# SCIENCE

A WEEKLY JOURNAL DEVOTED TO THE ADVANCEMENT OF SCIENCE, PUBLISHING THE OFFICIAL NOTICES AND PROCEEDINGS OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.





FRIDAY, MAY 16, 1902.


CONTENTS:




MSS. intended for publication and books, etc., intended for review should be sent to the responsible editor, Professor J. McKeen Cattell, Garrison-on-Hudson, N. Y.


## *METALLURGICAL LABORATORIES.**

To an old friend of the great captain whose munificence we celebrate to-day this privilege of adding a word of enthusiastic praise is most welcome. Let us congratulate Lafayette on this princely gift, and still more on the princely heart that prompted the princely gift. It is a pleasure to watch the growth and success of one whom we esteem; a very great pleasure to see the responsibility of that wealth which so often intoxicates where it should sober, so soberly and so wisely borne.

While the value of the metallurgical laboratory for purposes of investigation is evident, yet as instruments for teaching undergraduate students so few of these laboratories have been in long use, and their methods, aims and merits have been so little discussed, that not only the thoughtful part of the public, not only educators in general, but even a very large fraction of our metallurgical educators themselves, have but hazy notions about them. Indeed, there are many whose opinions cannot be ignored, many eminent metallurgical educators, who still doubt or even deny the value of the metallurgical laboratory for this purpose. Under these conditions it seems well that those of us

* An address delivered at the Dedication of the Gayley Laboratory of Chemistry and Metallurgy, Lafayette College, April 5, 1902.

who are confident that these laboratories are invaluable instruments should seize occasions like this to give the reasons for the faith that is in us, to the end that, if we are right, our allies, our sister schools here and abroad, may arm themselves with this potent weapon; and that, if we are wrong, we may discover our error through thus uncovering our reasons.

I ask your attention, then, to the use of these laboratories, not for purposes of investigation, for which their value is unquestioned, but for undergraduate instruction.

The objections urged against metallurgical laboratory instruction, so far as I understand them, are two:

First, metallurgy, like every other profession, has its art, and also its science, that is to say the systematic arrangement of the principles on which it is based. It is objected that professional education should be rather in the science than in the art, rather in the underlying and unchanging principles upon which the art reposes, than in the technique of the art itself. Principles, it is urged, are to be explained in words and thoughts, rather than in laboratory manipulations; they are to be imparted, then, by thought, by reasoning, by lectures and text-books, rather than by doing things with the fingers. The laboratory, it is urged, is no place to teach principles.

Second, the actual conditions of metallurgical practice on a commercial scale, that is to say the conditions of the art as it will have to be practiced, cannot be reproduced in any laboratory.

Let us examine these two objections.

The contention that education should be in principles rather than in the technique of practice, in the science rather than in the art, no educator worthy of the name can question. But this granted, the question remains how best to teach principles. To teach them effectively seems almost necessarily to require some conception of the things to which they relate; certainly, such conceptions must very greatly facilitate teaching. If the subject is of such a nature that sufficient conceptions concerning it have been formed during the student's prior life, then laboratory practice is less important or even superfluous; if not, if such conceptions are lacking or defective, then laboratory practice may be a most ready way of supplying or strengthening them.

Of the conditions attending metallurgy the student certainly has acquired no sufficient conceptions during his prior experience: his want here is more serious than in case of chemistry and physics; and because it is more serious, because these conceptions while hard to supply verbally, are readily supplied by laboratory practice, the metallurgical laboratory seems to me of the greatest value as a preparation to the study of the principles of this art.

Let us test this reasoning, this assertion that conceptions, if not a prerequisite, are at least an invaluable aid to the study of principles, of general laws. Surely, to grasp the principles of legislation there should be a conception of human nature; to understand the laws of music and painting there must be a conception of sound and color. Is not the same true then of chemistry and metallurgy, that in order to understand their laws the student should have a conception of the conditions and of the kinds of phenomena with which those laws deal?

