SCIENCE

VOL. LX JULY 11, 1924 No. 1541

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SCIENCE: A Weekly Journal devoted to the Advancement of Science, edited by J. McKeen Cattell and published every Friday by

THE SCIENCE PRESS

Lancaster, Pa. Garrison, N. Y.

New York City: Grand Central Terminal.

Annual Subscription, $6.00. Single Copies, 15 Cts.

SCIENCE is the official organ of the American Association for the Advancement of Science. Information regarding membership in the association may be secured from the office of the permanent secretary, in the Smithsonian Institution Building, Washington, D. C.

Entered as second-class matter July 18, 1923, at the Post Office at Lancaster, Pa., under the Act of March 3, 1879.

BACON'S COLLEGE OF RESEARCH[1]

IT is a common trick of the human mind to estimate the progress of science in a sort of backward survey, reversing the perspective glass of history by turning its eye-piece away from the observer. We unconsciously project into the record the connotations of a later experience and thus distort its true values. The process is as prejudicial to our judgment as it is flattering to our vanity. This is what Sir Henry Wotton means when he says, "we are extremely mistaken in the computation of antiquity by searching it backwards."

Nowhere is the computation of antiquity backwards more fatal to a clear understanding of the past than in dealing with language. We think of Shakspere, for example, not as employing the English of the early 17th century, the only English that he could possibly know, and doing it with a fullness and accuracy that has never been surpassed by any of the great masters of human speech; we think of him as patiently endeavoring to clothe his resistant genius in the connotations of twentieth-century English, and hitting them not quite happily.

So it is with Bacon. We think of him as attempting to formulate science in the terms of our modern concepts, and project into his words scientific connotations that were not born until a century later.

Let us, then, on this three-hundredth anniversary of the publication of a book which revolutionized scientific method and set in motion a "new Philosophy," whose infant society of a handful of enthusiasts was to be the parent of great scientific organizations like the British and American Associations for the Advancement of Science—let us, then, take 1623 as a bench-mark for our theodolite and make a forward survey of the "proficience and advancement" that learning has achieved during the last three centuries.

Putting ourselves in Bacon's position at the beginning of the seventeenth century and surveying the then state of learning through his eyes, we find an intellectual system that is based upon Plato and Aristotle. These great thinkers, master and pupil, had assumed as the foundation of knowledge certain self-existent and predetermined principles—Plato calls them "ideas," Aristotle, "forms"—which it was the business of nature to illustrate and of man to realize. Plato had concerned himself chiefly with the manward relations of his "ideas," and organized them into

[1] A paper read before Section L of the American Association for the Advancement of Science on the 300th anniversary of the publication of Bacon's *de Dignitate et Augmentis Scientiarum*, December 31, 1923.

a system of philosophy: Aristotle had chiefly devoted himself to an organization of the nature-ward aspects of his "forms," and organized them into a system of science.

It was this philosophy and this science, with all the subsequent elaborations of the Middle Ages, that Bacon found intrenched in the universities. The former, however, dealing with causes, was then called "science."[2] The latter, dealing with effects, was called "philosophy," and Aristotle, from the 14th to the 17th century, was styled "the philosopher" *par excellence*. Curiously enough, in the last three centuries the two words have just reversed their connotations.

In the Aristotelian science the *organum*, or tool of knowledge, was the syllogism; and to impugn the efficacy of the syllogism as the instrument of ultimate knowledge was in the 17th century to fly in the face of God himself. That Bacon should dare to do it while yet an undergraduate at Cambridge is evidence of the splendid audacity which always characterized his thinking. To project a new point of view when the world is prejudiced against it and "with loud clamor hooteth the projector, this is not an undertaking for dullness or cowardice." And Bacon's mind, "beating out its own way in untravelled places," never lacked the courage of its convictions.

