
THREE
AMERICAN
MICROSCOPE
BUILDERS

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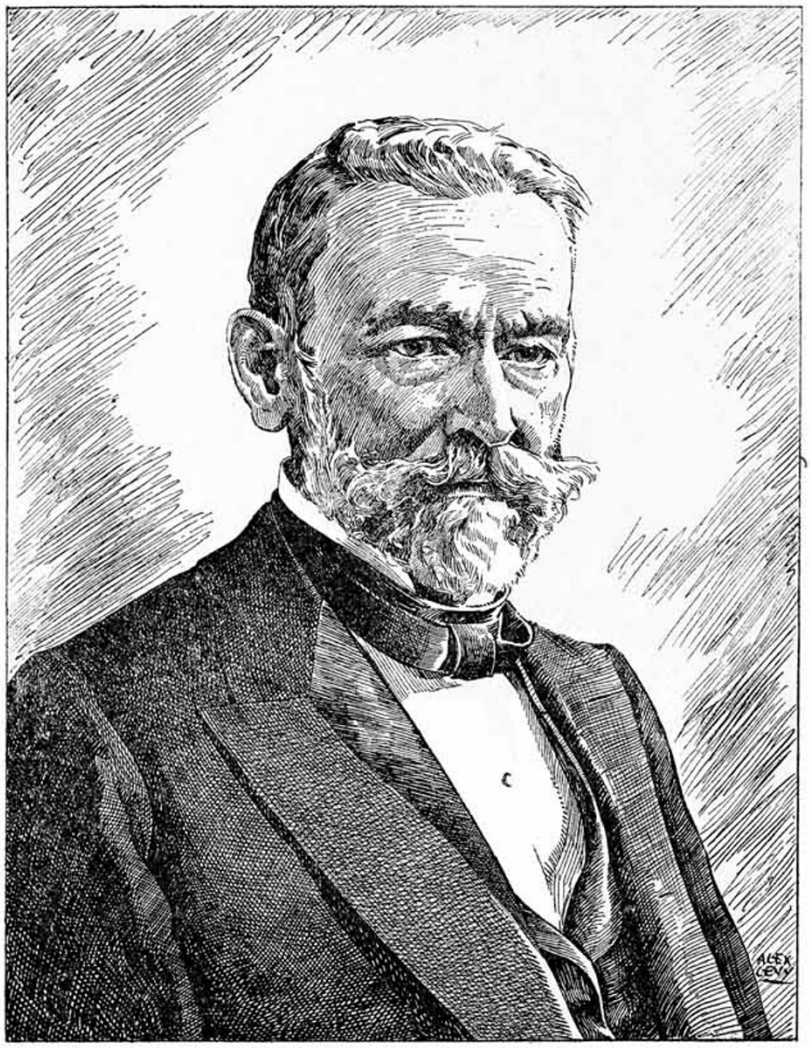

Charles A. Spencer, 1813-1881, first American microscope builder.

THREE AMERICAN MICROSCOPE BUILDERS

This booklet is published to memorialize these three early microscope builders—to point with pride to their achievements, with the hope that men and women who are using or building such instruments today, will fully appreciate the dominant position of, and the splendid opportunities before, the American optical industry.

American Optical Company
SCIENTIFIC INSTRUMENT DIVISION
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Scientific Instrument Division
Buffalo, New York, U. S. A.

FOREWORD

AFTER reading the manuscript THREE American MICROSCOPE BUILDERS, I am gratified to add a prefatory word in appreciation of the wisdom and generosity of the Spencer Lens Company in making available to microscopists these tributes to Americans who took such fundamental steps in the optics of the microscope. Steps which never faltered for a moment were taken by Charles A. Spencer and Robert B. Tolles with their high angle objectives and with Tolles's homogeneous immersion objectives of the early '70's, and the progress of the Spencer and Tolles optics was continued by Herbert R. Spencer as long as he lived.

The tributes are by men who themselves were masters in the use of the microscope and who helped greatly in the spread of microscopy in schools and colleges and in the appreciation of the microscope as an essential tool for use in medicine, biology and industry.

It is also gratifying to know that from the famous Spencer microscope of 1847, progress in excellence of the optics and mechanics of the microscope has been continuous until the present day. And I for one have faith at the end of seventy years' use of the microscope in all its forms that with the Electron Microscope and the constant advances made in perfecting the Refracting Microscope, great things are in store for the future teacher and investigator.

It is hoped and believed that this little book will help present and future microscopists to appreciate the accomplishments of the microscope builders in the early, hard days.

Professor Emeritus of Histology and Embryology
Cornell University. October 5, 1944.

S. H. Gage

We were particularly fortunate in having received the counsel and help of Professor Simon Henry Gage in reading this manuscript before it went to the printers. He was a militant defender of the American microscope builders—a leader in microscopy throughout his long life.

Seventeen editions of his book THE MICROSCOPE *were published. He served as President three times during his sixty-two years as a member of the American Microscopical Society.*

His "Foreword" on the preceding page was written a few days before his last illness. He died on October 20, 1944 at the age of 93.

INTRODUCTION

In the archives of science, many successful struggles for knowledge lie buried—the men, the inspirations, the achievements, all forgotten. Such is the case of the early Americans who labored so diligently during the last century advancing the science of optics. Only recently has their work come into perspective.

Although important contributions came from Holland, Italy, France and Germany, English opticians led in improving the microscope during the early days of the 19th century. It was the Americans, Charles A. Spencer and Robert B. Tolles, working in a "small interior town with the burnt stumps of the forest trees all around it" who challenged British leadership successfully. For almost fifty years, these Americans supplied the finest microscopes and microscope objectives. They won recognition on both sides of the Atlantic and received the gold medal in competition with the best work of Europe at the 1878 Paris Exposition.

They approached their work in the spirit of the artist and scientist rather than in that of the commercial aspirant. Unlike their German competitors they neither asked nor received government aid.

We trust that you will enjoy reading these tributes to the Spencers and Mr. Tolles from the eminent microscopists who were contemporary with them.

CONTENTS

"When the name of many a successful man, as the world counts success, shall have been forgotten, and the marble on which alone it is recorded shall have crumbled away, that of Spencer will live; nor will it be forgotten until the human eye no longer needs a microscope, but shall see clearly the now hidden things of God."

HAMILTON L. SMITH, LL.D., F.R.M.S.

ILLUSTRATIONS

A fire at Canastota destroyed the early records of Charles A. Spencer and only the diligence of a faithful friend, a scientist's accuracy and a flair for lucid writing make possible this fine memoir.

Hamilton L. Smith was Professor of Natural Philosophy at Hobart College during the years that Charles A. Spencer worked in Geneva. In addition to being an authority on diatoms, he was keenly interested in optical developments. He was a Fellow of the Royal Microscopical Society and twice president of the American Microscopical Society.

Quite naturally, he became a close friend of the Spencers. Dr. J. A. Spengler of Geneva, while reminiscing, tells us that he even computed a high power objective lens for them. (Probably the 1/75 inch).

It is fortunate that Charles A. Spencer had such a well qualified "Boswell".

CHARLES A. SPENCER*

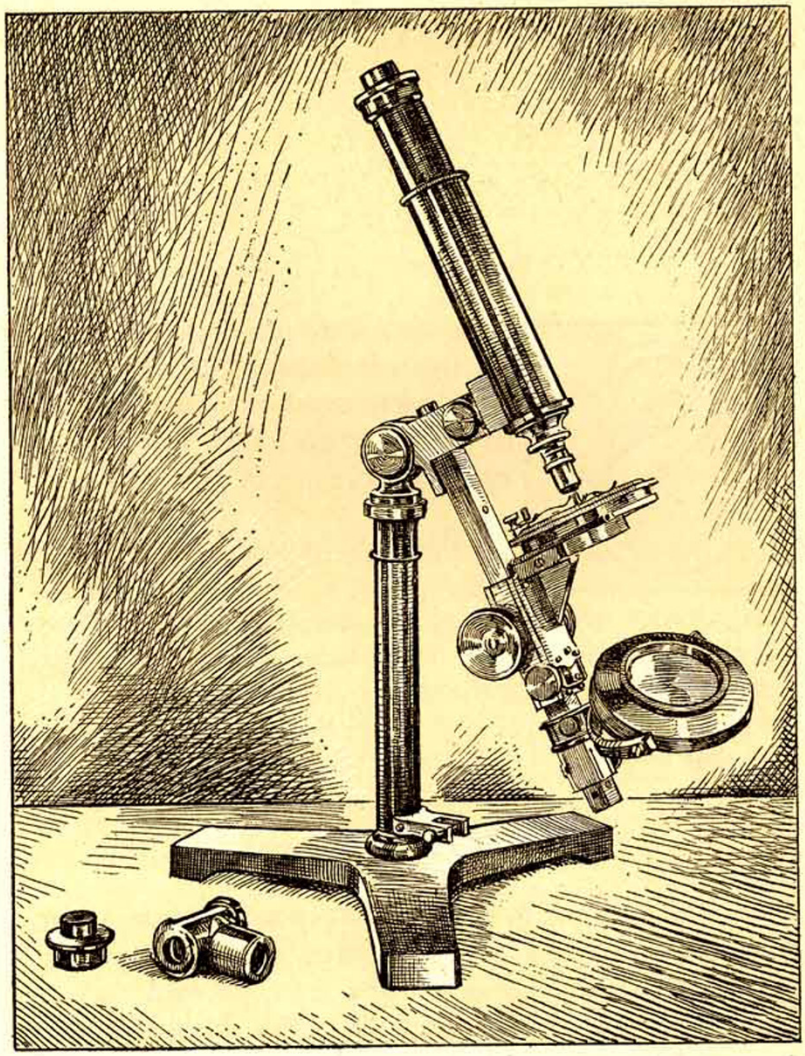
INCE our last meeting, one of our most distinguished associates, one who has been justly considered as the pioneer of scientific optics in this country, has been taken from us.

I shall do the best I can in presenting to you a brief synopsis of his labors, continued almost to the end of his life, in advancing the perfection of the microscope and telescope; and, although he has had a cheerfully accorded and world-wide reputation, yet few persons are really aware how much the scientific world is indebted to his persevering labor and ingenuity.

A TRUE GENIUS

Mr. Spencer was, in the truest acceptation of the word, a genius. Life was not to him a contest for the possession of what the world commonly calls gain; no man was ever more indifferent to this than he. From his boyhood he seems to have had an all-controlling idea, a self-consciousness, which seemed but conceit to those who did not understand him or realize how much there really was in him,

*Adapted from Smith, Hamilton L., LL.D., F.R.M.S., MEMOIR OF CHARLES A. SPENCER, from *The Proceedings of the Society of Microscopists*, 1882, pp. 49-74.



The first American Microscope was probably like this early one (about 1848). It may be used in the vertical, inclined or horizontal position. Presented to Spencer Lens Company by Mr. Edward Pennock.

of his ability to produce better optical work than the world had yet seen.

Almost fifty years have elapsed since Mr. Spencer first began the manufacture of telescopes and microscopes. The only instruments of this character then in the country were imported ones, and probably the whole number of achromatic microscopes was less than a dozen. European microscopists looked upon this country as but a wilderness, and though the labors of Bailey, Torrey, Silliman, and some half dozen others, were beginning to attract tardy recognition in the scientific world of Europe, the announcement that a "backwoodsman" somewhere in the wilds of Western New York had not only dared to question the dictum of England's famous artist, but had actually proved himself right by the constructing of objectives with a largely increased angle of aperture, was received with a smile of derision and considered as a Yankee fiction.

The merits of Mr. Spencer were however soon candidly acknowledged, and with him commenced that steady improvement of the microscopical objective which has continued to the present day. Mr. Spencer, happily, lived long enough to see the triumph of principles advocated by him, and first by him successfully carried into execution.

