls of valley C (Fig. 7), when plotted downward, give a depth for the bed rock quite in harmony with the record of the well-boring a short distance west of the line along which this valley blends into the east-west filled valley (Fig. 3). This well reaches a depth of about 150 feet below the general altitude of the outwash materials now observed in valley C; the well does not get into rock.[1] Leverett suggests that the surface of the Hanover Dam may stand 300 feet above the rock floor of the old valley.[2] The width of gap C is measurable; its depth is obviously below the surface of the drift under discussion. That the rock-sculpturing here observed antedated the formation of the Hanover Dam seems very probable.

If the disintegrated rock removed from these gaps, A, B, C, were replaced, and a wall of ice were standing across the east-west valley at Hanover, we would then have, so far as this immediate area is concerned, the requisite conditions for an ice-front lake. But since such a lake would extend eastward, its level in no case, save that of a hypothetical differential tilting, could rise higher than the overflow that would be established at the first outlet reached; such an outlet exists about one mile east of the area shown on Fig. 3; it joins the valley of the Licking at Nashport, and is traversed by the old canal. It appears therefore that any one of the valleys, A, B, C, was fatal to the existence of the conjectured lake. But if these gaps were not developed till after the Illinoian ice-invasion, and if the other southward-extending drainage lines to the immediate east did not exist, then a body of water was held up in this old valley by the ice.

INTERPRETATION FROM THE STANDPOINT OF A VALLEY DEPENDENCY.

Many difficulties of this problem clear up when we understand that the ice reached into Muskingum County. Judging from the amount of drift here deposited, from its stony texture, and from

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[1] In a letter dated Nov. 27, 1905, Mr. G. E. Swigert says concerning this well: It is a drilled well. It is 216 feet 3 inches from top of casing. We went through 10 feet of yellow clay; 90 feet of blue clay, or better known among drillers as hard pan; and from there 114 feet of quick sand; thence to gravel and completed the well in the finest (best?) coarse gravel I ever saw. There is 131 feet of water in the well. We struck a small seep of water about 85 feet down. * * * We took out a few leaves and one or two walnuts from the quick sand about 150 feet down. * * * I never saw such mean stuff to work with; we would work all day, and get 2 or 3 feet.

Tight, *Bull. Sci. Lab. Denison Univ.*, Vol. VIII (1904), p. 41 and Plate IV in his map and in his description places a 218 foot well just north of the rock spur near the Brick Plant; again he speaks of it as "about one mile east of Hanover." There is no other deep well in this part of the county, so Tight must have been alluding to the Swigert well.

Leverett (*Loc. cit.*, p. 156) in discussing the old drainage quotes Tight's data concerning this well.

[2] *Loc. cit.*, p. 286.

its surface features, we infer that this most distal position of the ice was maintained for some time (Fig. 3). Another rather prolonged halt[1] in the retreat is apparent at and immediately west of the Swigert well. The depth of clay found in this well, and in the well of Mr. Felix Claypool at Boston Corners is also evidence of unmodified drift. Kettle holes, many of them not yet filled by vegetation, are common. The topography indicates another halt of the ice across the valley near Boston Corners; the fourth halt going west is in the section crossed by the road northward from the Brick Plant; the last halt concerned in this problem is marked by the slope just east of the Rocky Fork (Fig. 8), a slope which has been considerably deformed by later stream terracing.

The delta-like reaches of the Hanover Dam, it should be noted, lie in rock-walled segments of this old valley. The apparent exception in the position of gap, B, is not real, for the following reason: when the ice retreated from the northern end of this gap it left a ridge of drift; this was the retreat that followed halt 2. This ridge of drift fitting against the rock hills both northwest and northeast of the letter B, on Fig. 3, had the effect of a rock enclosure, exerting the same control as the rock slope east of Hanover. The withdrawal of the ice from position 2 to position 3 was gradual, leaving in its path a marked morainic topography. The retreat between halts 3 and 4 was more rapid (Fig. 10); while a much longer period of time was used, and a correspondingly greater drift accumulation was formed (Fig. 9), by the ice before making the last stand, halt 5.

It appears then that when the ice-tongue fronted at position 3 there extended eastward as far as position 2 a fairly static reach of water; this was an evanescent condition, but was of sufficient duration to partially level-up the hummocky surfaces with an assorted deposit varying in thickness.

We note the same combination of conditions again when the ice stood at position 5. But here the work was probably on a larger scale, because the normal ice-front drainage was greatly augmented by the accession of the waters of the Rocky Fork which was carrying the run-off of a valley dependency extending eastward from Wilkins Run (p. 133). Gap A for some time conducted

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[1] These halts are indicated on the topographic map, Fig. 3, by 1, 2, etc.

these waters to the valley southward; the ice-front channels north of the Brick Plant (Fig. 9) were cut during the earlier stages of this halt.

Thus the two locations that favored slack water are marked by level areas; in spots this superficial material is gravel, elsewhere it resembles ordinary flood plain deposits.

ALTERNATE HYPOTHESES.

1. If gaps A, B and C are of post-glacial development, and if there were no cross valleys to the east lower than the top of the Hanover Dam, then a lake could have occupied the valley, provided further that the grade of the old east-west stream had not already been reversed. We feel that subaerial erosion even since Kansan-drift times is incompetent to accomplish the disintegration represented by these north-south gaps; only gap A ever carried much ice-front drainage, and since the cessation of this abnormal stream work, these gaps have controlled only slight drainage basins. In view of observations which the purposes of this paper do not warrant stating here the writer feels that this area was tributary to eastern drainage before the earliest ice invaded this part of the state.[1]

Such care has been taken in mapping the area, and in the description of the drainage lines, that it seems needless to point out the impossibility of this alternate hypothesis. It may be said in addition that the great amount of aggraded ice-stream deposits in the gaps B and C (Figs. 6 and 7), blending into the terraced floodplain of the Licking indicates that, before the ice had moved across or opposite their northern ends, these gaps existed in greater maturity than they now indicate. Furthermore if these gaps are post-glacial—even post-Wisconsin—in development, then at their up-stream terminals they should open into marked flat areas, since streams equal to removing the succession of rock formations already described should have carried off, incident to the lateral planation activity indicated by the width of the gaps, a much greater mass of glacial drift.