His first step on the new path, taken in his young Socratic faith that all men would follow the truth once they caught a glimmer of its light, he enthusiastically termed *Temporis Partus Maximus, i.e.*, "The Greatest Thing that Ever Happened." Fancy the effect of a title like that on the staid sensibilities of an Oxford or Cambridge don as he confronted it for the first time staring at him from the shelves of a university bookstall. No wonder Bacon never achieved an academic degree! Even his later admirers were shocked at the audacity of this title. Archbishop Tenison, in "An Account of all Lord Bacon's Works" (1679, p. 9), has this to say of the *Partus* (later absorbed in the *Instauratio*): "That book (pompous in its title but solid in its matter, like a great feather put sometimes on a good headpiece) contained in it, though in imperfect manner and so far as the greenness of his years permitted, the principal rudiments of his Instauration—a work so vast and complete that—it seemeth true that he framed the whole model of the House of Wisdom." (Note this phrase, "the House of Wisdom," the *Aedes Salomonis:* it is Bacon's name for his college of research, which we shall concern ourselves with shortly.)

In like manner all Bacon's titles were calculated to insult the complaisant mediocrity of the academic powers that then were—as he himself puts it, they "fly high over men's heads." His works are always sounding the triumphant note of discovery—the *Novum Organum Scientiarum* ("The New Instrument of Knowledge"), the *Parasceve* ("The Passover Preparation"), the *New Atlantis* ("The Lost Continent Found Again"). And they are written *in verbis masculis*—no "flourishing or painted words, but words such as are fit to go before deeds."

He later lost his faith in the open-mindedness of humanity, but he never lost the conviction that he was on the right path, and never faltered in the courage necessary to pursue it. The goal toward which he consistently pressed all his life long was a new world enriched by the fruit of an organized scientific research systematically proceeding, discovery by discovery, to the ultimate fullness of truth.

Ever practical, with this end in view he undertook a complete survey of the state of human knowledge in 1605. The result of his labors he dedicates to his scholar-king, James I, under the English title "The Proficience and Advancement of Learning." With our habit of "computing antiquity backwards" we quite miss the significance of this title. For in the 17th century "proficience" may mean "worth," "practical value." That this was the meaning Bacon had in mind is obvious from his corresponding Latin title, *de Dignitate*. His purpose in writing the book was thus practical; not academic—*to demonstrate the value of science in the service of humanity and point out the means by which this value might be progressively enhanced.* His survey covers the whole field of human knowledge at the beginning of the 17th century.

He finds most of the contemporary sciences dry and barren—*deficiens.*

It may be of interest to note in passing that he has no fault to find with the science of language. The two divisions of this *rational knowledge* (which is his term for what we think of as "applied science") are grammar and literature, with poetry as the highest form of the latter. Bacon's conception of language was the then prevailing, and not yet quite extinct, view of Aquinas. God gave it to Adam in the Garden of Eden as a means of naming things. Man perfected it until the awful disaster of Babel. Bacon naïvely maintains that man has partially recovered from the effects of his "second curse," as it was known among the schoolmen, by adopting the comparatively perfect language of the Latins as a means of universal communication.

A scientific conception of language was not to dawn on the world until the end of the 18th century through the patient labors of such scholars as Hickes and Junius; its fundamental laws were not to reach a definite formulation until 1822 with Jacob Grimm's discovery of the Germanic Sound Shift; its "proficiency" as a science was not to be formally recognized until the present Year of Grace, 1923.

[2] Milton's Eve, when she first discerns the knowledge of good and evil on eating the forbidden fruit, apostrophizes the apple as the "mother of science" (P. L. IX, 980).

Proceeding in his relentless logic Bacon inquires into the cause of the deficiency he has pointed out. He finds it in the universities with their inevitable tendency to sacrifice the original mind to the exigencies of the academic system.

The second book of the "Proficience and Advancement" is worthy our careful attention as clearly demonstrating Bacon's conception of the proper place of research in university education. He finds (p. 95) that the great universities are "dedicated to professions, and none left free to arts and sciences at large." This frantic pursuit of professorial and professional learning, he says, is the folly described in the ancient fable of the idle stomach and the active members. "If any man thinks pure science to be an idle pursuit he fails to realize that from thence is all applied science supplied." He maintains that this neglect of pure science in the universities is the "great obstacle that stands in the way of the advancement of science," because, in consequence of it, "fundamental knowledges are studied but in passage"—*i.e.*, the sciences that are fundamental to progress are studied only superficially. "If you will have a tree bear more fruit than it hath used to do, it is not anything you can do to the boughs, but it is the tilling of the earth and the supplying of fresh energies to the roots that must worke it."[3]