NEVER QUITE SATISFIED

I have said that Mr. Spencer was, in the best sense of the word, a genius; if he had been anything else he would have accumulated a fortune. The unfilled orders on his books were often $20,000 to $25,000 in advance—orders from all parts of the world, but alas, many of them, such is genius, never filled, for Mr. Spencer was never quite satisfied with his work. No matter how perfect it was, for that time;

no matter that it would have more than satisfied those for whom it had been done, and who had already waited patiently for it; if it did not come up to his ideal, or if he could possibly see that any improvements could be made, conditions constantly occurring, what to him was time, what was money, nay, what were all his promises, what was anything, compared with this yet to be accomplished higher excellence? And so it happened that very often it cost him much more to produce a given piece of work than the pay be received for it.

In preparing a sketch of the life and work of our late associate, I regret that the materials at my command are so meager. Mr. Spencer had a most wonderful memory and he found that he could trust it so completely that he felt independent of written notes. The voluminous correspondence that he must have carried on, in those days when letters really meant something, was destroyed in the disastrous fire at Canastota. The correspondence to which I have had access is very limited and I can present but little in addition to what has already been published.

The disastrous fire at Canastota in 1873 destroyed C. A. Spencer's shop.

SCHOLARLY FOREBEARS

Mr. Spencer was born on Quality Hill, in the town of Lennox, N. Y. in the year 1813. He was the youngest son of General Ichabod S. Spencer and nephew of the late Joshua A. Spencer of Utica, N. Y. Mr. Spencer was educated at Cazenovia Academy, and after graduating there, he entered the Freshman Class at Hobart, then Geneva College at Geneva, N. Y; his uncle, Dr. Thomas Spencer, being at that time a professor in the medical department of the college. He remained, however, less than a year, and soon after went to Hamilton College, Clinton, N. Y. of which his uncle, Judge Joshua A. Spencer, was then one of the trustees. His repugnance to being educated at the expense of others, or as a "charity student", as he termed it, was so great, that he did not long remain at Hamilton, but returned to Canastota to study and experiment by himself; as he had found that at this early day comparatively little attention was paid in the colleges to the subjects which most interested him, most of the time being devoted to classical studies. He betook himself, therefore, to more earnest practical work in science; not, however, neglecting to give a fair attention to classical literature; and in later years he received the honorary degree of A. M., from Hamilton College.

STARTED IN 1838

The first appearance of Mr. Spencer before the public as a manufacturer of telescopes and microscopes was announced by a circular printed upon a sheet of the large-sized letter-paper of the day. It was a list of prices of various sized reflecting telescopes, and of Dr. Goring's "engiscope" or reflecting microscope. The date must have been near 1838.

Charles A. Spencer as a young man, from a painting by Franklin Spencer

About two years after this, he issued a descriptive catalogue, "Optical, Philosophical, Mathematical, Chemical and other instruments and apparatus." The telescopes listed are chiefly reflectors, from 10 to 3 inches aperture, and ranging in price from $8.00 to $75.00. The achromatics are from 1 to 3 inches in diameter, and prices from $12.00 to $200.00. The "Amician Reflecting Microscope" and the "Compound Achromatic Microscope", with complete apparatus, are also listed. In a foot-note, relative to the powers of these microscopes, the tests named are the scales of the white cabbage butterfly, the podura, and the small brown moth. Besides these the catalogue enumerates various solar, lucernal, botanical, pocket and other microscopes and various mechanical, hydrodynamical, pneumatical, electrical, meteorological, galvanic, pyronomical and chemical instruments.

I believe the business did not prove to be profitable, but Mr. Charles A. Spencer continued to devote himself to the perfection of the achromatic microscope and telescope, which seem now to have chiefly engrossed his attention; and probably his experiments were more in the way of making achromatic telescopes than microscopes. There is no doubt that the study of astronomy was particularly fascinating to him, and his fondness for the telescope and telescopic pursuits never diminished, though he found in the development of the microscopical objective a more promising field for his genius.

AMERICA'S FIRST ACHROMATIC

It cannot be ascertained just when or by whom his attention was first called to the possible capabilities of the achromatic combinations for microscopical objectives.

Dr. C. R. Gilman was a professor at this institution when Charles Spencer made the first American microscope for him.

The old-fashioned triplets as first made by Chevalier, and better by Oberhauser, were those chiefly used. Powell and Ross had indeed improved on these, but there were few in this country who had their glasses; and, indeed, in 1847, when Spencer made for Dr. Gilman, of New York, the first microscope that attracted attention, there were not over four or five achromatic microscopes in the city of New York. Dr. Gilman, having showed to Mr. Spencer one of these, a Chevalier, Mr. Spencer remarked that he thought he could make a better one, and the doctor decided to let him try. It was accordingly made after the same pattern, and on his way to New York with it, he stopped off at West Point to show it to Prof. J. W. Bailey.

He had heard of the use of diatoms as test objects, but had never tried them, which was his purpose of calling on Prof. Bailey. It was his first interview with Prof. Bailey and he describes it in a letter written to Dr. John Frey, of New York, dated October 21, 1847.

"Now, between ourselves, I did not make as good an instrument for Dr. Gilman as I know I can make. I used the Swiss Flint, with the intention of beating the foreign instruments with their own materials. Knowing that Prof. Bailey's Navicula Hippocampus (name later changed to to Pleurasigma Hippocampus) test would prove the matter well, I called upon him. I had some misgivings, so I set up my instruments for the scales of the Podura. He almost instantly exclaimed, with warm earnestness; 'I am sure that it will show the hippocampus.' I replied that I feared not, as I had not one of my best highest powers with the instrument. Prof. Bailey insisted upon finding the object on the slide, and the instant his eye caught it, he exclaimed: 'It shows it beautifully—this is a perfect treat!' I then looked at it, and must confess almost instantly lost my reverence for the English test object *par excellence*."

PROUD TRIUMPH

Prof. Bailey gives a glowing account of the performance of the microscope made for Dr. Gilman, in Silliman's Journal, Vol. 5, second series, 1848, in a letter to the editors under date, Nov. 27th, 1847. He states that Spencer's lenses are far superior to any of Chevalier's which he had as yet seen. He says: "I do not think Spencer's microscope quite equal to the far more expensive English ones made by Ross or Powell, and I cannot positively assert that it is superior to the best of those made by Oberhauser or Ploes-

sels, as I have not an opportunity to compare them properly side by side in the same light. My impressions, however, are that the microscope made by Mr. Spencer for Dr. Gilman is in no respect inferior to any of Oberhauser's that I have seen, and I am by no means certain that it is not superior. I certainly had a better view by *candle-light*, of the transverse lines of the N. hippocampus, by means of Spencer's instrument, than I was able, subsequently, to do by *day-light* by means of Oberhauser's. I look upon the results obtained by Mr. Spencer as a proud triumph for American Art."

In the same article of Silliman's Journal, a committee—John Torrey, J. F. Holton and John L. LeConte—in its report to the New York Lyceum of Natural History, said "The superiority of Mr. Spencer's microscopes over Chevalier's Number 1 *is very decided*, although made on a much smaller and less expensive scale."

In an article dated February 4, 1848, we learn that Spencer promised he would make an objective that would show the lines in spite of the most awkward illumination. Mr. Spencer fulfilled his pledge, and more—he resolved the lines on a Sigmoid navicula—a test object that made all other test objects mere child's play; so Prof. Bailey called it Navicula Spencerii.

SCIENTIFIC BOMBSHELL

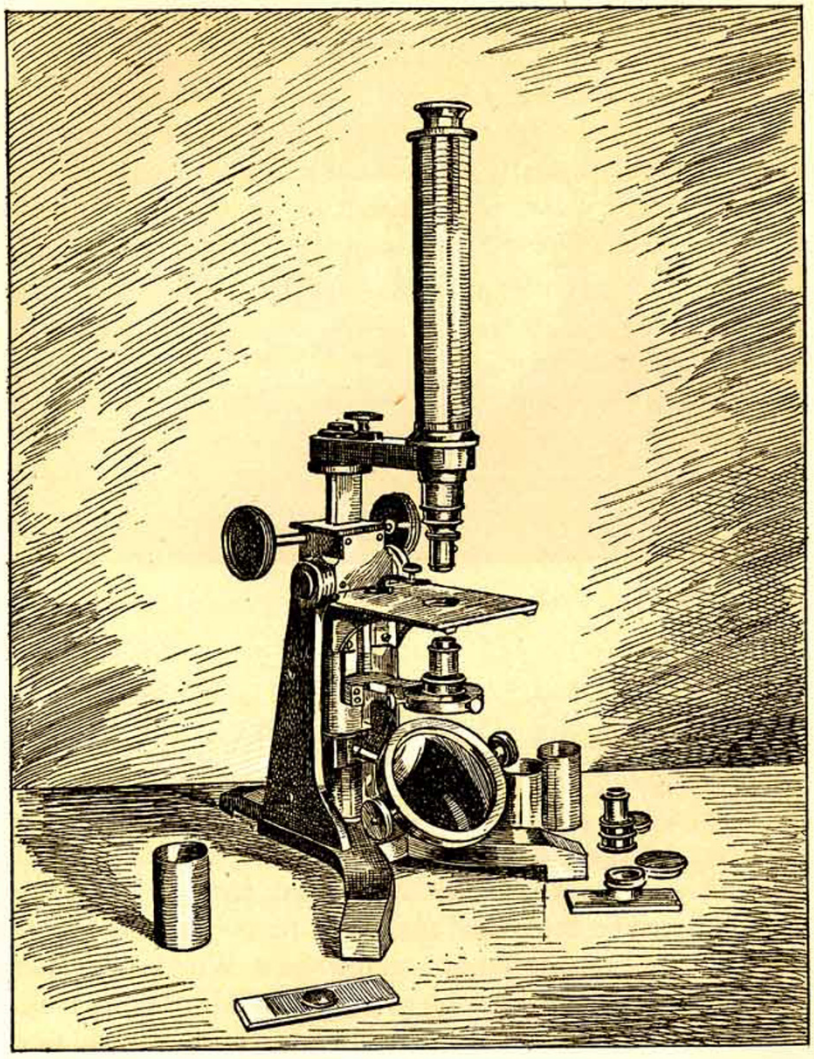
Subsequently, Prof. Bailey sent specimens of the Navicula Spencerii to microscopical friends in London, with a statement of what Mr. Spencer had done. It was like exploding a bomb shell in the enemy's camp; the name of Spencer became at once famous.

Prof. J. W. Bailey using a Chevalier microscope. Sketched from a painting by Robert W. Weir.

At this time Drs. C. A. Beck and Paul Goddard of Philadelphia each possessed a 1/12 inch objective of Powell, considered by them the very best in the world.

Subsequently Dr. Beck went to West Point to test his objective on the Navicula Spencerii. Prof. Bailey and Dr. Beck looked together, day and night, for two or three days, only to be convinced that both transverse and longitudinal lines existed, but not seeing them. When they tried indirect light, the lines showed up beautifully and as Prof. Bailey reported to Mr. Spencer: "With a light less oblique than your lenses required. It does not lower your position at all to admit the excellence of Powell's lenses; you have only a 'bait ahead' to see if you can really beat him."

The same problem of indirect light, prevented the best



Spencer Trunnion microscope (about 1854), one of the early types made by Spencer is now at St. Bernard College, Alabama.

English microscopists from resolving the lines on the Navicula Spencerii. Mr. Marshall, Prof. Bailey's London correspondent, stated in a letter: "We had some of the finest glasses of Smith, Ross and Powell in our examination of the N. Spencerii, and at present the result is unsatisfactory. I shall be most particularly obliged by your directing your 'backwoodsman' to make me one of his best object glasses."

Professor Bailey's comment on the Englishmen's experience was "verily, the good Cockneys need the ghost of Goring to teach them how to put proper objects at each end of their microscopes. I wonder if they believe in my 'statements' at all?"

It is hardly necessary to say that, when the proper illumination was applied, the English microscopists easily resolved the N. Spencerii, but it was two or three months before they succeeded.