2. If there was a general subsidence of the land shortly after

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[1] This interpretation is contrary to the findings of Leverett, *loc. cit.*, p. 155; and of Tight, *loc. cit.*, p. 47.

the maximum development of the ice which deposited this drift, then a lake may have existed here, but its area must have been greater than has been supposed.[1] In discussing the silts found in Ohio, Leverett says: That this region had an unfavorable altitude for drainage in the preceding Sangamon interglacial stage, and probably stood much lower than at present, seems evident from the shallowness of the valleys which were opened on the surface of the Illinoian drift. The drainage conditions seem to have become still more unfavorable during the silt deposition, so that erosion was either suspended or became so weak that it could not keep pace with deposition. This increased imperfection of drainage conditions seems best explained by a depression of the land.[2]

Assuming that this depression was well in progress when the Illinoian ice commenced to wane, it is possible then, with the ice front at halt 5 (Fig. 3), the depression of the land not attaining its maximum during this halt, that, as the level of the water gradually rose, the load from the ice was distributed by this water, developing the existing delta-like surfaces. Under this explanation it follows that the silt which is common over the surface of the Hanover Dam was deposited after the ice had further retreated. In any event, if connection is to be established between this possible silt-producing depression of the land and the origin of the Hanover Dam, no long period of time can intervene; the successive halts of the ice, after its farthest reach into Muskingum County, indicate appreciable time periods; the retreat following halt 5 terminated all connection of the ice with any such explanation of the origin of this mass of drift. It is necessary, however, before admitting even the feasibility of this hypothesis to recall that contemporaneously with the development of the Hanover Dam other deltas should have been in progress of formation, evidence of which is wanting.

With the establishment of certain prerequisite conditions either of these hypotheses is sufficient to account for this delta-like accumulation. But this drift dam is so morainic locally in surface

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[1] Leverett, *loc. cit.*, p. 286.

[2] *Loc. cit.*, p. 301.

features, and contains so much till, that its two level areas, which indeed simulate true deltas, must be regarded as the result of an unusual slack-water condition of immediately ice-front drainage.

SUMMARY.

1. The ice-front in eastern Licking County was characterized by valley dependencies. Further work will doubtless show a fringe of valley dependencies wherever the lobes of the ice sheets reached into the rough topography, resulting from the weathering of the Mississippian and Pennsylvanian formations.

2. The Hanover Dam is the product of one such valley dependency.

3. The amount of disintegration accomplished by all weathering agents since the invasion of the Illinoian ice sheet may easily be overestimated.

4. The principles of sedimentation illustrated by the above formations furnish suggestions in deciphering the erosion history of this part of Ohio.

Geological Department, Denison University, Granville, Ohio, March, 1907.

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Vol. XIII. Article VI. September, 1907.

THE ORIGIN OF SPRING VALLEY GORGE.[1]

EARL R. SCHEFFEL.

OUTLINE.

- INTRODUCTION:
    - The Old Valley.
    - Spring Valley and Its Tributaries.
- THE OLD VALLEY—THEORIES OF TIME ORIGIN:
    - Pre-Glacial.
    - Ice-Erosion.
    - Inter-Glacial.
- SPRING VALLEY GORGE:
    - Description of Abnormal Course.
    - Theories of Time Origin:
        - Pre-Glacial.
        - Inter-Glacial.
        - Post-Glacial.
        - Glacial.—Early, Sub-, Late.

INTRODUCTION.

The area considered in this article is the Old Valley lying approximately southwest of Granville, Licking County, Ohio, a valley about one mile wide at its junction with the valley of the Raccoon to which it is tributary, with a longitudinal axis trending southward nearly one and one-half miles. Fig 2 shows a general view looking from the high knob on the west (marked in Fig. 1, 156 ft.) toward the east.

Among the features of this Old Valley attention is particularly called to the main drainage line following, contrary to general drainage laws, a course neither the longitudinal axis nor tributary to this axis, but parallel to it, flowing for a part of its course laterally on the east valley wall in a rock channel. This rock walled incision is locally known as Spring Valley and is so designated in this paper.

The purpose of this investigation is to determine the Geologic time and genesis of this stream, particularly with reference to the Spring Valley (between X and X, Fig. 1 and Fig. 2) part of its course. For purposes of proof, it is requisite that not only Spring Valley should be studied, but also its tributary streams, as well as

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[1] This work was performed under the direction of Professor Frank Carney as partial requirement for the Master's degree.