The objection which at once arises is that, in case of mathematics no laboratory work is needed; that in case even of music and painting exercise in the art itself is certainly not necessary to enjoyment of its products, and probably not necessary to a clear comprehension of its principles. Why then in chemistry and metallurgy?

The answer is that the conceptions underlying mathematics, music and painting have already been acquired spontaneously, have become part of our very nature; and that in case congenital blindness or deafness has forcibly prevented the acquisition of the conceptions of color or sound, it has thereby made the study of the principles of painting or of music impossible.

Let us look at this a little more closely.

That every youth has acquired spontaneously and inevitably the conceptions underlying mathematics, the conceptions of number, distance, direction and force, seems clear.

The child deprived of every sense save touch begins with its first breath to familiarize itself with these conceptions. The resistance offered by fixed objects, the mobility of movable ones, the resistance which friction and inertia oppose to his moving them, the fact that he cannot move the bed post, that he can move his hand with ease, and his heaviest toy with difficulty, from the first give him the conception of force. The conception of two hands as distinguished from one is the conception of number, forced on him by every scene. Every glance of the eye, or if he is blind, every reaching out for toy or foot, gives the conceptions of distance and direction. These conceptions then are inevitable; they cannot be shut out by defects of the senses; hence the study of mathematics does not call for any special preparation comparable with the laboratory preparation for the study of chemistry and metallurgy.

So is it with music and painting to the child with all his senses.

The sighted youth comes to the study of painting with an eye trained from first infancy through sixteen hours of every day of most of his seventeen years, in color perceptions. They have been sunk into his very nature by the glories of the sunset, by the marvelous harmonies of the landscape, by the play of human expression, by the effects of shadow and perspective. He comes with conceptions so familiar and complete, so essential a part of his very being, that henceforth he cannot think shape without interjecting his conceptions of shade and color; he cannot conceive any object without conceiving it as colored or shaded.

To the study of the laws of music the youth with normal ear, the so-called ear for music, comes with the experience of seventeen years, those wax-like plastic years, of the sensuous pleasure due to certain sounds and sequences of sound, and the annoyance which others cause, not only to himself, but to those about him. The mother's lullaby begins his acquaintance with pleasurable sound; his own shrieks, the clanging bell, the squeaking slate pencil, early impress on him the disagreeable sound. So complete and familiar are his sound-conceptions that no special training in them is imperatively needed to enable him to begin the study of the science of music.

But let congenital blindness or deafness forcibly prevent him from acquiring these conceptions, and it thereby as forcibly and as absolutely unfits him for the study of the science of color or music. How can the congenitally blind, to whom red is but as the blare of the trumpet, comprehend a discourse on chiaroscuro? Or with what profit can you explain to them the proper tint of shadows while all conception of both tint and shadow is not simply vague, imperfect, rudimentary, but absent? Or how can the congenitally deaf understand the very terms harmony, discord, major and minor? Before they can conceive what minor means, must they not have some conception of sound?

Even after the missing sense has been given to one thus congenitally defective, to acquire the missing conceptions is a work of time. Open blind eyes at seventeen, and all is seen in confusion; time and acquaintance must make conceptions clear and familiar, conceptions and interpretations of shade and perspective, before the science of painting becomes comprehensible. Unstop deaf ears at seventeen, and not only is a symphony of Beethoven absolutely meaningless, but all sound fails to be interpreted. Only after time has supplied the familiarity with sound conceptions which childhood should have given, only then can the study of the principles of music be begun.

These cases thus support the contention that familiarity with conceptions and conditions, if not absolutely necessary to the study of principles, is at least an invaluable, an incalculable aid.

The student beginning the study of metallurgy has something in common with one who should begin the study of the science of music immediately after the instantaneous cure of congenital deafness. As it is hard for us to grasp our own infantile difficulties in interpreting the sensations on our retinas, so one who begins to teach metallurgy late enough in life to have lost sight of the mental condition of his student days is at first puzzled by the density of his pupils' ignorance. They lack the very beginning of those every-day conceptions so familiar to the teacher himself. To a man from the moon the conception that water runs down rather than up hill would be novel.