NEW GLASS—NEW CORRECTIONS

Before Spencer heard of the success of the English, he announced the discovery of a still more difficult test, and of such improvement in his objectives to enable him to resolve it. He was now fairly a rival of the best foreign artists, and acknowledged by them as such. He was obtaining wider angles than anyone else, and yet with excellent corrections of the chromatic and spherical aberrations; and we are told that Mr. Ross said Mr. Spencer must have some mode of working glass as yet unknown to other opticians. About the same time, Mr. Ross was stating that an angle of aperture of 135° was the possible limit of usefulness.

Mr. Spencer was making costly experiments in the attempt to produce a glass of higher dispersive and refractive

power than was then made for sale, so that many of his best objectives at this time were made with his own glass. His chief success, however, was from his tact in *figuring the lenses* so as to balance the aberrations, a process so delicate that it would have availed no one not possessed of the same skill to copy the curves.

His new test was a variety of Grammatophora marina, Ehr., found in gatherings from Greenpost, L. I. in November, 1848, Spencer produced a 1/16 which resolved this diatom, and it proved too difficult for any foreign objectives in this country.

Spencer also seemed to have kept steadily in advance of foreign opticians as to angle of aperture, and in June, 1850, he produced a 1/12 having the then marvelous aperture of 174½°, as measured by the old sector method, while his ¼ was 100° or more. At the same time the aperture of Mr. Ross's 1/12 was 135°, and of the 1/8, 107°.

APERTURE CONTROVERSY

In the controversy on angle of aperture, Spencer stated: "Since the discovery of Dr. Goring that the penetrating powers of the microscope depends directly upon the angle of aperture of its objectives, all judicious and successful artists have made this discovery the basis of their labors for improvement. All the later advances which have been made have given additional evidence of the truth of this principle. In the report of the jury of the Great Exhibition on microscopes, we have observed an indirect doubt expressed as to the truth of this law. The report, and opinions, agreed 'that it was advisable not to extend the angle of aperture of the combination to its utmost possible limit, when destined for general purpose of natural history or

anatomical investigation;' that is to say, we must *diminish* the angle of aperture and *increase* the penetrating power, when it is a perfectly established law that penetration is absolutely dependent upon angle of aperture! So true is this that *penetration* and *angle of aperture* are convertible terms."

Penetration should be considered here as the power by which faint or minute markings are revealed, markings which remain invisible to the most perfect *defining* and *magnifying* powers when unaccompanied by penetration. A more appropriate term would be *resolving power*.

The explanation of these differences is not so difficult. The addition of a very few degrees to any angle of aperture so changes the thickness and arrangements of the component lenses of an objective that the balance of corrections for color and figure is entirely destroyed. The prac-

Charles A. Spencer visiting Prof. J. W. Bailey at West Point.

tical defects can only be remedied after repeated trials, and as the artist cannot afford to bear either the loss of time or the heavy expense involved in such experiments, it follows that his work must leave his hands in an imperfect state during such periods.

BEST OBJECTIVE

As an illustration, it took Spencer nearly two years to overcome the defects of wide aperture and during that period he refused to permit any such objectives to leave his hands.

We have arrived now at the period when Mr. Spencer's microscopical objectives were considered as perhaps the best in the world. T. R. Robinson, D.D. of Dublin, Ireland, President of the Royal Irish Academy, who had devised the best method of measuring angular aperture, on March 6, 1855, wrote to Prof. Bailey:

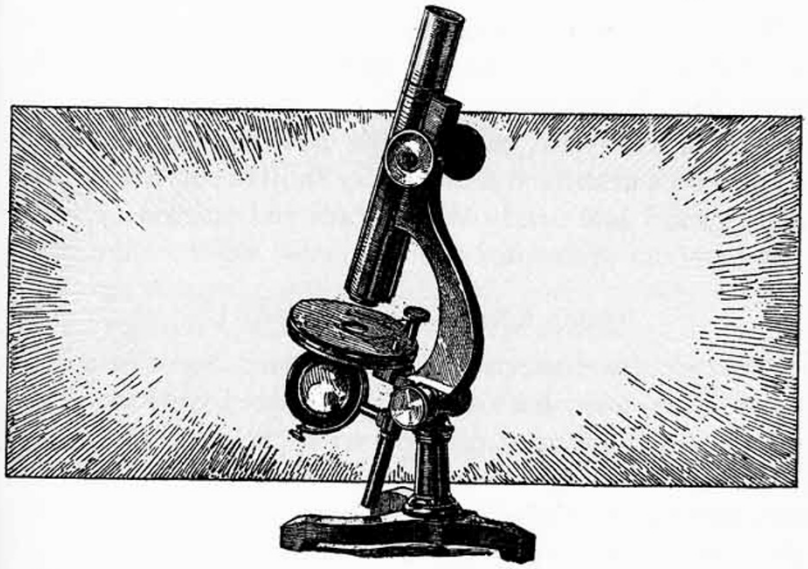
"In reference to the performance of Mr. Spencer's objective (a 1/12, aperture about 170°), it is the best objective *I* have ever seen. I have only met with one that compares with it in sharpness of definition, a 1/6 by Ross, 132° aperture. Of course the enormous aperture of Spencer prevents any other comparison, and the great working distance is equally remarkable. If I might wish for any improvement, it is that Mr. Spencer would put some graduation to the compensation, which in many cases is a great convenience, and which I have had applied to several of mine with advantage."

In a review of Frey's book on the Microscope, which appeared in the American Journal of Microscopy, May, 1880, the reviewer gives Mr. Tolles credit for a device on cover corrections, which Mr. Frey claimed for English opticians.

Mr. Spencer refuted this claim in a letter which, for some reason, he never mailed. "The device of making cover-adjustment by the movement of the inner systems of an objective was devised by me while Mr. Tolles was employed by me under instruction, and before he had made or mounted any adjustable objectives."

EQUATORIAL TELESCOPE

Meanwhile Mr. Spencer was not neglecting the telescopes. About the year 1854 he formed a partnership with Mr. A. K. Eaton, and in addition to the microscopical work, they completed various achromatic telescopes, of apertures varying from 3 to 5 inches. In 1865 they finished the large Equatorial for Hamilton College, having an object glass of 13½ inches diameter, and a focal length of 16



Microscope, now at the Smithsonian Institution made about 1875 by C. A. Spencer & Sons.

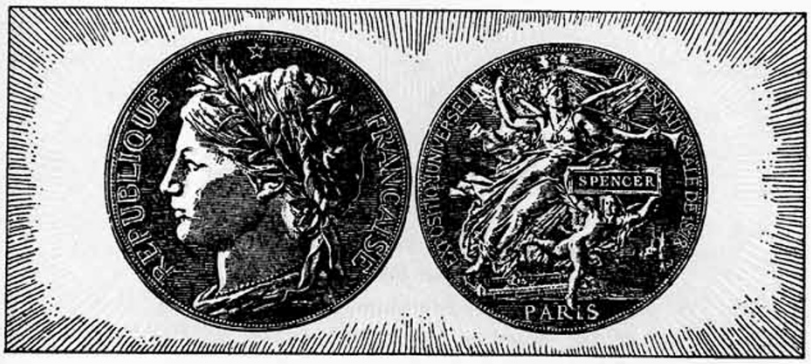
feet—at the time the largest telescope in this country. The contract price was $10,000 and in its performance it compared favorably with the best Munich instruments.

In 1856, Messrs. Spencer and Eaton entered into a contract with the Trustees of the Dudley Observatory at Albany to construct a magnificent heliometer, for the sum of $14,500. Mr. Spencer was sent abroad to visit the principal workshops of Europe and the celebrated observatories, so that the instrument might surpass anything hitherto made. He spent some six months abroad, and made many friends among the scientific men of England and the Continent; but the heliometer was never built. A bitter controversy arose between some of the trustees of the Observatory and Dr. Gould, the director, so that the work of the Observatory was suspended for years.

The partnership between Spencer and Eaton was dissolved after a few years, and Mr. Spencer, with the aid of his sons, still carried on the business, until the year 1873. In the fall of this year, occurred the disastrous fire at Canastota, which destroyed nearly every shop in the village, and Mr. Spencer lost nearly all his tools and machinery and a large amount of finished and unfinished work.

PARIS EXPOSITION AWARD

Not wholly disheartened they started anew in a barn for a workshop, but in 1875 they moved to Geneva and for two years were connected with the Geneva Optical Works. After this, for about three years, the business was conducted under the name of C. A. Spencer & Sons. During this period they received, at the Paris Exposition, the highest award, a magnificent large gold medal, for excellence of their microscopical objectives. This award was all



Spencer received the only gold medal awarded for microscope objectives at the Paris exposition of 1897.

the more gratifying, in as much as C. A. Spencer & Sons had not sent any objectives themselves to the exposition, President Barnard, of Columbia College, New York, who was one of the U. S. Commissioners to the exposition, had a number of their recent objectives, and was so convinced of their excellence that he took the necessary steps for entering them.

About a year before Mr. Spencer's death, his son, Mr. Herbert Spencer, commenced business in Geneva under his own name, while Mr. C. A. Spencer remained in the old shop. He spent most of his time in reading, occasionally experimenting with some new combination, but always genial to such of his old friends who visited him. His last illness was short. After confinement to his room for some three weeks, he died peacefully Wednesday evening, September 28th, 1881, sincerely mourned by every friend of the microscope.

Robert B. Tolles, Spencer's apprentice and collaborator, was one of the most important optical workers of his day. Quotations from two different articles cover his life and works.

Dr. George E. Blackham, a former president of the American Microscopical Society, has given us a rather brief account of Tolles in his memoir of 1884. Dr. Blackham expected to get considerable help from Charles Stodder, Mr. Tolles' business manager, in the preparation of his memoir. Mr. Stodder, however, died soon after Tolles, and Dr. Blackham had to obtain most of his material from Robert Tolles' sister, whose concern for her brother's health, overshadowed her appreciation of his optical genius.

General Jacob D. Cox, lawyer, governor of Ohio and Secretary of the Interior, was a prominent amateur microscopist. He was a Fellow of the Royal Microscopical Society and twice president of the American Microscopical Society. He covered competently, the "Great Debate Upon Aperture" in which Tolles was an active participant. This controversy continued from 1854 to 1875. The original text fills over thirty pages.

The material that will be of greatest interest today, has been selected for reprinting.

ROBERT B. TOLLES*

OBERT B. TOLLES was born in Winchester, Litchfield County, Connecticut in 1822. He was the son of Elisha and Harriet Tolles, and the second of five children.

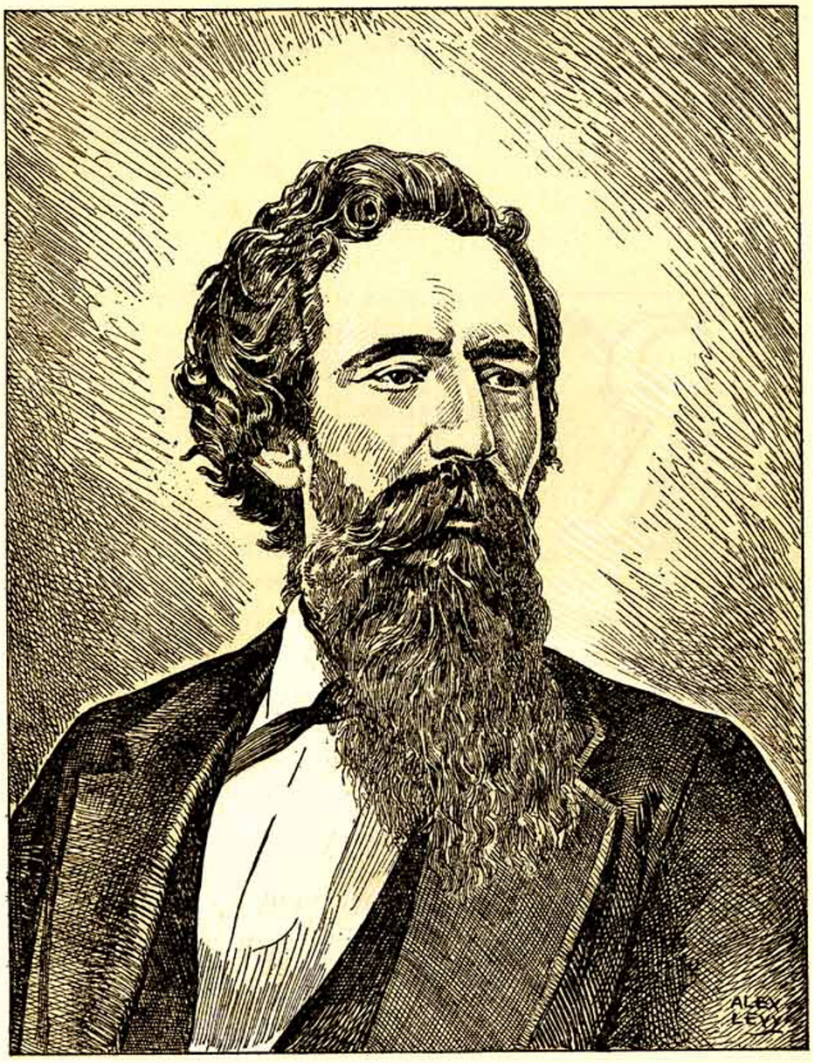
His early life was spent at home and on his grandfather's farm near by, where he worked to aid in supporting the family, which was very poor. His educational advantages were limited, being only those offered by the common district school. He was even then an eager seeker after knowledge, and earnestly desired a collegiate education, but poverty and ill-health combined to prevent him from obtaining this object of his ambition.