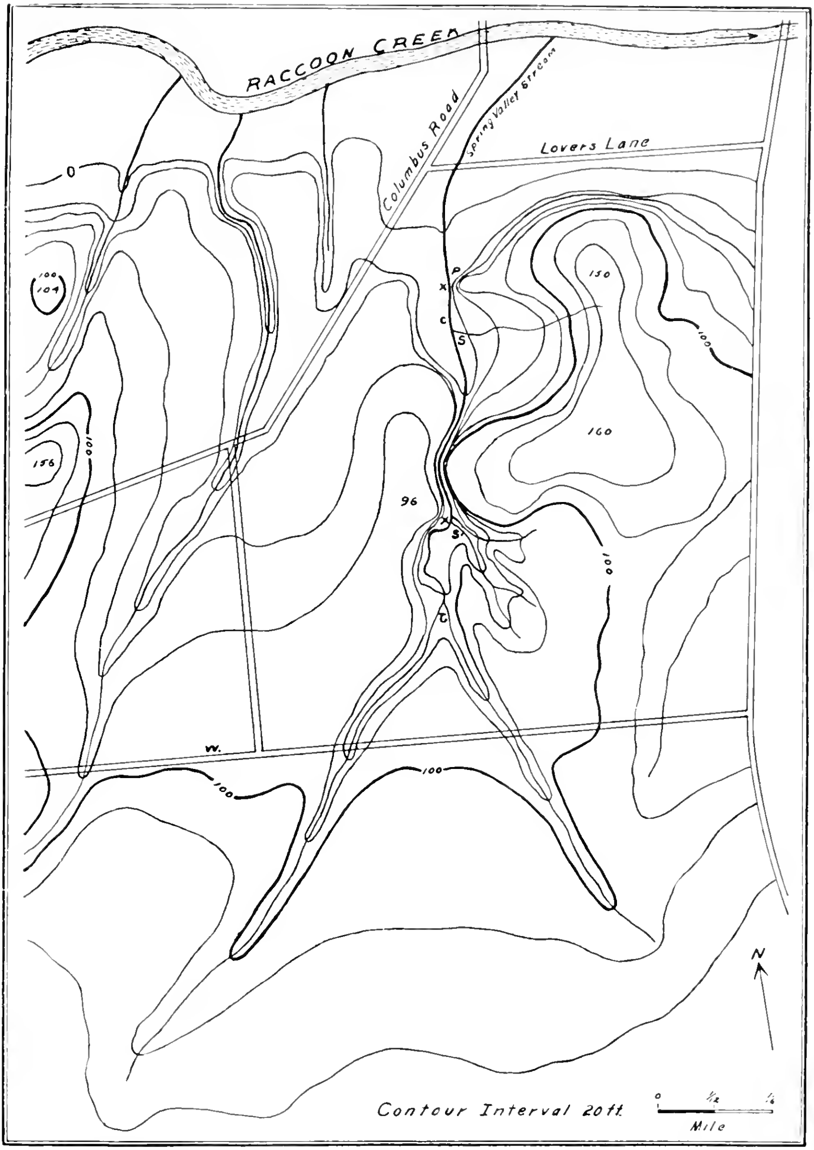

Fig. 1. Contour map of the Old Valley. *X-X* marks the limits of Spring Valley. *S* and *S'* are captured streams now tributary to Spring Valley stream. *J*—The junction of two streams forming Spring Valley stream. *C*—Cut of this stream across the old pre-glacial channel of the tributary *S*. *W*—145 ft. well. *P*—At this point the Spring Valley stream is flowing on rock, between a rock wall on the east, and a wall of glacial debris across the flood plain on the west.

the Old Valley referred to above, which includes within its boundaries nearly all the data given.

THE OLD VALLEY.[1]

That the Old Valley is of pre-glacial origin is obvious. If the walls were of glacial debris, a post-glacial theory might obtain; but while the floor is covered with a heavy glacial deposit, rock of the Black Hand formation outcrops in corresponding horizons near the Raccoon ends of the east and west walls, and also at points on the western side near the valley head. It is equally clear that originally the valley was deeper than at present, as it has been partially filled with drift.[2] Its situation was particularly favorable for such accumulation. Overridden by ice, as shown by glacial accumulations on the highest parts of its walls, the situation with respect to glacial-motion (from the north and northwest) was particularly favorable for holding a mass of ice as in a pocket, retarding onward progress, and admitting continuous accessions to take the place of the ice melted.

That such a process continued during a long period of time, and very effectively from a depositional standpoint, is evidenced by the great depth of debris in the valley. Data for many portions was not available. Among such portions may be included the valley divide on its eastern wall and also the southern end of this wall which present peculiar phases suggestive of old and new drainage complications, a discussion of which would not be relevant to this article. Above the exposed rock walls a thin deposit of drift varying in depth in accordance with simple topographic laws is found. At the point marked W on Fig. 1, where a 145 foot well was drilled two years ago, 136 feet of drift was penetrated before rock was reached. The point mentioned is but a short distance from the valley wall where rock outcrops in a drainage bed, with only about 15 ft. of debris above it. This would indicate a far greater thickness of deposit in the lower part of the valley course. None of the wells in this section about which information was obtained are as deep as the one above mentioned, nor do they reach the rock, but a gas well drilled in the flood plain

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[1] Leverett, U. S. Monograph XLI (1902), p. 172.

[2] Wright refers to drift about Granville in his "The Ice Age in North America" (1891), pp. 468, 493. Cut on p. 284.

of Raccoon Valley at a point about one-half mile east of Spring Valley struck rock 275 ft. below the surface, a depth quite likely approximating the greatest thickness of aggraded material (some of which, however, may represent the pre-glacial flood plain), in the tributary "Old Valley."

Spring Valley, then, can not be explained as coincident in origin with the development of the Old Valley, for such an explanation would present the incongruity of two parallel streams, one flowing near the axis of the valley, with normal tributaries, the other elevated possibly over two hundred feet flowing laterally along the eastern side in a rock gorge. If any possibilties of structural weakness or of topography could even permit the formation or origin of such a stream, its course would not be maintained for any long period of time. Soon a vulnerable point in the relatively narrow west bank separating it from the old valley would be discovered, and the waters released to take a natural course tributary to the stream occupying the axis of the Old Valley.

Before dismissing the topic "The Old Valley" it may be remarked that a theory of glacial origin due to erosional processes of glacial ice is not tenable. The thickness of debris in this section and its low percentage of local constituents suggest the erosional-inactivity of the enclosed ice during at least the later stages of the Ice Age, while protecting hills of rock in height about the same as the walls of the Old Valley, lying on the farther side of Raccoon Valley and opposite to the entrance of the Old Valley into the latter, as well as the trend of this valley transverse to ice-movement, offer irreconcilable difficulties to any theory of active erosional processes in this section during any glacial epoch.