The pursuit of these professional ends, Bacon goes on to say, produces college professors who are quite unfit for intellectual leadership; they are not "able" (*virile* in modern English) and "sufficient" (our modern *efficient*) men, but the kind that easily submit to authority and tradition. The professorial class, he maintains, should be selected and set apart with a view to breeding the intellects of the coming generation. They should therefore be men who are conspicuous for intellectual virility and vigor. But their present mode of selection defeats this purpose. For the "smallness and meanness" of its rewards and emoluments as compared with those attainable by the practice of other professions is such that an academic career holds out no attractions to induce virile men to devote their entire energies and whole lifetime to it; and the consequent imbecility propagates itself into succeeding generations, so that the devitalized children reflect the starved features of their fathers—

Et Patrum invalidi referent jejunia nati.

Another deficiency Bacon points out in the universities of his day is their reliance upon text-books, and their failure to provide adequate facilities for research in the way of laboratories, botanical gardens and other instrumentalities of investigation (p. 97). Those in authority refuse to authorize the bills of expense, necessarily large, which the provision of such tools renders necessary. With that peculiar aptness of pointed analogy which characterizes his thinking, Bacon maintains that research is the intelligence department of organized knowledge, and that scientific investigators are the "espialls and intelligencers" of nature. When a government cuts down the bills of its intelligence department it puts out its own eyes, and as a consequence is ill advertised of the plans and movements of its enemies.

As to text-books, the situation is to be met not by ceasing to produce books, but "by making more good books."

Another weakness in the contemporary institutions of higher learning, he maintains, is the admission of students immature and untrained in the processes of scientific thinking (p. 99); in catering to the capacity of these immature students, knowledge "is made almost contemptible, and has degenerated into childish sophistry and ridiculous affectation"; and the precocious pupils develop the superficiality characteristic of the capacity of children.

Bacon stigmatizes still another deficiency in the universities of his time in their lack of mutual understanding and sympathetic aims and ideals—"intelligence mutual, contract and fraternity"—and their waste of energy and duplication of effort consequent upon a lack of cooperation and coordination—"conjunction of labors."

On page 215 he reaches his final conclusion that there is no health in these institutions because they forestall research; they have abandoned this road and walled it up—it has become a *via deserta et interclusa*. With a lawyer's shrewdness he points out the fact that the fundamental contract of these university societies is one by which the parties agree to hoodwink each other.

'As knowledge is now delivered there is a kind of contract of error between the deliverer and the receiver. The one desires to present his knowledge in such a way that it will fit in with established opinions, and not in such a way that it may be tested by actual experience; the other desires immediate satisfaction rather than stimulus to further enquiry—to believe without qualification rather than to ascertain the truth through his own efforts. Thus regard for his reputation makes the Master conceal his ignorance, and mental inertia keeps the disciple from liberating his own intellectual energies.' (Adv., p. 215.)

Bacon's magnificent program for establishing research as the means of regenerating learning in the service of humanity followed two lines: one to provide the scientific method for the *magna instauratio;*

[3] Pasteur's later words, "There exists no category of the sciences to which the name applied science could rightly be given; we have science and the application of science, *which are united together as the tree and its fruit,*" sound like an echo of Bacon's.

the other to provide the material and personnel to make it effective.

The former task proved greater than he had anticipated, but was at last accomplished in his 59th year with the publication of the *Novum Organum* in 1620. In 1623 he incorporated the new system in an enlarged and extended Latin version of the proficience and advancement, under the title *de Dignitate et Augmentis Scientiarum,* bringing the New Philosophy to a point.

We are apt to take this book out of its context and compute its significance backwards. But when we look at it with the eyes of Bacon's contemporaries we can easily realize how an arraignment of the intellectual life of the time as shrewd and relentless as this was should raise for its author such a host of implacable enemies that he would have little opportunity to carry out the second part of his program. And that was what happened. Six years later their animosity culminated in the tragic triumph which broke Bacon's heart and sent him down to posterity a dishonored name.