At the age of eighteen he suffered a very severe attack of pleurisy, from the effects of which he never wholly recovered, and which probably laid the foundation for his life-long sufferings.

INHERITED GENIUS

His father, from whom he doubtless inherited much of his genius and skill, was an inventor, and several of his

*Adapted from Blackham, George E., M.D., F.R.M.S., MEMOIR OF ROBERT B. TOLLES, from *The Proceedings of the American Society of Microscopists*, 1884.



Robert B. Tolles, 1824-1883, gained fame for wide angle objectives.

inventions were patented; but he seems to have realized very little pecuniary advantage from them, partly no doubt, because his poverty prevented him from developing them. The father died in 1848. After the death of his mother in 1843, Robert, then just of age, went to visit an uncle residing near Rochester, N. Y., performing much of the journey on foot. When his visit was finished he started for New York City, but stopping on the way at Canastota, N. Y., a happy chance led him to the little work-shop where Charles A. Spencer was turning out the wonderful optical work which eventually became the admiration and despair of the old world opticians. The young Yankee boy looked about him, and in that moment saw his life work before him. "Here," said he, "is the place and the work for me." Soon after he entered the service of Mr. Spencer as an apprentice, and as apprentice and journeyman he remained with him till 1858, when he started in business on his own account in a little loft in Canastota.

KNOWLEDGE AND SKILL

In 1867 he received, through Mr. Charles Stodder, a proposition from several Boston gentlemen to remove his business to that city and organize it under the name of The Boston Optical Works, with himself as superintendent. The offer was accepted, and the business carried on in this way for four years, when it was deemed best to place the business entirely in his hands, and from that time until his death on the 17th of November, 1883, R. B. Tolles and The Boston Optical Works were one and the same.

Mr. Tolles combined many qualities essential to the great work of his life—the improvement of the microscope. To great theoretical and practical knowledge of the

science of optics he united mechanical and inventive genius, and marvelous skill of eye and hand.

While still in the service of Mr. Spencer he devised the form of cover correction for objectives in which the back and middle combinations have a rectilinear motion only, and the front remains entirely stationary.

A NEW ERA

In 1854 he invented and patented his solid eyepiece. In 1858 he made his first immersion objectives, though of course, this plan was not original with him. In 1858 he constructed objectives with two fronts—one to be as an immersion and the other dry. In August, 1873, he made the great step forward which placed him at the head of his profession, the Columbus of a new era of microscopy. He made an immersion 1/10 with an aperture greater than that corresponding to infinitely near 180° in air. It was a three-system lens and had an aperture of more than 110° in balsam, or 1.25 N.A. The same month he made his first lens of the duplex front formula 1/5 inch glycerine immersion of 110° balsam angle. Both passed into the possession of the Army Medical Museum at Washington, and both were practically homogeneous immersion lenses.

The importance of this bold step, and its influence upon the progress of microscopy, can scarcely be estimated at this time, but it is certain that it was the cause of a revolution of opinion and practice among users and makers of microscopes all over the world.

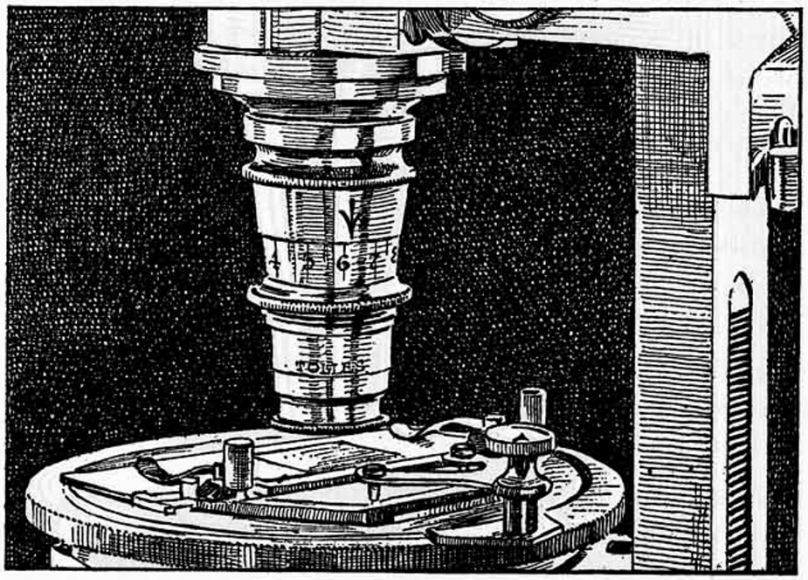
And now to turn from the work to the man himself. He was, as I knew him, a tall, thin man, of slight build and careless dress; a long, full beard and moustache, of soft, dark-brown hair streaked with gray. His life was one long

struggle with poverty and disease; the attack of pleurisy (or whatever it was) from which he suffered in his eighteenth year, left his lungs in a permanently damaged condition and frequent hemorrhages from them disabled him from time to time.

THE PRICE OF GENIUS

Ten years before his death, his brother-in-law, Mr. Lewis besought him to go to Florida and provided the funds for the journey. He was absent nearly four months and returned much improved.

During his last illness when he could no longer go to his shop, he had his microscope brought to the hospital, and



Close-up view showing a Tolles objective lens.

there on his death-bed examined and tested his lenses till the physicians took it from him and forbade his using it.

PERFECTION—HIS REWARD

As a business man Mr. Tolles was not a success. Though he always received good prices for his productions he failed to make money; and this was chiefly because he was never fully satisfied with his own work but would spend time and money altering and improving objectives and other apparatus that were already better than the contract called for and which would have been more than satisfactory to the purchaser. But his reward was in the perfection of his work; here was his satisfaction, not in the paltry dollars he received in exchange, for he was more of an artist than an artisan. So he toiled on in proverty and suffering with but scant recognition from those who should have been proud to have encouraged and aided him. At last, on the 17th of November, 1883, he died in the hospital, worn out with labor and pain.

Only a few moments before his death he was occupied in counting the degrees of aperture of an imaginary lens, as he reached 150° he stopped, turned his head and said faintly, "Good-bye, good-bye." and all was over.

His funeral was attended by Dr. Oliver Wendell Holmes, Professor Rogers, Professor Pickering and Professor Eaton of Harvard, and many other of his old friends.

An appropriate monument will be erected to his memory. But his best and most endearing memorials are in the beautiful lenses, the products of his brain and hand, that are now treasured by their fortunate owners.

ANGULAR APERTURE*

"During the past year the world of science has met with a great, one is tempted to say an irreparable, loss in the death of Robert B. Tolles. It is but a little while since we had to mourn the death of Charles A. Spencer, the pioneer in the work of producing the modern wide-angled lenses for the microscope, and now his pupil in the art, who for many years before his death was easily 'chief' in it, has followed his old master.

"It was no figure of speech to say they were working in the backwoods. They sent out lenses with which no others then made in the world could compete. The tests which these lenses resolved were for years the puzzle and the despair of the microscopists of Europe, and the glasses would be ranked in the first class even in these days, when we think we are approaching the limit of what the optician can do in aid of scientific research.

"My own purpose here, is to give a historical sketch of the great debate over the practicability of enlarging the aperture of microscope objectives beyond the maximum angle in air. Tolles' part was, by common consent, the leading one. I think a review of the discussion will show that he deserves to rank high in it for his clear and accurate scientific comprehension of the principles. He had passed beyond the field of the skillful artisan, into that of a systematic and able investigator, who worked toward valuable results by the proper application of well understood laws.

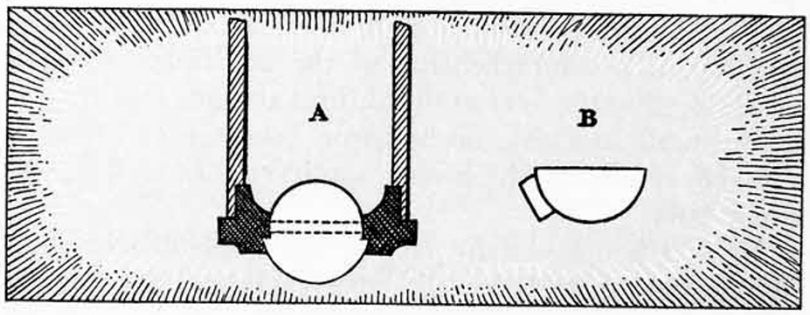
"It was a noteworthy fact in the great debate upon *Aperture* that it opened with a sharp though brief, presen-

*From Cox, Jacob D., LL.D., F. R. M. S., Robert B. Tolles and the Angular Aperture Question. *Proc. Am. Soc. Microsc.*, 1884, pp. 5-39.

tation of the opposing views, after which there was silence for many years, during which the American opticians, Spencer and Tolles, were perfecting their work, and the latter preparing to make an objective which was to become more famous perhaps, than any other bit of glass ever was. I trust that it reposes safely in the cabinet of the Royal Microscopical Society, where it may for centuries be pointed out as the scientific instrument over which a great historic battle was waged.

"In looking back at the controversy it seems to me that the modesty of Mr. Tolles' way of stating the characteristics of his objective, acted upon Mr. F. H. Wenham as if it had been a trap laid for him, into which he had fallen headlong. He thought he understood Tolles' ignorance, but alas, the fact was, he was himself ignorant of Tolles' understanding."

In 1870, in the British journals, a discussion arose regarding the true marking of the Podura scale and Dr. Royston-Pigott included in his series of articles a discussion of the qualities of immersion objectives. Mr. Wenham, with his usual force entered the debate and made the noteworthy suggestion that, if a medium (immersion) of



Tolles' sketch to show his method of determining actual angle of aperture.

similar refraction to the glass were used, no adjustment would be required for any thickness of cover. "The principle of the homogeneous immersion glasses was here distinctly stated, and justice demands that it would not be forgotten. The inexplicable marvel is that he should not have seen the relation of this principle to the general question of aperture."

He argued that the immersion principle did not give increase of aperture to an objective. Dr. Pigott attempted to show in reply, that a larger angle was included. This brought the following statement from Mr. Wenham. "I challenge Dr. Pigott, or anyone, to get through the object-glass into the immersion front, a greater angle, or any portion of the extraneous rays than would in the other case be totally reflected, as no object-glass can collect image-forming rays beyond this limit."