Also the topography of the valley, its great width relative to its length, and the great depth to bed rock, is indicative of an earlier drainage line, a line continuing during such a long interval of time that this area was probably reduced to a mature condition with erosional processes declining in a rapidly changing ratio as cutting proceeded. At the period of its history just before glaciation this Old Valley may be regarded as having about as nearly approximated a condition of base-level as its distance from the sea would permit.[1] This evidence of maturity in the Old Valley

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[1] Davis, "Base Level, Grade and Peneplain," Journal of Geology, Vol. 10 (1902), pp. 77-111.

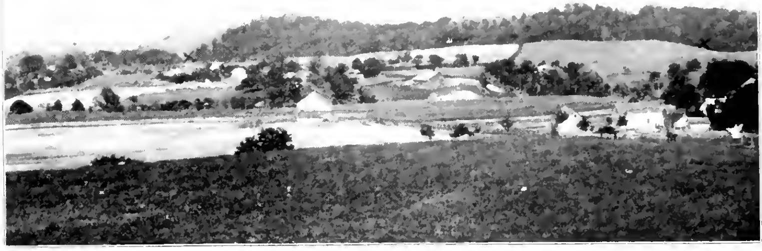

Fig. 2. View looking across the Old Valley toward the east. Note the continuous upward slope of the east wall, almost concealing Spring Valley lying between X-X. The mature appearance of the Old Valley, with the cut of the central drainage line through unconsolidated material is shown.

may be also urged against any theory of inter-glacial origin.

The present drainage lines of the Old Valley, with the exception of Spring Valley, offer little of interest following as they do subsequent courses over the drift.

In connection with this discussion of the Old Valley, it may be mentioned that there is evidence of a west-flowing pre-glacial stream in the valley of the Raccoon (to which this Old Valley is tributary). The cause for the diversion of Raccoon Creek at this point from a west-flowing to an east-flowing stream will be the subject of a future paper.

SPRING VALLEY STREAM.[2]

Spring Valley Stream is formed by the union of two slight creeks, converging and draining the entire southerly portion of the Old Valley. These two streamlets, starting on the valley walls, follow lines through the drift, and present no peculiar drainage features until a short distance beyond their junction (J. Fig. 1), where a sharp bend eastward then a northward turn leads the united stream through a gorge cut into the eastern wall of the Old Valley. This portion of its course is known as Spring Valley. Both data and theory will be given to show that Spring Valley

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[2] See reference under the Old Valley.

can be neither of pre-, inter-, nor post-glacial origin, but must be of late glacial development.

One step of the proof that Spring Valley is not of pre-glacial origin has already been given in connection with the discussion of the Old Valley, but the most striking evidence against such a theory is found along the course of Spring Valley itself. Its rock walls rise almost perpendicular. Above them the banks reach still higher, particularly on the eastern side, over a gentle debris-laden slope. The effect is such that viewing the east wall of the Old Valley, as in Fig. 2, a continuous even slope almost concealing Spring Valley (between the points *X* and *X*) is observed. Such a continuity of slope could not obtain if the stream were of pre-glacial origin for if, as stated above, such a stream were once formed it would soon cut through its western bank at some point and drain into the major stream.

Only abnormal conditions, as might operate during a glacial epoch, could originate such a course. The divergence of the united stream from debris into a rock channel on the valley wall, when the course could far more readily be continued under normal conditions through drift to the axis of the major valley, can not be consistently explained on any other hypothesis.

The steep rock walls of Spring Valley are evidence of newness. The gentler slopes above them, debris-covered, indicating a well eroded surface sloping to the axis of the old valley, contrast sharply with these but slightly weathered almost vertical rock walls. The slope of the stream bed is also an indication of comparative newness. The fall through Spring Valley alone, a distance less than one-third of a mile, is 35 feet.

The most striking proof of the late origin of Spring Valley is found in its tributaries. It is obvious from the description of this valley already given that all secondary drainage must be received from the eastern side. This tributary drainage is represented by the stream S, Fig. 1, in the lower part of its course, and by the two streams, which for reasons to be explained later may be regarded as one, marked S′, Fig. 1 and Fig. 3, in the upper part of its course.

The first of these tributaries, a tiny stream draining a small area, occupies a short valley showing every evidence of maturity.

No rock walls are exposed and the slope from the valley top is uniformly gentle to the stream bed, which is an insignificant cut in glacial debris. Presumably this valley at one time contained much more debris than at present, but this unconsolidated material has permitted rapid erosion, lowering the stream to the grade of Spring Valley, and developing a valley similar to the original in its upward slopes. One essential difference, however, is noted: At the junction of this valley with Spring Valley in a cut (*C*, Fig. 1) through the flood plain which the latter has built across the present mouth of the former is exposed compactly bedded deposits of blue and yellow clay-like material, located in what would naturally be the bed of this tributary stream; in places these deposits are nearly homogeneous, showing little evidence of foreign gravels. Again, especially in some of the yellowish or brown colored sections, ample evidence is found of foreign pebbles.

At a point (*P*, Fig. 1) just north of this tributary to Spring Valley, in the cut of the latter, the east rock wall abutting Spring Valley and the rock bed of its stream is noted. Proceeding southward the rock wall gradually declines forming the even north slope of the tributary valley. For a short distance further the rock shows but a few feet vertical exposure in the cut of Spring Valley flood plain. Then the outcrop becomes more and more

Fig. 3. View from flood plain of Spring Valley stream, looking north. *S'* — Captured drainage now tributary to Spring Valley stream. X Entrance to Spring Valley gorge. Rock outcrop shows to the left.

broken, finally blending into the clay-like material previously mentioned. This material, with some modifications, continues until near a point opposite the south bank of the tributary valley when a progressive change to solid rock walls and bottom is noted as first instanced. In general a consistent arrangement of materials is observed on both banks of the cut in this flood plain.