But in spite of the fact that Bacon is only known by his system of induction, which, by the way, is fundamentally different from the Aristotelian ἐπαγωγή in that it has discovery and not demonstration for its end, and definitely provides for working hypotheses which may either run counter to ἐπιστήμη or for a time prove mutually irreconcilable—in spite of this fact, there appear here and there throughout the records of his life evidences that he had always in mind the practical side of his problem, and contemplated the establishment of a great college of research independent of the universities, as the goal of his endeavor. It was probably this end, requiring enormous financial resources for its achievement, that made him so avid of money that posterity has stigmatized him as avaricious.

We fortunately have Bacon's own memoranda of his plan of organization for this new college (Spedding IV, pp. 25, 26). These rough notes were made in July, 1608. The real purpose and intent of the proposed foundation are involved in a phrasing whose significance we quite miss because its Elizabethan words have changed their meanings since Bacon's time. "Invention," for instance, in the 16th century means "research," or "discovery," and an "inventor" is a discoverer of new knowledge (see New English Dictionary, 1); the restricted modern sense of "inventor" is expressed in Elizabethan English by "engineer." The draft for the College of Research that was to build the New Philosophy into a scientific working organization runs as follows:

> The foundation of a College for Inventors. . . . Galeries with statuas for Inventors past and spaces or bases for Inventors to come. And a Library and Inginary.
>
> The Order and Discipline to be mixt with some poynts popular to invite many to contribute and joine.
>
> The rules and prescripts of their studyes and inquyries.
>
> Allowance for travailing; allowance for experiments; Intelligence and Correspondence with Universities abroad.
>
> The manner and Prescripts touching Secrecy, Tradition, and Publication.
>
> Removes and Expulsions in case within a tyme some Invention worthy be not produced and likewise the honors and rewards for Inventors.
>
> Vaults, furnaces, Tarraces for insulation, woork houses of all sorts.

Translated into modern English this gives us the following scheme:

(a) The foundation of a college of research with (1) a hall of fame for statues of those who have contributed to the advancement of science in the past, and (2) bases for statues of those to come, together with (3) adequate library and laboratory facilities.

(b) The plan of organization must contain attractive features to induce public-spirited benefactors to contribute to the support of the college, and scientific men to join its fraternity.

(c) Rules and regulations for the conduct of studies and investigations.

(d) Allowances for travelling expenses; allowances for experiments; allowances for correspondence and communication with foreign universities.

(e) Methods of and regulations for recording such conclusions as are to be kept in cipher until the time is ripe for their publication; for imparting instruction to new-comers; and for the publication of such discoveries as are to be given to the world.

(f) Regulations for removing members who produce no valuable discoveries, and for honoring and rewarding those who do.

(g) Vaults, furnaces, platforms for exposing things to the action of the sun, work-shops of all kinds.

The outstanding feature of this project for a college of research is its startlingly practical character. With the exception of its fifth provision of secrecy and restricted publication,[4] which the subsequent progress

[4] It was an endeavor to determine the scientific significance of his Bi-Literal cipher to which Bacon gives so much space in the *de Augmentis,* that led the writer of this paper first to organize the material here presented—and he is especially indebted to Colonel George Fabyan for free access to the magnificent library of Bacon's work and Baconiana assembled at Riverbank. This library, besides containing one of the very rare copies of Bacon's "de Augmentis," 1623, is unusually rich in materials relating to cryptography and Rosicrucianism. Out of the latter movement developed the earliest ascription of Shakspere's Works to Francis Bacon. Bacon divides research into *Inventio* (*i.e.,* discovery), *Memoria* (*i.e.,* record) and *Traditio* (*i.e.,* handing down to posterity). His *Traditio* is to be selective; for he clearly realizes that the New Philosophy will yield new principles of science which

of science has rendered supererogatory, Bacon's program might well be adopted *in toto* by modern foundations for research.

Its controlling idea is service—"proficience"—and its end the "advancement" of science through successive discoveries; moreover it mechanically excludes from "research" all those multifarious varieties of compilatory investigation (what Zupitza used to call *reine belesenheit*) which so clog our modern research endowments.