A SOFT ANSWER

"Without any reference by name to any disputant, and in the most absolutely impersonal manner, he (Robert B. Tolles) begins a little article with 'The following is given to illustrate the comparative available angle of dry and immersion objectives.' Then follows a brief description of what has since become well known, as an immersion illuminator, under the name of his 'traverse lens'. In this case he applied the little hemispherical lens directly to the front of an objective which had an angle of over 170°. A film of air being between the traverse lens and the objective front, the interior angle in the latter was, of course, less than 80°; but upon flowing a drop of water between the front and the illuminating lens, the interior angle was found to be over 100°. The little facet, applied to the il-

luminating lens, enabled him to convert it into a prism with a face at right angles to the immergent ray, which was not refracted but proceeded by a radial line to the object. The same device enabled him to limit the illumination to this small beam of light, and to measure its angle with the axis of the objective. Blood discs in the immersion film thus introduced were distinctly seen under this illumination, demonstrating that the rays were image-forming rays.

OPPONENT'S IGNORANCE

"No demonstration could be neater or more conclusive, nor could it more perfectly cover the whole ground. Mr. Tolles said it had already been in use 'a year or two here,' meaning in Boston, and with his own wide-angled immersion lenses. It meant that immersion lenses of greater aperture than 82° in balsam (or the equivalent 180° in air) had already been made and were in use, and that the appropriate method of illumination for the full use of the aperture had been perfected also, accompanied by a practical means of demonstrating the angle."

Mr. Wenham concluded thus—"Messrs. Tolles and Stodder have girded on a convex front, and then ventured forth to make a stand against my unwelcome statements—that the aperture of object-glasses is reduced on balsam-mounted objects, and that there is no subsequent increase of this aperture by using an immersion lens. I had not the pleasure of shaking hands with them before the collision, but in the absence of this ceremony I hope that they may take the reception that they have met with, in good part."

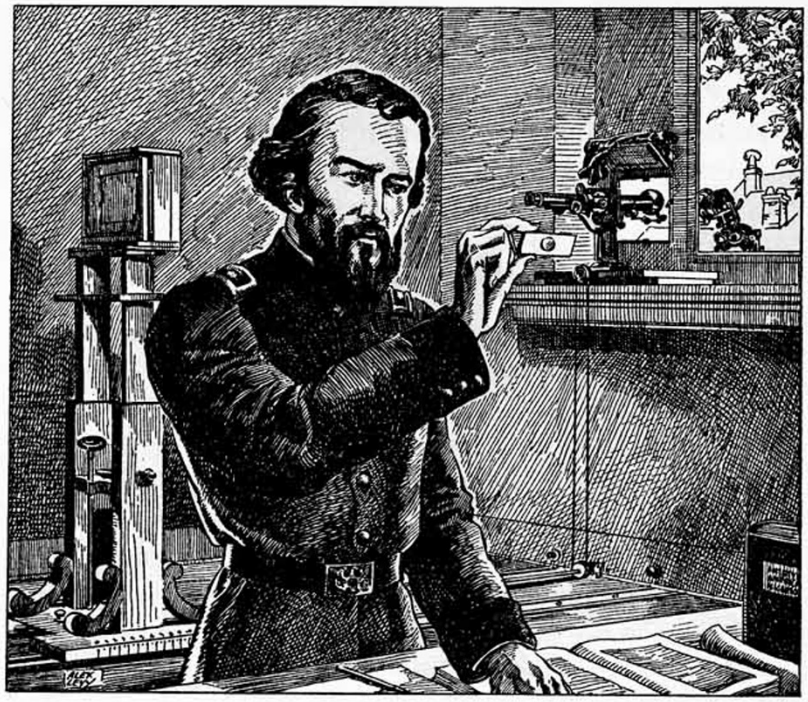
"His great influence among English microscopists made his contempt a powerful weapon in such a controversy,

and one that he had no right to use unless he was quite sure he understood his opponent's ignorance. His followers echoed his sarcastic laughter, and for a time it looked as if Tolles would be sneered down for a charlatan who was puffing his wares by pretending they had qualities which they demonstrably did not possess."

J. J. WOODWARD

Among Tolles' American supporters was Dr. Joseph J. Woodward of the Army Medical Museum, who staunchly defended Tolles throughout the whole controversy. He published various articles in which he gave the results of the examination of several of Tolles' lenses in the Army Medical Museum. He gave the result of measurements with the balsam tank of a one-fifth objective made by Tolles. In the dark room of the Museum at Washington, with the heliostat, he threw a beam of parallel rays of sunlight down the tube, and measured the emergent cone in the tank where it was beautifully illuminated and sharply defined. He certified its balsam angle to be somewhat over 100° at closed point.

In order to further verify his statements, Tolles gave Dr. Woodward the formula of one of his objectives and authorized him to make and publish the computation of all the curves and lines of refraction, so that the fact that the glass had a greater aperture than 82° in balsam might be mathematically demonstrated. The results were published in an article by Professor Keith and were accompanied by photographic copies of the detailed computation. Dr. Woodward followed this article with another of his own in which he said the glass selected was the one-tenth belonging to the Army Medical Museum. It had a single



Dr. J. J. Woodward and some of the apparatus which he used to make his world-famous photo-micrographs.

hemispherical front and "superb definition" as shown by photographs of Amphipleura pellucida. Its computed angle was 110½° in balsam, or allowing for the encroachment of the brass mounting on the front, 87°.

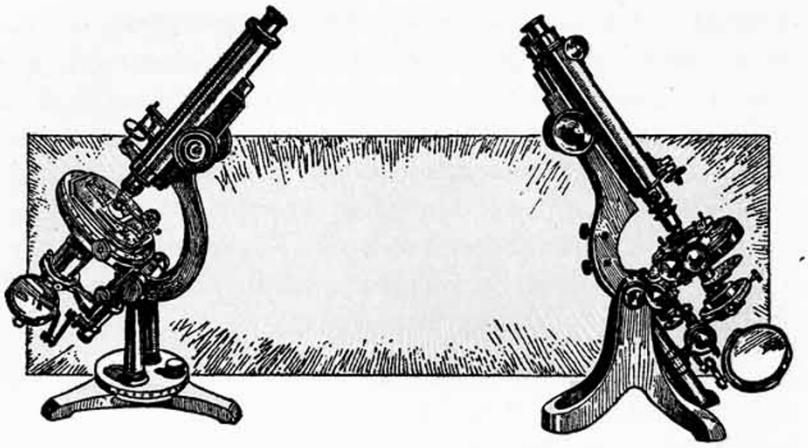
Mr. Wenham, however, failed to criticize the diagram or candidly to admit its accuracy.

INDISPUTABLE TRUTH

Mr. Brooke, President of the Royal Microscopical Society, in February, 1874, sustained the position of Mr. Wenham in his annual address, but later noticed that a new

English product, a Powell & Leland one-eighth—a "decided improvement in the construction of object-glasses" was being used by Drysdale and Dallinger in making their brilliant discoveries in the life history of septic organisms. The makers of the objective did not publish its angle, but of course, Mr. Powell knew the aperture of every glass which went through his hands. He wished to avoid controversy. The objective was made on the principles which Tolles had been battling for.

"The attention of the Royal Microscopical Society had now been challenged in a way that set all appeals to mere authority at defiance. Mr. Mayall and Mr. Crisp exposed the errors in measuring the aperture of Tolles' objective, and procured the endorsement of a distinguished English physicist, Prof. Stokes, for the theory of the wide-angled glasses and the computation of Prof. Keith. The authority of Prof. Abbe was already upon the same side, and his later series of lucid articles systematized the instruction of microscopists upon the subject. Mr. Wenham has, so far as I know, never retracted his errors, nor apologized to Tolles, but every point for which the latter contended has passed into the common possession of the scientific world, as the indisputable scientific truth upon the subjects he was treating. He was right, theoretically and practically, in every assertion he made, and he knew he was right. He understood (to use again Coleridge's phrase) the ignorance of his opponent, whilst the latter was also ignorant of his (Tolles') understanding, yet he never, in a single instance, allowed himself to say a discourteous or irritating word. From the very first article of the series he was jeered at and "chaffed" as ignorant of the primary principles of optics and not understanding the simplest laws of



Typical microscopes used during the Wenham-Tolles controversy. Left, a Tolles and right, a Crouch-Wenham.

refraction, but his answers were as impersonal and as free from all indication of feeling as if dictated by the pure Spirit of Science itself. It was not simply the patience of one who is convinced that 'he laughs best who laughs last' —he did not laugh at all. He saw his opponent shift to his own ground and assume the truth of what he had denied, or forced to deny the truth of what he had before affirmed, but he was content with the result, and did not even once shout 'Victory'. It was for him enough (would that it were so for all scientific disputants), absolutely enough, to demonstrate the error to which he was opposed.

SPIRIT OF SCIENCE

"I wish to say, without limitation, that I do not remember anywhere to have met with an earnest dispute, extending over years as this did, in which so perfect a model is furnished of the spirit which ought to rule a scientific debate; and it would be hard to find one in which

greater provocation was given. We have no right to forget that Tolles' calm equanimity, accompanied by intrepid assertion of his conclusions, was a mark of high intellectual ability and large grasp.

"For years, he practically had to contend with the organized authority of the Royal Microscopical Society. He was not simply a practical "rule of thumb" man, who made improvements he could not explain, and who was indebted to others for an intelligible explanation of them. His own ideas were the clearest of all, and despite a somewhat rugged and over-terse style of speech, his own arguments were the strongest as well as the earliest that were put forth in the controversy on the side of the truth. His conception of the capability of immersion glasses was, from the first, absolutely clear, and he embodied it in practice and worked toward its perfection with strictest application of correct principle. His devices for demonstrating each controverted point in turn, were as happy and ingenious as is possible, and excite the same admiration we feel for the happy adaptation of experiment which makes the charm of the lectures of great teachers like Tyndall, and which is no mere trick of mechanical skill, but the legitimate offspring of perfect lucidity in the application of theory to practice. He seized upon the conditions his opponent presented, and turned his experiments and the consequent argument against him with an easy mastery which only judicial blindness could have prevented that opponent himself from seeing.

MASTER OF OPTICS

"The re-perusal of the controversy has impressed me deeply with the conviction that we have lost not merely

an artisan of skillful eye and wonderfully delicate touch and skill, but a man who had made himself in the largest sense master of the science which lay beneath his art, and held its principles with an easy strength of grasp which is rarely matched. One (Wenham) who was by common consent ranked among the leading experts in geometric optics, and whose mere authority ruled for years a great scientific association, was worsted in the debate, not because he was not worthy of his reputation, but because the greater mastery of the principles of optics made it easy for Tolles to put the exposure of his errors in a light almost ludicrous from its completeness.

"It is a matter for satisfaction that this Society made him an honorary member of it during his life, not merely because he had done much for microscopy by the improvement of our object-glasses, but because he had given such evidence of scientific attainments as to put his name in the honorable list of men who like Lister and Andrew Ross were inventors because they were scientists, and worthy to rank with the investigators who made use of their lenses in the various departments of scientific inquiry. I am glad also to perform the duty of placing on our records a summary of Tolles' part in the controversy which has been narrated, that it may encourage others by showing that the Society will not willingly allow worthy achievements in any department of microscopical work to be forgotten, but will endeavor to keep them in perpetual remembrance. We have young American opticians worthy to be successors of Spencer and Tolles, and they may be assured that zeal in mastering everything which science can teach and art can apply in the further development and perfection of the microscope, will not be overlooked or

forgotten; but our successors will take pride in recording it as we now do in recording our judgment that Robert B. Tolles is entitled to a permanent place in the list of the world's scientific worthies. May they rest content with nothing short of being as 'easily chief' in their department of work as was he!"

Charles A. Spencer, Robert B. Tolles and Herbert R. Spencer were similar in several respects. All made of their work a labor of love with optical perfection as a goal, all won the respect and admiration of scientific workers who depended on the microscope for their achievements, all died without leaving an estate.