Only one explanation for this peculiar arrangement of debris in the mouth of this tributary to Spring Valley seems plausible. It is readily accounted for on the hypothesis that this drainage line formerly crossed what is now Spring Valley, emptying into the stream of the Old Valley. During glacial times this channel was filled with drift, part of which is now revealed as before mentioned. That a flood plain has been formed by the Spring Valley stream at this point and on both sides (the area surrounding *C*, Fig. 1) is due to the comparatively soft material constituting the debris filling the old channel (tributary to the Old Valley) which it has been able to cut out rapidly at an earlier period of its history. Thus for a part of its course this old valley was exposed, while its drainage was captured at the same time.

In this connection it may be noted that there is no high rock wall corresponding on the west side to *P*, Fig. 1, on the right side. Instead the bank shown is of glacial debris deposited over the old channel of the captured tributary S. This tributary in its original course to the axis of the Old Valley cut off what would otherwise have been the northern end of the western rock bank of Spring Valley.

The Old Valley and this tributary *S* doubtless were long under the influence of glaciation. The immense depth of debris in the former would alone indicate this, but in the tributary S, particularly in the cut through this old filled channel, as stated above, evidence is found of the varying age of the drift. Some of this material, as before described, is clay-like, yellowish in color indicative of a long period of exposure and resultant weathering, probably during an inter-glacial epoch. A blue clay also frequently outcrops. It is difficult to determine in this limited exposure the relative positions of these clays. The blue clay horizon, however, seems to be below the yellow, hence is suggestive of an earlier protected deposit. The appearance of these clays corresponds to Leverett's description of the Illinoian drift[1]. At several points in the cut a thin bedding of foreign pebbles cemented into a conglomerate like mass was noted. The stained and weather-worn appearance of these masses suggests great antiquity.

The compactness of all the drift lying below the recent deposit of the Spring Valley flood plain at the point mentioned implies great pressure, due probably to overlying debris which has been removed, and the weight of the over-riding ice. Many large granite bowlders are also noted at this point and southward, the presence of which will be discussed later.

The history for the second tributary streams *S'* is similar to that for *S*, but the explanation is more complicated. The more northerly of the two small streams runs over rock near its junction with the Spring Valley stream, and shows rock walls extending about one foot vertical height on either side. But on the north side alone can be traced the gradual rise of rock along Spring Valley, representing probably the old north wall for this second pre-glacial stream now tributary. Drift alone is found for some distance south of this point, the other and smaller stream showing no evidence of rock exposure. Presumably the first stream is pursuing a course lying just at the base of the north rock wall of this second valley tributary to Spring Valley. The south rock wall has not been definitely located. It is hence evident that these two streams have their rise in a drift-filled channel tributary to the Old Valley, as in the case of the stream *S*. The debris-evidence in the cut of Spring Valley stream through its flood plain at this point before entering the gorge, confirms this theory.

It may be added that the flood plain material directly above the rock at the points between the two tributary valleys just discussed, and imposed on the clay-like debris marking the old preglacial channels of these tributaries, is itself evidence of the comparatively recent origin of Spring Valley. This flood plain material is composed of stratified layers of broken local sedimentary rock mingled with glacial debris, the former generally in excess.

THEORIES FOR ORIGIN OF SPRING VALLEY.

This article has endeavored to show that Spring Valley does

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[1] Leverett, U. S. Monograph XLI, p. 272.

not mark a pre-glacial drainage line. The other possible time periods of origin are inter-glacial, post-glacial and glacial.

Inter-glacial Theory. The arguments for an inter-glacial theory of origin must be similar to those amplified in the succeeding paragraph. The same objections also hold. This theory has an even less secure basis, for admitting that such a stream might be formed inter-glacially, later glacial epochs would probably obliterate its channel with debris.

Post-glacial Theories. On the supposition that the Old Valley was formerly filled high up on its walls with glacial debris, it might be concluded that the Spring Valley drainage formerly pursued a consequent course superimposed over solid rock, in glacial debris; soon cutting through this drift into the rock, its course became fixed. Then the western portion of the Old Valley with its greater depth of glacial rubbish, permitting more rapid cutting than did the rock bound Spring Valley, has been given its present topography as hitherto described, leaving Spring Valley following laterally on the east valley wall. This theory is hardly tenable since a mature transverse valley is rarely so completely buried that its topography is not a factor in post-glacial time. The drift would tend to slope downward to the axis of the original valley, and drainage lines originated on the drift-covered valley wall would normally tend toward this axis, rather than cut a channel through solid rock parallel to it.

One theory for the origin of rock gorges in Licking County is that they have been formed by the undermining of the rock by springs, the action being accelerated by the caving in of the rock roof from time to time.[1] Such an explanation does not adequately account for the great depth (Fig. 1) and the width of Spring Valley gorge, especially considered with reference to its appearance of newness as elsewhere described. Neither does it account for the large number of granite bowlders found along this valley, which must, according to such an explanation, have come from an area above but little larger than that of the present valley. The eastern slope of the old valley does not carry many bowlders. This theory, moreover, would demand that the lower

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[1] M. C. Read, "Licking County," Geological Survey of Ohio, Vol. III, Part I, (1878), pp. 350, 351.

part of the rock be the most weathered, a reversal of what is found in normal streams. Spring Valley gorge corresponds with the latter in this respect.