That Bacon's project was no mere passing display of intellectual acumen—in his own words, a "matter of strangeness without worthyness"—is at once evident when we turn to the *Atlantis* and read this fragment in the light of the provisions outlined above.

Scattered through Bacon's writings here and there are references to the "House of Wisdom," or its Latin equivalent *Aedes Salomonis*. This was his name for his projected college. We have seen Archbishop Tenison definitely employing it with this significance. That it was familiar to the two generations following Bacon is evident in the writings of the 17th century century Rosicrucians, whose organization was an offshoot of the New Philosophy and made the *Atlantis* a part of its constitution.

The New Atlantis was first published by Rawley, Bacon's secretary-chaplain, in the year after Bacon's death. From Rawley's description of the fragment it is evident that Bacon intended it to be the introduction to an imaginary picture of his college of research in practical operation to make organized knowledge "proficient" to the regeneration of human society—the *Aedes Salomonis operans*.

We have not time here to describe this book, beyond pointing out the fact that it is *not* the weak imitation of the *Utopia* that our proneness to compute antiquity backwards makes it appear.

Bacon's project, however, was not destined to bear fruit in the way its author planned. It has never been actually realized. But in the inscrutable providence of science it was destined to fructify centuries later in the activities of organizations like that which brings us together this afternoon.

About fifteen years after Bacon's death a group of "divers worthy persons inquisitive into Natural Philosophy and other parts of Humane Learning, and particularly what has been called the New Philosophy" . . . began "by agreement to meet weekly in London to treat and discourse of such affairs."

One of these enthusiasts was Dr. John Wallis, later Savilian professor of astronomy in Oxford. Wallis was especially interested in the scientific study of philology, and in 1653 published his *Grammatica Linguae Anglicanae*, still one of our most valuable sources for an accurate knowledge of seventeenth-century English phonology. The sub-title of this work is significant — *Tractatus Grammatico-Physicus* — clearly recognizing as it does the fact that the phenomena of speech are subject to physical laws.

It is Wallis who has preserved for us the interesting record of the proceedings of this infant scientific society from which we are quoting.[5]

The weekly meetings were often held, Wallis says, at Mr. Goddard's lodgings in Wood Street, because Goddard employed a man to grind glasses for telescopes and microscopes, then becoming useful tools for scientific investigation. The business of the meetings, we are told, precluded theology and politics, and was devoted solely to the scientific discussion of such topics as "the circulation of the blood," "the lymphatic vessels," "the Copernican hypothesis," "the satellites of Jupiter," "the spots in the sun," "the improvement of telescopes," "the weight of air," "the possibility or impossibility of vacuities," "the descent of heavy bodies and the degrees of acceleration therein"—"with other things pertaining to the new philosophy."

The hypotheses indicated by these titles are the foundation stones of our modern scientific research. Some of them were laid by the original members of the new society; others were new points of view which the world was still prejudiced against and "with loud clamor hooted their projectors."

> About the year 1648 some of our company being removed to Oxford . . . those in London continued to meet there as before; . . . and those of us in Oxford . . . continued such meetings in Oxford and brought those studies into fashion there.
>
> After the King's return in 1660, the London meetings were increased with the accession of diver's worthy and Honorable Persons; and were afterwards [the exact date is 15 July, 1662] incorporated by the name of the *Royal Society &c.* ["for the improving of Natural Knowledge by Experiments," as the charter completely styles the new organization] and so continue to this day.

The first proceedings were published in March, 1664, under the title "Philosophical Transactions," with the distinct *caveat* that the society was not responsible for the views expressed by its members.

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may contradict received truth, and for the good of society these discoveries must be held back until such time as the world can bear their light, by recording them in a cipher (probably the Bi-Literal), the key to which is to be transmitted to posterity through a line of trusted heads of the college who are in the secret.

[5] It appears among certain autobiographic notes which in the form of a letter to Dr. Thomas Smith are included in Appendix XI to the preface of Hearne's edition of "Peter Langtoft's Chronicle" (1725). The passage relating to the Royal Society is also found in the later editions of Wallis's "Grammatica."