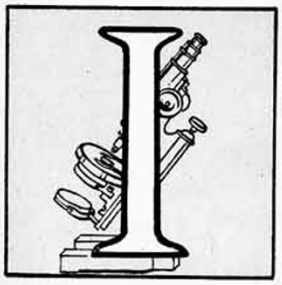
Herbert R. Spencer visualized his work as the basis of an industry and was finally successful in obtaining the support of a number of professional and business men in Buffalo. He organized first, the Spencer & Smith Optical Company, Inc. in 1893 and two years later the Spencer Lens Company.

A number of physicians were interested in the new company. Dr. Roswell Park, an eminent Buffalo surgeon, was president for a number of years.

Henry R. Howland, a Buffalo industrial executive and later Director of the Buffalo Museum of Science, became Secretary and Treasurer of the Spencer Lens Company shortly before Herbert R. Spencer died.

The expressions in this article come from a close association with the man and a detailed experience in the organization built around him.

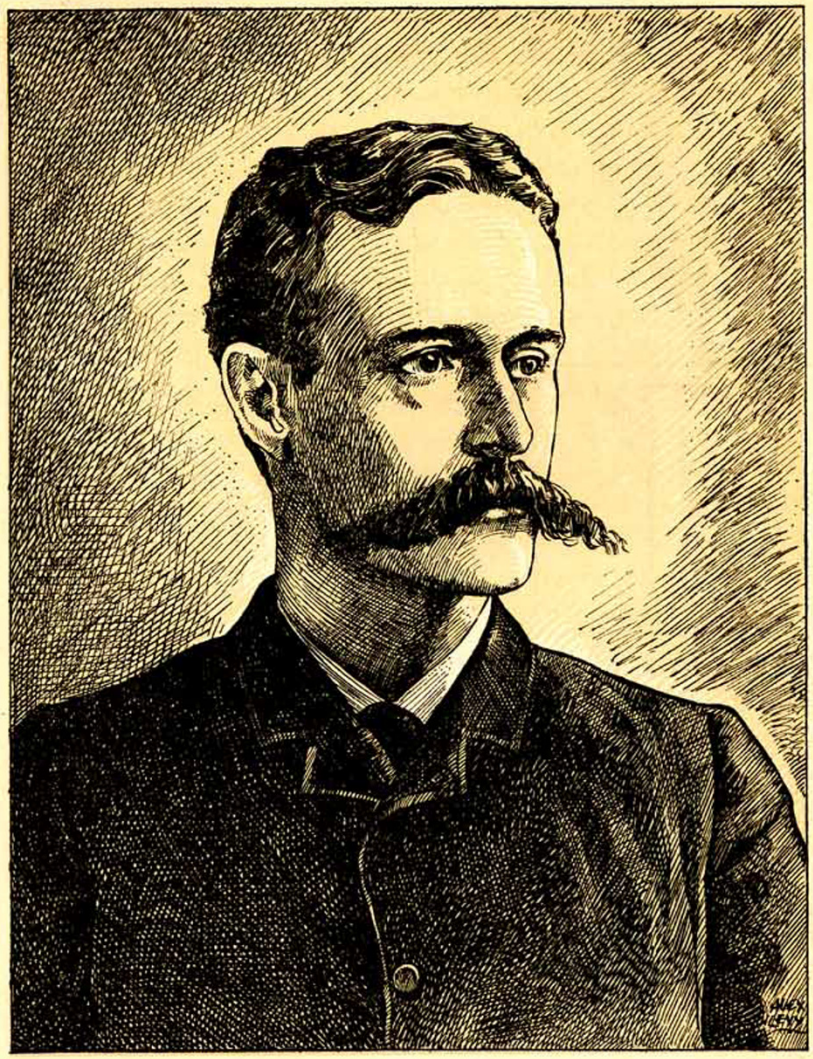
HERBERT R. SPENCER*



N the death of Herbert R. Spencer, which occurred at Buffalo, N. Y., February 7th, 1900, American Microscopy has lost the last of its three famous workers to whose successful efforts in the development of microscope and telescope objectives the scientific world has acknowledged its indebtedness. (The other two were Charles A. Spencer and Robert B. Tolles.)

Herbert R. Spencer was born at Canastota, N. Y., November 1, 1849, and was one of six children. In boyhood he was fond of scientific study and work. He loved, too, the outdoor life of the woods and fields, and his fondness for hunting gave him that perceiving eye which sees so much that with less favored mortals escapes their sight. He was quite young when he began his pupilage in his father's shop at Canastota, but from the beginning he loved his work and was ambitious to excel in it. This made him an apt pupil and to a great degree he inherited his father's genius. They worked together in constant effort to improve what had already been accomplished and to

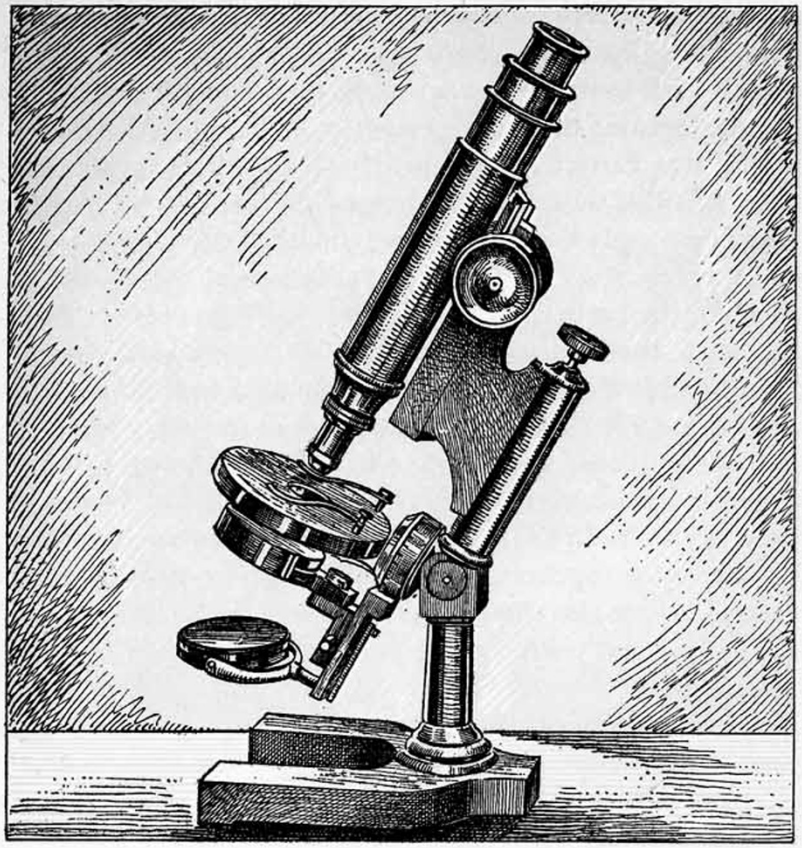
*Adapted from Howland, Henry R., HERBERT R. SPENCER, from *Transactions of the American Microscopical Society*, 21; 252, 1900.



Herbert R. Spencer, 1849-1900, son of C. A. Spencer.

develop new work of still greater perfection. After the partnership between Charles A. Spencer and A. K. Eaton which had been formed in 1854 was dissolved, Herbert Spencer became his father's partner in the optical business which was carried on by them at Canastota until the autumn of 1873, when their shop was destroyed in a disastrous fire. Their tools and machinery which they had accumulated by many years of toil and saving were lost, as was all their finished work and much that was in process of making with their valuable records and drawings. It was a crippling blow but father and son plucked up their courage and taking a little barn for their workshop struggled along as best they could until 1875, when they left Canastota and connected themselves with the Geneva Optical Works at Geneva, N. Y. In 1877 they formed the partnership known as Charles A. Spencer & Sons which continued for three years. In these last three years of his life the father's health was failing and with waning vigor his own productiveness ceased, while that of his son, Herbert increased with his increasing responsibilities and the new objectives of those years were the product of his own genius and skill. Several of these came into the hands of President Barnard of Columbia College, New York, who was one of the United States Commissioners to the Paris Exposition of 1878 and they were exhibited by him there with the happy result that the highest award of the Exposition—its large gold medal—was awarded to Charles A. Spencer & Sons for their superior excellence.

Charles A. Spencer died in 1881 and from 1880 until 1889 Herbert R. Spencer carried on the business of making microscopes, telescopes and their objectives under his own name at Geneva, N. Y., removing in the latter year to



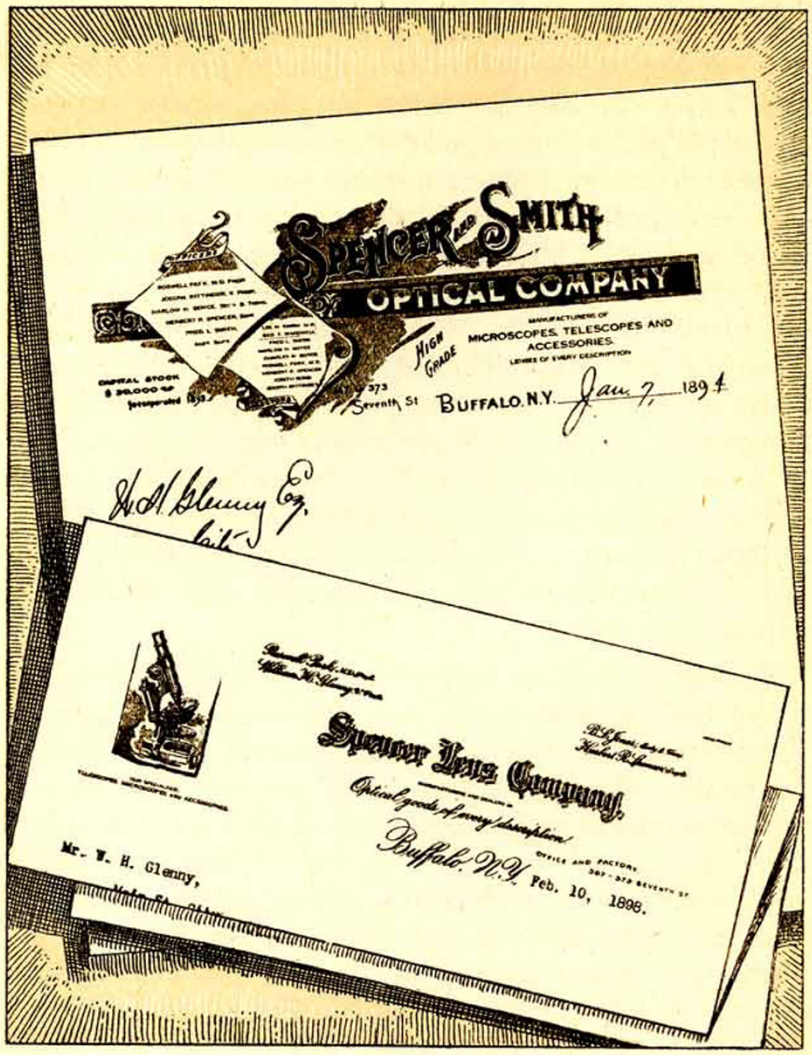
Microscope made by the Spencer & Smith Optical Co. about 1894.

Cleveland, Ohio, where he established the H. R. Spencer Optical Company. In 1891 the Spencer & Smith Optical Company of Buffalo, N. Y., was organized and Buffalo became his home for the remaining years of his life.

In 1895 the Spencer Lens Company was incorporated and bought out the Spencer & Smith Company. Herbert R.

Spencer became the superintendent of its shops and found in its systemized business a larger and better field for his efforts than he had before known. He became warmly interested in developing and perfecting the several types of their well-known Spencer microscopes and in largely increasing the line of their Spencer objectives and microscope accessories. He was greatly interested in the wonderful developments of later years in optical science. He placed all his formulas in the hands of the Spencer Lens Company and taught skillful assistants the processes of construction and correction which he himself had so laboriously learned, so that when he felt the approach of sickness in the autumn of 1899 he expressed his keen satisfaction that his work, so well begun, could be continued without difficulty in his absence. He had assumed a trust and was faithful to it to the end. He died at Buffalo, February 7, 1900.