Glacial Theories. Early Glacial.—That such a gorge as that of Spring Valley might have been formed during early glacial times would be quite in accordance with the accepted explanation given later. The difference, however, is apparent. It is not probable that the ice would maintain a stable position relative to this channel throughout a long interval of time. There would be many advances, retreats and halts. Its chance for survival during such changes in the ice movement would be the same as for any deep depression. It would be filled with debris and smoothed to correspond with the adjacent topography.

Sub-glacial Theory.—That sub-glacial streams are of frequent occurrence is a fact well known to the literature. That such streams frequently follow courses independent of topography is equally well known. Such streams, however, are usually overladen with debris received directly from the ice. This, together with the restraint of the ice-covering reduces their cutting efficiency, sometimes even making them so inactive that deposition rather than erosion obtains. In Spring Valley an erosional activity is evidenced with few parallels in known sub-glacial stream courses. Further argument against this theory is similar to that in the preceding paragraph. Even if formed under such conditions as mentioned, the instability of the ice would tend to change the channel, as well as to fill any channels that might be formed with glacial debris. However favorable the conditions, none of these channels could escape the influence of the ice-retreat.

Late-Glacial Theory.—While it is impossible to prove without question such a genesis, nevertheless in the theory of a late-glacial origin of Spring Valley it is difficult, if not impossible, to find unanswerable objections to any of its phases.

During this period the Old Valley can be imagined as occupied by ice reaching out over the west, abutting against its east wall and extending as a tongue for some distance along the valley of the Raccoon, the ratio between advance and retreat at this time approximating unity. Under such conditions the ice would melt away from its upper contact with the east wall of the

Old Valley on both the west and north exposures, leaving a channel between the rock and ice. This channel would afford a ready outlet for ice-front waters, and with the ice maintaining a permanent position, the gorge cutting would proceed rapidly. After a certain period of time, a period determinable by the volume of glacial waters and its cutting tools, a channel would be developed which, by incising the solid rock of the valley wall, might become fixed for an indefinite period.

The large number of big granite bowlders found, especially near the outlet end of the Spring Valley course, is indicative of the vigor of this late glacial drainage. This circumstance also supports the theory, later elaborated, that Spring Valley drainage, while the ice maintained its position in Raccoon Valley, took a course eastward around the north end of the Old Valley wall; the lowering in the velocity of the water near the turn would cause the heavier part of its load to be dropped.

The stratigraphy of the Black Hand rock also favors the late-glacial theory; of sandy shale-like character, with numerous joints and bedding planes [1] both normal weathering and the removal of large blocks of stone would be facilitated.[2]

While on the western slope of the east wall of the Old Valley the waters soon cut a channel into the rock so far that a guarding boundary of ice was no longer essential, it is probable that towards the northern end the ice constituted one bank of the stream for a longer period of time. Here the conditions differed, the stream channel, being parallel to the direction of ice movement in the Raccoon Valley, could maintain its position even while the ice tongue was retreating.

The theory that this drainage line after emerging from Spring Valley continued its course around the end of the valley wall as before suggested constitutes in itself a problem. There are several facts in accord with such an explanation. The steepness of this slope indicates but little weathering. If this steep condition had been produced pre-glacially it would present a more mature appearance, and if eroded by ice the tendency would have been to accentuate such a condition. There is, moreover, practically

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[1] Carney, "Geology of Perry Township, Licking County, O." Bulletins Scientific Laboratories, Denison University, Vol. XIII (1906), p. 120, 123.

[2] Westgate, "Abrasion by Glaciers, Rivers and Waves." Journal of Geology, Vol. XV (1907), pp. 116, 117.

no glacial debris on this end. Its absence can readily be explained by the presence of such a stream which, turning the bend eastward on emerging from Spring Valley, would first be checked in its speed, leaving a large part of its load behind, then with renewed force would sweep along between the northern end of the east valley wall and the ice, clearing from the former any debris which may have been laid before the genesis of this stream.

Part of this debris would be carried forward with the stream, part dropped to its bottom, this process continuing as the stream lowered itself between the rock wall and the ice. As the Raccoon ice tongue retreated back of this valley end, this stream would be finally released so that a normal route could be followed from Spring Valley to the drainage line of Raccoon Valley. Any terrace left would be rapidly obliterated by weathering and erosion, though even now the lower slope of this end wall is suggestive of a former stream terrace.

SUMMARY.

A. That the Spring Valley stream is not of pre-glacial origin is proved by
  1. Its position on the east rock wall of the Old Valley, following a lateral course parallel to the axis of this Old Valley.
  2. The fact that its tributaries formerly emptied into the drainage line of the Old Valley.
  3. The character of its rock walls and of the glacial debris found along its course.

B. That Spring Valley is of late glacial origin, having started between the margin of the ice and the valley wall, is supported by
  1. The elimination as not plausible of a pre-, post-, and early glacial genesis.
  2. By the strict accordance of this theory with the possibilities.

C. Theory and data suggest that the Spring Valley stream continued around the north end of the east wall of the Old Valley between ice and rock until the retreat of the Raccoon ice-tongue.

Geological Department, Denison University, Granville, Ohio, July, 1907.