Without conceptions of metallurgical conditions and surroundings, your reasoning about metallurgical processes may wring an acquiescence from the student's intellect, but all remains unreal, unheld by the memory, unimpressed, like a pale algebraic demonstration.

Now I take it that the great object of laboratory instruction is to supply lacking conceptions. Though the youth has seen chemical actions going on around him, his attention has not been sufficiently concentrated on their essential features. The chemical laboratory reinforces his deficient observation, and clarifies his hazy conceptions of gasification, sublimation, precipitation, solution, fusion, liquefaction, solidification, freezing, diffusion, the exact balancing of reaction, substitution, the indestructibility of matter. Beyond this it impresses on his memory the chief characteristics of the more important chemical substances by vivid picture, and by personal acquaintance, instead of by mere description from the lips or pen of teacher. They become to him as his playmates in the flesh, instead of as the heroes of his story books. It is no just reproach to call this kindergarten work; calling names is poor argument. It does to the youth what the kindergarten does to the little child, directing observation into fruitful fields.

Why, now, have I said that the need of laboratory instruction is even more pressing in case of metallurgy than in that of chemistry or of physics? Because the conditions, especially the high temperature conditions, which surround metallurgy are stranger, less foreshadowed by childhood's prior experience, less readily evolved from our consciousness, less easily pictured by the words of lecture or textbook than those which attend chemistry and physics as these are chiefly taught, the chemistry and physics of the normal or every-day temperature, that little range between the freezing and boiling points of water. The conditions and phenomena even of common-temperature chemistry and physics indeed are relatively unfamiliar to the beginner; this however is not so much because they and their likes have not been seen, as because attention has not been concentrated upon them. The pictures are already in the memory, and respond readily to developing and fixing by skilful language. The daily ablutions teach the integration of soap and certain dirt, and the insolubility of other dirt; sugar and salt at the breakfast table teach solution; the settling of fine mud in the brooklet's pools teaches decantation; the clearness of the spring exemplifies filtration; the tea kettle and soda-water teach ebullition; the drying roofs show evaporation; the sweating of the ice pitcher illustrates the principle of the dew point; the sponge teaches surface tension. All these and a hundred like images already exist in the memory, and have but to be recalled to become vivid, but to be interpreted to serve as types of our chemical and physical phenomena.

But of metallurgical conditions the youth's past has given little foretaste. Especially is this true of the solvent fluxing action of that high temperature at which the rocks and most of the metals are as water, many other metals are gaseous, and strength and even solidity itself are to be found in only a very few substances. And even these react energetically on almost everything they can touch. In the crucible of the iron blast furnace there is but one substance which remains solid, which can offer support, and that is carbon; but this itself reacts on most things exposed to it, and is in turn attacked and destroyed by them. This reciprocal destruction, this Kilkenny-cat attitude of nearly every available substance toward every other, is not only itself unlike anything the student has previously known, but it results in a difficulty previously unthought of, the baffling difficulty of devising any retaining vessel whatsoever. The solids we children have known stay put; the liquids rest peacefully in the familiar tin can, or, in the few cases in which this may not be used, then in vessels of wood, glass, porcelain or clay indiscriminately.

Indeed, the fiery magmas with which metallurgy has to do, the molten metal, molten slag and molten matter, are in themselves and apart from their corrosive nature substances unlike anything in the notice of our early years, which has been directed chiefly to solids and aqueous liquids. The nearest approach to acquaintance with this class is the hazy conception of lava streams of which we have read. Still more remote from our experience are the reactions between these plutonic bodies which play so large a part in metallurgy, the purifying action of slag on metal, the slag's retentivity of metal or of metalloid, according to whether it is acid or basic; the coalescing of the oxides and acids into one magma, the slag; of the sulphides into a second, the matte; of unoxidized and unsulphuretted elements, both metals and metalloids, into a third magma, the metal; and the reciprocal expulsion which each magma exerts towards the other. Here indeed we have a class of bodies and of reactions so unlike those of which the usual chemical laboratory instruction treats, that metallurgical laboratory practice should be added to chemical.