The first volume of these transactions makes interesting reading to-day. It shows that one of the most active pioneer members, besides the philologist, John Wallis, was Mr. Robert Boyle, who in his letters refers to himself as also a member of the "invisible college," probably the Rosicrucian offshoot of the New Philosophy, composed originally of scientific men bound together as an esoteric sodality without name or meeting place and having for its sole end the alleviation of the physical and spiritual ills of humanity.

It seems that at first Sir Isaac Newton held somewhat aloof from the infant Royal Society. They appear, however, to have felt that they could not get along without him, and in January, 1671 (O. S.), he was elected a fellow and accepted the honor.

But difficulties soon arose with the secretary, Oldenburg, in connection, apparently, with some disposition to criticize Newton's new theory of light. On the 8th of March, 1673, Sir Isaac writes a tart note to the secretary saying that he desires "to be put out from being any longer fellow of the Royal Society" on the ground that "the connection is not profitable to either party."

The society then offered to excuse him from paying his dues, a proffer which Sir Isaac, in his reply to the letter announcing the action, affects to consider immaterial.

In 1675 the matter seems to have been satisfactorily adjusted and Newton is reenrolled as a fellow. But evidently peace did not last long, and the controversy over his theory of light did not subside; for in 1676 he writes to the secretary saying that 'he will resolutely bid adieu to philosophy eternally, excepting what he does for his private satisfaction or leaves for publication after his death; for he sees that a man must either resolve to publish nothing new, or spend his whole life in defending his hypothesis.'

Fortunately for the world, he later revoked his decision and from 1703 to his death was president of the organization which published his *Principia*.

I have dwelt on these excerpts from the early minutes of the Royal Society because they are so eloquent of the personal equations involved in bringing scientific men together for what Bacon calls "intelligence mutual, contract, fraternity, and conjunction of labors."

The subsequent history of the Royal Society and later similar organizations like our own is in large part the history of the "proficience and advancement of learning," and I hope our brief computation of antiquity forwards will have made evident that in one sense we are this afternoon really celebrating the 300th birthday of the "able and sufficient" parent of the American Association for the Advancement of Science.

PURDUE UNIVERSITY MARK H. LIDDELL

THE TERMINOLOGY OF CERTAIN PHYSICAL AND BIOLOGICAL EFFECTS OF LIGHT

IN any discussion of the nomenclature of matters pertaining to light one must first make clear what he means by the term light. For there are several definitions extant in illuminating engineering and other literature. In the present case I shall define light as electromagnetic radiation of such wavelength that it may effect adequate stimulation of the sense of sight.[1] Or, light is photic radiation, where photic means effective in producing the sensation of brightness contrast. In this definition light has an objective reality, as all measurable things in physics have. To bring out clearly what the present usage[2] of the term radiation is and how the above definition of light is related thereto I am giving the chart of Fig. 1.

When one surveys the effects of light he finds that there is a considerable confusion of terminology, leading in some cases to an actual confusion of the phenomena. This results in some instances from a lack of short connotative words. The purpose of this note is to point out how a few of these shortcomings in nomenclature may be rectified. For example, the term phototropy has a meaning in zoology different from that in physics. In fact, this word has two different meanings in each of these two sciences. The word photolysis has had a meaning in botany different from that in chemistry.

To make certain suggestions regarding this matter clear and yet succinct, the chart of Fig. 2 is given. Here the various effects of radiation are enumerated and the effects of light are there also as effects of radiation of particular wavelengths. The gross classification into the physical, the chemical and the biological is conventional, having practical but no logical significance. When more shall have been learned about the effects, a better classification no doubt may be had by ignoring this convention. It must be obvious to every one that such a classification has always fringes where the subject-matter may not be clearly demarcated. Some effects are indicated under more than one class, and many others might have been or will be probably as data are accumulated.

The first items for consideration as new suggestions are the terms describing the electrical effects. The phenomenon referred to sometimes as the electromotive force due to light I have termed photovoltic. Certain substances like silver sulphide will, when made a part of a metal circuit, exhibit a difference of potential between illuminated and unilluminated

[1] For other definitions of light see Trans. I. E. S. 1918 and 1922. For a discussion of the definition given above see J. Fr. Inst., 1923.

[2] This matter will be discussed in greater detail in another paper.