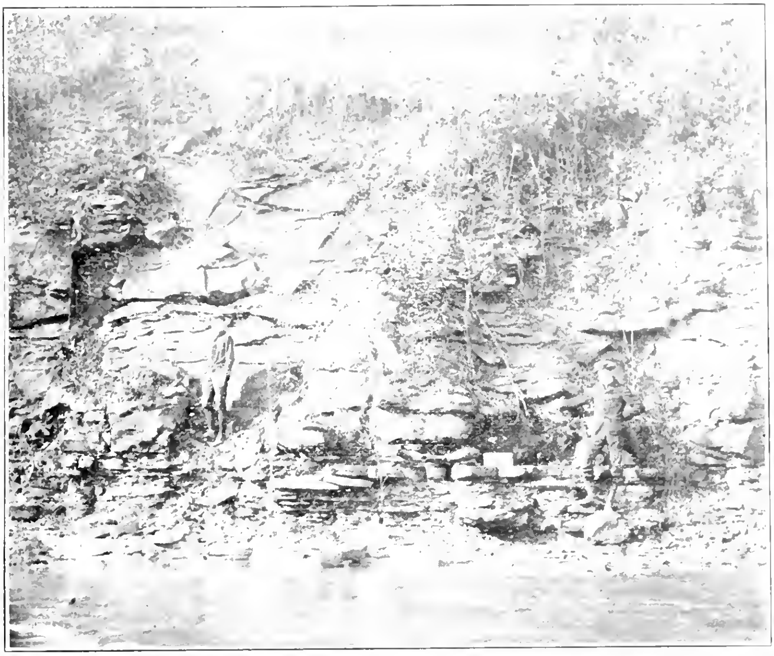

Fig. 1. A section along the Rocky Fork in southwestern part of Perry township, marking contact of the Cuyahoga and Black Hand formations. The lower 3 feet is Cuyahoga.

Fig. 4. Disintegration of the Sharon. This view is in an escarpment, over a mile long, the result of differential weathering.

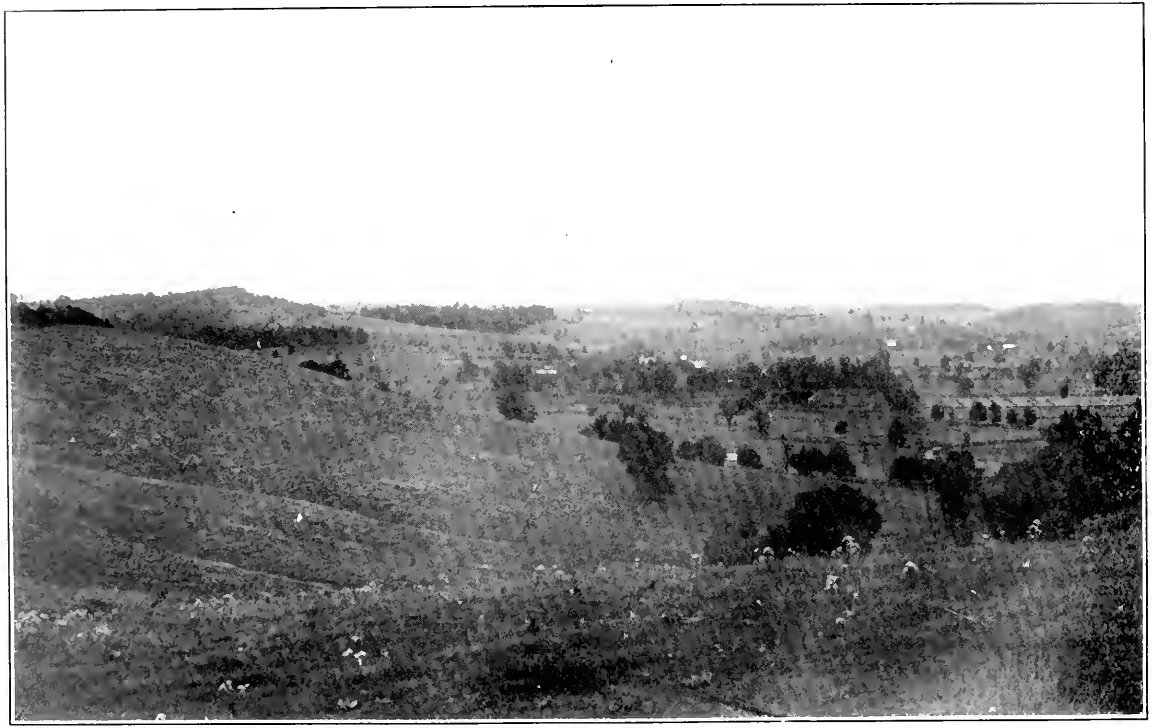

Fig. 2. Looking north over Perryton. A typical Logan slope shows in the foreground. The broad flat area is a local expansion in the Wakatomaka valley, a section where the rocks have yielded readily to lateral planation.

Fig. 3. Looking west through the converging cliffs of the tributary valley next to well No. 1; only the southern rock wall shows conspicuously. Cross-section M-P is drawn through the foreground.

Fig. 5. The work of solution in the Sharon conglomerate, a characteristic form of weathering observed in these coarse formations. Lichens also show here.

PLATE V.