At fifty years of age he was seemingly in the prime of a useful life too soon ended, and yet in his comparatively short career he had done much for science. By his genius, his tireless efforts and painstaking researches he accomplished results in applied optics which gave him rank with the foremost of the world's workers in that field, with Leeuwenhoek, Amici, Hartnack, Zeiss and Abbe in Europe, with the elder Spencer and Tolles in America; accomplishments which have made possible the modern discoveries in medical science and hygiene with their beneficent life-saving results. Like his father he was ambitious in his work and critical of it; there was always in his own vision a better that mocked his best, and he was never satisfied until that better was secured and a better still beckoned him forward. He was most skillful in his manip-



Quaint letterheads used during the transitional period.

ulation as in formulating and the objectives made under his instructions at each step in his progress kept rank even-paced with the best of similar grades made elsewhere at the time. He was of a generous temperament towards others and never spoke unkindly of their work. To his friends whom he knew well there was a genial side to his personality which was very attractive. Towards others he manifested a quiet reserve but in all his relations he was modest and unassuming. His early death is a loss not only to his many friends but to the scientific world.

Dr. Oliver Wendell Holmes and other eminent leaders of the day, testified to the unimpeachable accomplishments of these pioneer American microscope builders.

Holmes defended them from their European critics who looked with distrust and suspicion upon the cultural and scientific attempts of their "uncouth" American cousins.

From the great mass of material, a few quotations from the records have been selected to complete the picture.

Dr. Oliver Wendell Holmes gives a professional viewpoint.

Mr. F. J. Keeley and Herbert R. Spencer describe the early use of fluorite.

Dr. William C. Krauss covers "The Debt of American Microscopy to Spencer and Tolles".

The Smithsonian Institution reports on early microscopes.

The Smithsonian Institution reports on a contract for a telescope.

Dr. Edward Bausch reminisces about meeting Charles A. Spencer.

Dr. W. B. Carpenter mentions Spencer in the 1856 edition of his book.

QUOTATIONS

QUOTATIONS OF DR. OLIVER WENDELL HOLMES

"I should like to live over again in words the triumphs of Charles Spencer, who, "in the backwoods of America, "as our English friends put it, wrought lenses that turned the London makers paler than blue glass would make them look, and with angles of aperture that straddled far outside of the limits which Andrew Ross, the King of them all, declared to be the boundaries of the possible. I visited Mr. Spencer twice at Canastota, a small interior town with the burnt stumps of the forest trees all around it, and felt that I was a pilgrim to the microscopic Mecca.

"I have had the wholly unexpected pleasure of a visit this very day, since writing what I have just read, from the two great masters who have made the reputation of American microscopes,—Mr. Spencer and Mr. Tolles,—and I hope I have the honor of counting them among my audience. Their presence shall not prevent my alluding once more to the large debt we owe them. We, Americans, are sometimes thought to be too forward in asserting the claims of our countrymen. But it must not be forgotten that our compatriots have often had to contend with a jealousy that ignored their existence, or a dishonesty that cheated them of their due. As an evidence of this I will refer to the manner in which the name of Mr. Spencer was coolly dropped from the second edition of Quckett's

Treatise on the Microscope, for no better reason, I believe, than that he had insulted the nature of things and violated the order of the universe by doing what King Andrew Ross had declared to be an impossibility.

"I have owned and own a good many objectives, and have made trial of a great many. Three of Spencer's which I have, made a quarter of a century ago, are admirable glasses. The 1/12 once owned by Waldo Burnett was carried to Europe by him and pitted against the best English and French objectives he could meet with, coming out, if not always with victory, never with defeat. I need not speak to you of Tolles' objectives, since they are recognized by the experts as unsurpassed if not as unequalled by any made in any part of the world."

*From an Address delivered at the Annual Meeting of the Boston Microscopical Society by Oliver Wendell Holmes, M.D. and printed at the Riverside Press, Cambridge, 1877.

QUOTATIONS ON USE OF FLUORITE

"Mr. F. J. Keeley described a microscope objective of one-fourth inch focus, made in 1860 by Charles A. Spencer. It was recently necessary to take apart the back system for re-balsaming, when it was found to consist of five lenses, three of which were convex and two concave. One of these proved, on examination with polarized light to be fluorite.

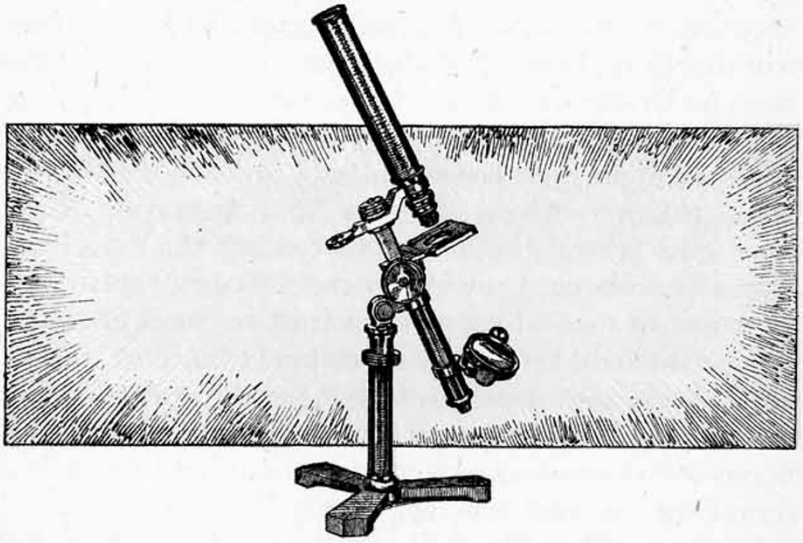
"This objective is historically interesting as illustrating the complex nature of the corrections adopted by Spencer at so early a date, as well as confirming the previous reports that he had appreciated the possibilities connected with the use of fluorite in securing superior color correc-

tions and employed it for the purpose twenty years before it came into use abroad."

Bulletin of the State Microscopical Society of Illinois, Feb., 1922, Vol. 4.

A letter from H. R. Spencer addressed to Professor T. J. Burrill, dated January 27, 1891, was printed in the Journal of the Royal Microscopical Society of April, 1892. The following paragraphs are of interest.

"During the summer of 1860, Dr. Rufus King Brown, who was at that time a resident of Brooklyn, New York, visited my father at Canastota, and during his stay there my father made for him a 1/8 objective, which was con-



Microscope made by the firm of C. A. & H. Spencer about 1850.

sidered by all who saw it to be the best ever made up to that date. Although but a young boy at the time, I was greatly interested in my father's work, and knew pretty well what was going on—hearing a great deal of talk—and remember well Dr. Brown's high praise of the performance of the objective, but of course knew nothing of its construction until some years later.

"The angular aperture of the objective was 175°. One of the systems contained fluor-spar, and it is on record in the formula that it was remarkably perfect in its corrections for both figure and colour, with both oblique and central illumination. In the years 1864 and 1865, I made lenses for quite a number of objectives, mostly 1/4 in., containing at least one lens of fluor-spar, and having apertures from 170° to 176°; but of course with very short working focus. In all these objectives, as well as in the one made for Dr. Brown, the spar lenses were cemented between others, as owing to its softness and liability to become scratched it was not considered safe to leave it in an exposed position. About the time that immersion lenses came into general favour in this country the use of the spar was abandoned, owing to the difficulty experienced in procuring that which was free from fractures or seams. When used in the 1/4—I dreaded making them more than all others in the objectives, often having to throw them away, owing to their having such defects. Shortly after our removal from Canastota to Geneva I made a 1/12 water im., containing one spar lens; but that is the only one since I was a boy. When Dr. H. J. Detmers, of Columbus, O., visited me at Cleveland (about the time of the meeting of the A. S. M. at Detroit) I showed to him the old book containing the records of all these objectives as kept by

my father, and among them the 1/8 marked R. K. B., also 1/8 containing a spar lens, which was made as far back as 1851, about the time my father began making objectives of large angle, showing how early in the fight he appreciated the valuable optical qualities of fluor-spar in the construction of objectives. The angular aperture of this 1/8 was not given, but I can readily see that it could not have been less than 160°."

Journal of Royal Microscopical Society, April, 1892, pp. 260, 261.

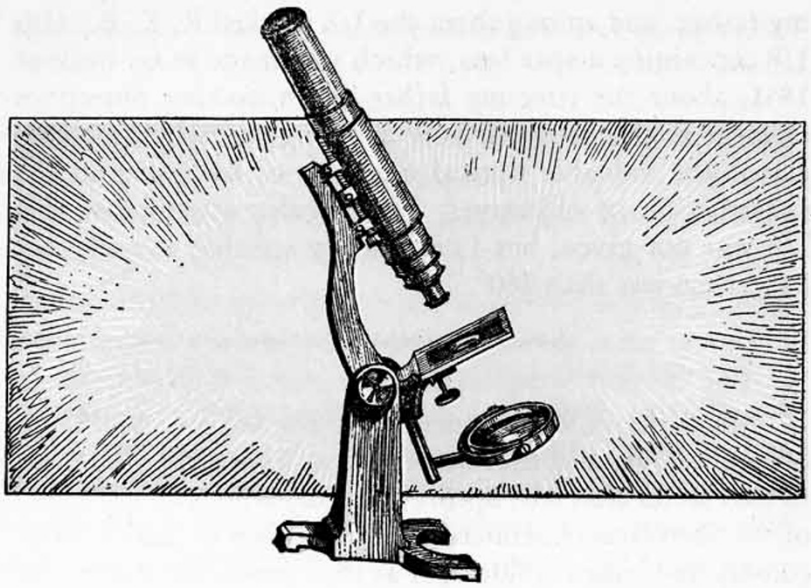
"Mr. William Wales, referring to the letter of Mr. H. R. Spencer above, said that he desired to verify the statement of that letter that Mr. Spencer, Senior, who was the father of the manufacture of microscope objectives in this country, constructed lenses of fluorspar at that time—the summer of 1860. From his personal knowledge he could verify the fact that Mr. Spencer made the said one-eighth objective for Dr. Rufus King Brown, and also a one-quarter objective, of 175° air angle, with perfect color correction, containing a fluorspar lens, for Dr. Louis Tice, which objective is now in the possession of Dr. Charles E. West, of Brooklyn."

Journal of the New York Microscopical Society, October, 1892, p. 113 Meeting of May 20th, 1892.

QUOTATIONS FROM DR. WILLIAM C. KRAUSS

"The prime requisite of a lens is not that it shall magnify so many hundred or thousand diameters, but that it shall have great resolving power or resolution.

"It was this superior quality of a lens that Charles A. Spencer, Robert B. Tolles, and Herbert R. Spencer sought



Student microscope made by C. A. Spencer about 1855.

after so assiduously and succeeded so admirably in attaining that made them the peers of the greatest among lensmakers the world over. They were the pioneers, the pathfinders, among lensmakers, and they succeeded in making objectives of such superior quality and such high merit that their work had to be well-nigh forgotten and then rediscovered, or better, resurrected by some foreign genius before the world realized what the Spencers and Tolles had accomplished in the '40s and '50s. So true is this that hardly had the din of applause died out over the discovery of the apochromatic lens by a well-known German scientist than Herbert R. Spencer showed me a lens constructed on the same principle and of the same substance, fluor-spar, that his father made in the early '50s and had abandoned because of the great deteriorating quality of the fluor-spar.

The same fault is again being found with the resurrected lenses.

"Spencer was induced, while still a lad, by the perusal of the article on "Optics" in the Edinburgh Encyclopedia, to construct a compound microscope. His first attempt at making a lens was when he had scarcely attained his twelfth birthday, and although crude and unfinished it spoke to him of the vast possibilities which lay before him in the field of applied optics. Genius that he was, he discovered its error and imperfections, and the master within him asserting itself, he set out upon his life's journey of correcting these and improving each subsequent endeavor. He then attempted to combine his lenses and succeeded in making several compound microscopes and a refracting microscope upon the original plan of Professor Amici. He also constructed several Gregorian and Newtonian telescopes with specula of six and eight inches diameter, some of which were quite successful. He also learned of the successful researches of Guinaud, Fraunhofer, and Faraday in the manufacture of optical glass. By laborious and protracted experiments, frequently working over the furnace for eighteen consecutive hours, he succeeded in improving the homogeneousness and other qualities of the glass considerably, enabling him thereby to make an evident advance upon his previous efforts in constructing lenses.