To supply clear conceptions of these strange metallurgical conditions, and thus to build a foundation for thought and reasoning, is I believe the chief work, the invaluable work of the metallurgical laboratory.

To build this foundation well, the student should, I think, perform a great variety of simple experiments, each of which should direct his attention to a very few or even to one important principle, and avoid diverting it to attendant administrative details. For instance, his furnaces should in general be heated by gas or electric resistance, so that his attention may be concentrated on the phenomenon which he is studying, and not diverted to keeping a coal fire in proper condition. As far as possible these experiments should be quantitative.

If I am right in saying that the laboratory is thus an invaluable instrument for preparing the student for the study of principles, the first of the two objections urged against metallurgical laboratories, that education should be in principles rather than in practice, falls to the ground.

The second objection, that the conditions of actual practice cannot be reproduced in the laboratory would be unworthy of notice, were it not offered by men of such weight that even their errors must be considered.

The error lies in supposing that this instruction aims to anticipate practice in commercial establishments: whereas its aim is to facilitate instruction in metallurgical principles by lectures and text-books. There is no more reason for reproducing commercial practice exactly in the metallurgical laboratory than for reproducing in the chemical laboratory the system of kilns, towers and leaden chambers of the sulphuric acid works. But even from this mistaken point of view the objection is without weight. With equal force it can be urged that fire drill and military drill are useless, because they cannot reproduce exactly the actual conflagration, and the actual carnage and confusion of battle.

Another and important work of the metallurgical laboratory is to give a certain skill in the use of the instruments of precision of the art, in pyrometry, colorimetry and the microscopy of metals and alloys. It seems to me nearly as imperative that the metallurgist's diploma to-day should imply this skill as that the civil engineer's should imply skill in the use of the transit.

Finally, just as into a barrel full of potatoes a quarter of a barrel of sand can be poured, and then a quarter of a barrel of water, so after the student's power of study and note-taking in lectures has been thoroughly utilized, he still has power for much of this different, this observational and administrative laboratory work, in which he absorbs and assimilates priceless information like a sponge, and acquires along the path of least resistance and with but little mental effort the needed metallurgical conceptions.

Henry M. Howe.

---

## *A NEGLECTED FACTOR IN EVOLUTION.**

An eminent Swedish zoologist, Dr. G. Adlerz, in a very suggestive paper† has recently called attention to some hitherto neglected conditions affecting the variability of organisms. Starting from the high degree of variability which has long been known to obtain in organisms in a state of domestication, Dr. Adlerz directs attention to the similar phenomena presented by wild animals during the great periodic increases in numbers brought about by unusually favorable trophic and meteorologic conditions.

In regard to the domestic organisms Dr. Adlerz gives expression to very generally accepted views when he says: "The changed conditions to which animals and plants are subjected in a state of domestication must, of course, mean a decided mitigation or even a complete cessation of the struggle for existence. They are provided with better and more abundant food than in the feral state and the survival of offspring is better insured. On the whole therefore the individual organisms are able to grow up under the most favorable circumstances.

"No matter how completely the germplasma may be shielded from external influences, it must, nevertheless, be susceptible to changes in the kind and amount of food, as Weismann admits, though he appears to lay little stress on this matter. If, as seems probable, variations are ultimately the resultants of physico-chemical processes in the germ-cells, it would seem to be very

* Contributions from the Zoological Laboratory of the University of Texas, No. 33.

† 'Periodische Massenvermehrung als Evolutionsfaktor,' *Biol. Centralbl.*, 22. Bd., No. 4, Feb. 15, 1902, pp. 108–119.