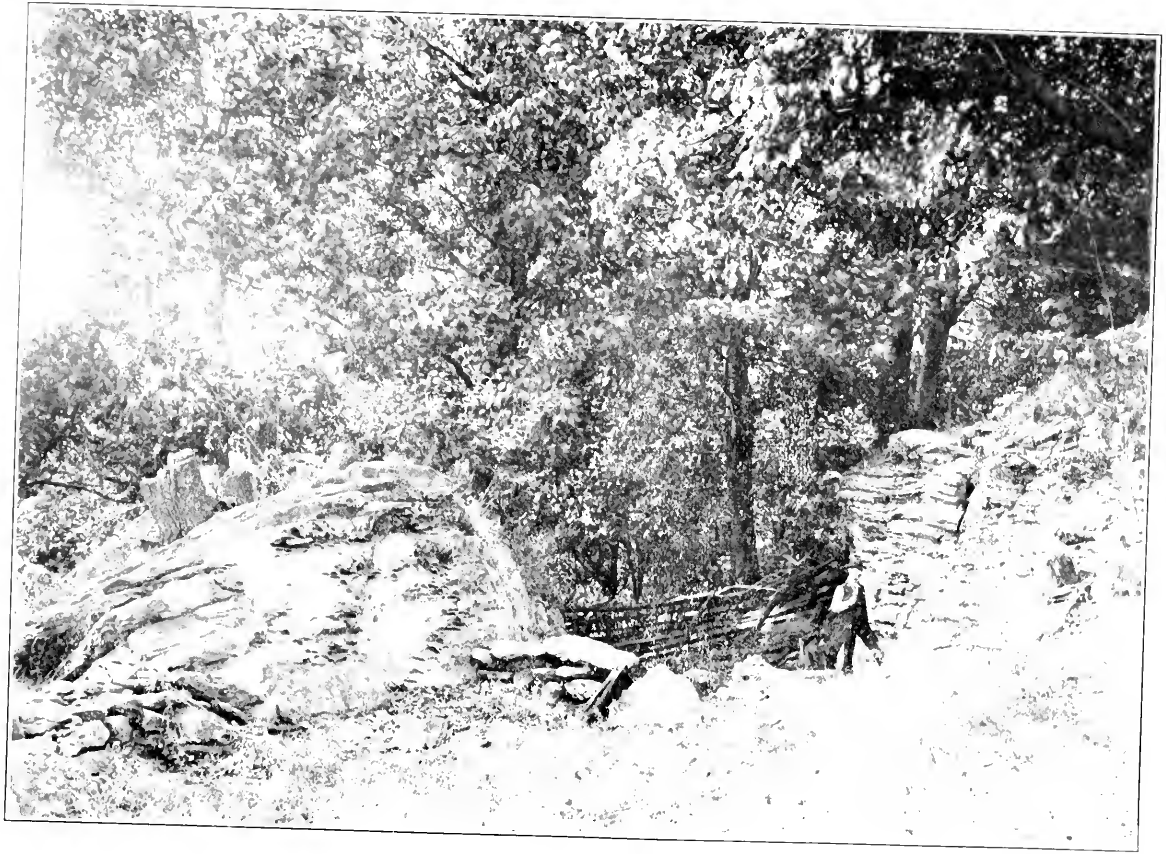

Fig. 6. Looking through an opening about 40 feet long in the Sharon Conglomerate; this marks the position of a main joint plane. The mass on the left is gradually creeping.

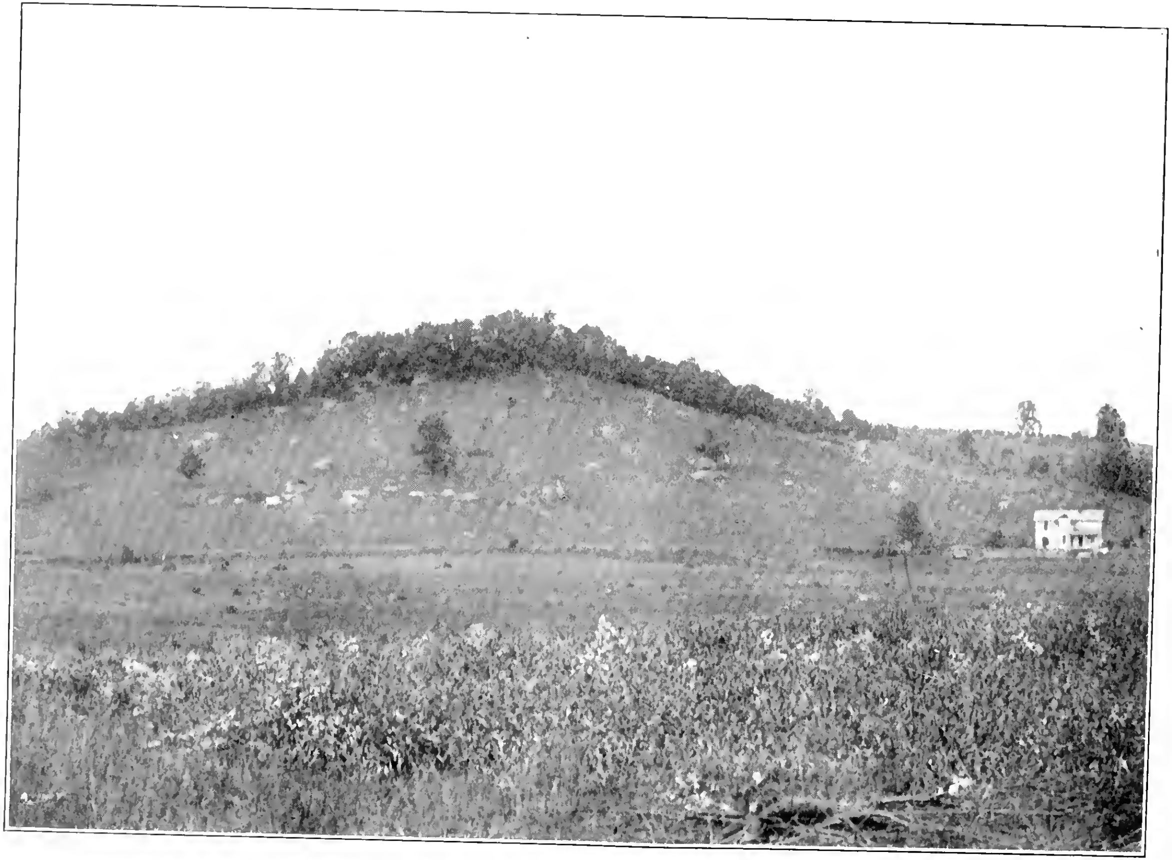

Fig. 7. This Logan slope strewn with Sharon blocks is on the north wall of the Wakatomaka Creek a short distance over the Perry township line in Muskingum Co.

Fig. 8. Columnar remnants that could not have withstood ice-abrasion.

Fig. 9. A highway-cut, about 65 feet below the highest point of Claggett's Hill, in residual soil; in upper part of Section is a block which has crept down from above.