"The second member of the illustrious trio was Robert B. Tolles. In 1843 he entered the service of Mr. Spencer as apprentice and remained with him for fifteen years, imbibing the spirit of the master and adding to the fame of the little backwoods shop by numerous inventions.

"The third member of the illustrious group, Herbert R. Spencer, at an early age became imbued with the atmos-

phere of genius which surrounded him, and while yet a mere lad began to make lenses on a lathe of his own construction, equaled in those days only by those of his father and co-worker Tolles. A more suitable workshop and better tutelage than that offered at Canastota could not have been found for young Spencer. To be in daily touch with a mind like his father's and rubbing against an all-around inventive genius like Tolles sharpened his imaginative and perceptive faculties so that as understudy he was prepared to step into their places at any time, without the scientific world knowing or realizing that succession had taken place.

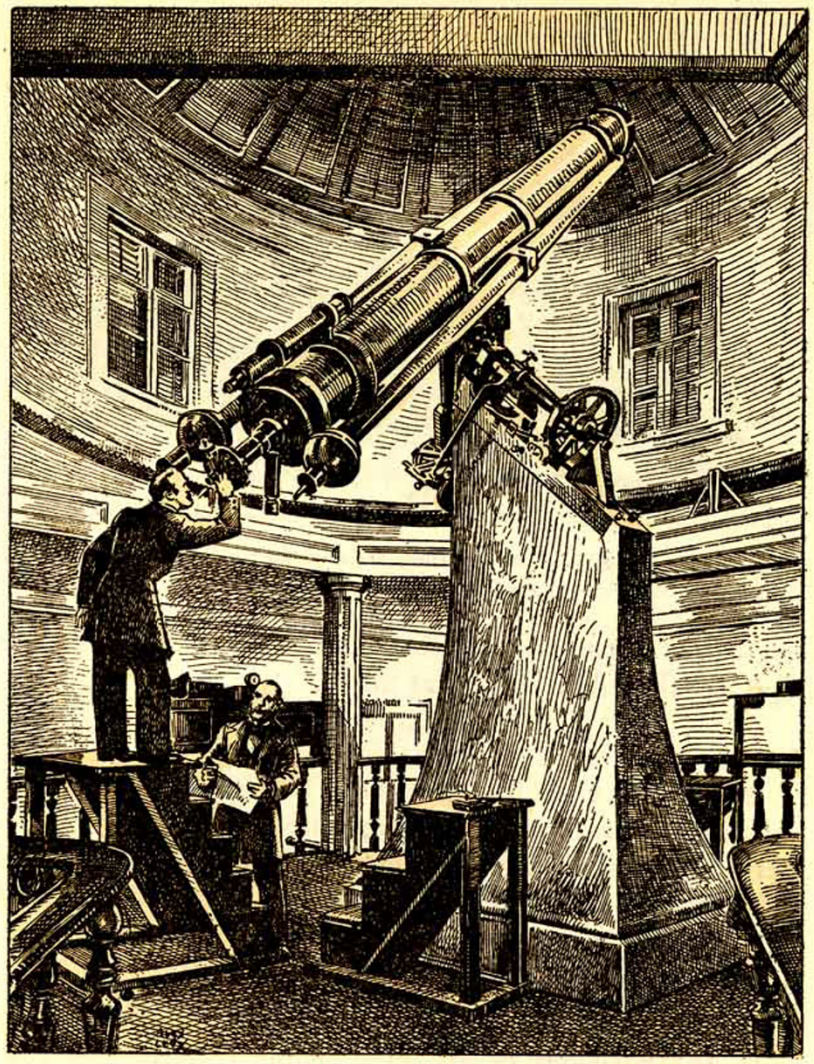
"These three men, giants in their line, had many traits in common, some to be commended, others, especially in this age of materialism, to be condoned."

From Krauss, W. C.; "The Debt of American Microscopy To Spencer and Tolles," *Trans. Am. Microsc. Soc.*, 1902, pp. 19-28.

QUOTATIONS COVERING THE SPENCER TELESCOPE

"The trustees of Hamilton College, in the State of New York, made, on the 22d day of July 1854, a contract with Messrs. C. A. Spencer & Co. of Canastota, in the same State, for the construction of an 'equatorial telescope of the first class, with all the mountings and other incidents necessary and usual thereto.'

"First. This telescope is the largest ever constructed in this country—constructed in the face of many obstacles, with an adverse public opinion. If it be equal to instruments made in Europe, its construction is a triumph of American genius in a hitherto untried field. The contractors, if successful, deserve that their success should be made known through some medium whose judgment shall be



Made by C. A. Spencer and A. K. Eaton, this telescope was in the **Litchfield Observatory** *at Hamilton College.*

Smithsonian Institution about 1850. Prof. Henry, Secretary of the Smithsonian Institution, ordered one of the first Spencer microscopes.

rigid and impartial, and shall have a character to be respected abroad as well as at home."

Smithsonian Institution Tenth Annual Report, 1856, p. 78.

In 1858, Dr. C. H. F. Peters, who had gained distinction in astronomical work, was appointed director of the observatory at Hamilton College and in 1867, Litchfield Professor of Astronomy and director of the Litchfield Observatory which was built to house the Spencer telecope.

In the process of preparing charts of the Zodiac, to give the positions of all stars visible through his 13½ inch telescope, he discovered 48 minor planets. He also discovered two comets and made many contributions to our knowledge of the sun, sun spots and the motion of sun spots on the solar disc.

"(2.) Achromatic Microscope.—In the first report of the Secretary it was mentioned that an individual, in the interior of the State of New York, had successfully devoted himself to the study and construction of the microscope, and was able to produce specimens of this instrument which would compete with the best of those constructed in Europe; and that, to do justice to the talents and labor of this person, Mr. Spencer had been requested to construct a microscope of the first quality, to be paid for by the Institution, if a commission appointed to examine it should find it capable of producing certain effects. The artist made a number of instruments which fully satisfied the conditions required by the agreement, but which still fell short of the ideal standard of perfection which existed in his own mind.

"He has, however, at length completed a microscope, the performance of which far exceeds that which was anticipated when the proposition was made; and the Institution has thus not only secured a valuable instrument of research, but has assisted in developing the talents and making more generally known the skill of a native artist of surpassing merit. I may mention that Mr. Spencer has associated with himself Professor Eaton, of Troy, New York; and they are now able to supply the increasing demand in this country for this invaluable means of research which, within the last few years, has opened a new world to the physiologist and botanist, as well as to the investigator of inorganic matter."

Smithsonian Institution Ninth Annual Report 1855.

QUOTATIONS FROM DR. EDWARD BAUSCH

"One of my earliest recollections is my father's shop at 20 Arcade. I can remember his pointing out to me how, with his small earnings, he had purchased a Microscope made by the American, Spencer. I do not remember the instrument very well, but I remember my father saying that it was of a wonderful quality.

"Father always had a great admiration for optical work of such a high order, and always had a desire to get into production beyond spectacles and eyeglasses. The examination of Spencer's work only served to stimulate that impulse to get into a higher plane of optics.

"I met Mr. Spencer several times at the meetings of the Microscopic Society. He was of medium size, with one of the finest faces I have ever seen in a human being. He conveyed the impression more of a poet and idealist than of the practical artisan which he was.

"When I mention these facts, I have in mind the difficulties which beset his progress. Here was a boy who grew up without any knowledge either of producing lenses or making glass, but who first accomplished successfully the grinding of lenses and then the combination of these lenses. It is difficult for us to imagine how he was able to combine his crowns and flints and vary these types of glass to do what he did. These accomplishments were in advance at that time, of anything which was being done in Europe.

"The isolation of both Spencer and Tolles threw them on their own resources and led them into original channels which astounded the world. America had little touch with Europe in those days. It is a very peculiar thing that with all of the changes and modifications which have been

going on during the 56 years we have been making microscopes, the design of some of our leading instruments today have returned to the principles which were used by Spencer and Tolles."

From an Address by Dr. Edward Bausch at the meeting of the Optical Society of America at the Brooklea Country Club, Rochester, New York. May 5, 1931

QUOTATIONS FROM CARPENTER

"Microscopes of great excellence are manufactured in this country (U. S.), Mr. Charles A. Spencer, of Canastota, New York, has manufactured a microscope the objectives of which will bear comparison with the best of foreign construction. His common angle of aperture for 1/16 inch objectives is 176°. This is believed to be the largest angle ever given to an object-glass and for sharpness of definition and power of penetration (resolution), they are unexcelled by any of foreign make."

Carpenter, W. B., *The Microscope And Its Revelations*, Am. Ed., Philadelphia, 1856, 724 pp.

QUOTATIONS FROM A COMPETITOR

In a J. & W. Grunow catalog which describes the advantages of Grunow scientific instruments, the following statement is made.

"J. & W. G. call the attention of Medical men particularly, and of Microscopists generally to their ACHROMATIC MICROSCOPES, for which they received a Prize at the New York Exhibition, in 1853.

"The quality of their Object-Glasses is unsurpassed, unless by Mr. Spencer's best productions in the highest powers, (above the 1/8)".

From a catalog *Microscopes and Optical and Physical Instruments* made by J. & W. Grunow, New Haven, Conn.

THE SPENCER-TOLLES MEMORIAL FUND

The Spencer-Tolles Fund originally was a memorial to Charles A. Spencer and Robert B. Tolles. It was established by the American Microscopical Society in 1884 for the encouragement and furtherance of research in which the microscope is employed.

The very first subscription to this fund came from the Royal Microscopical Society of London, and is indicative of the widespread fame and universal esteem attributed to these two scientists. Initial contributions were small, however, and as no effort was made to promote the fund outside the membership of the Society, by 1902 it had barely exceeded twelve hundred dollars. At the annual meeting that year the Fund Committee offered the following recommendation:

> "Officially the Fund now stands in honor of the memory of Robert B. Tolles and Charles A. Spencer. With the name of Spencer, however, is associated not only the illustrious father but also his distinguished son, the late Herbert R. Spencer, a loyal member of this organization and a successful worker for the advancement of microscopical science. Accordingly, your committee deems it appropriate that the Fund should stand as a memorial to the genius of this trio of American scientific workers, and recommends that it be designated as such officially and be known hereafter as the Spencer-Tolles Fund.

"Regarding the use of the income, it may be stated in advance that the object which the contributors have had in mind, and which members of the Society have cherished, seems to be in general the *encouragement of research, especially such as depends upon the microscope for its accomplishment or is connected with the improvement of that instrument.*"

As time went on, however, it was believed that research on the construction and operation of the instrument itself might better be continued by manufacturers. It was decided, therefore, to devote available funds to the publishing and putting into permanent form, of research material.

The Fund is administered by a Committee of three of which the present Chairman and Custodian is Henry B. Ward of the University of Illinois. He is the son of the distinguished surgeon and first president of the Society, Dr. Richard Halsted Ward.

Professor Ward, himself, has been active in the Society since 1887 and has been a member of the Spencer-Tolles Fund Committee since 1900.

Their procedure, evolved out of the experience of years and the recommendations of the National Academy of Science and National Research Council, is sufficiently flexible to meet changing needs and conditions.

Grants, aiding the research of worthy students, come from the income of the Fund, while its principal—now amounting to some $14,000—is kept inviolate. According to the Custodian, Dr. H. B. Ward, grants in aid of researches from the income of from $50 to $100 have been made since 1894 in 40 cases. The fund has thus become a truly living memorial to the Three Microscope Builders.

These outstanding men
have left a heritage
that has inspired all
who have felt the influence
of their accomplishments.
They have pointed the way
—ours is to accept the challenge
to insure a continuance
and progression
of the fine work
which they started.