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SCIENCE AND LIFE[1]

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THE explorers of the heavens tell us they have located a galaxy of stars, the light of which, transmitted at the rate of 186,000 miles a second, has been traveling through space for a period of 140 million years before becoming visible to the eye. We may perhaps be pardoned if we take account of the position of some other things which are a little nearer to us. For example, the position of metabolism research has lately been defined by a friend of mine who told me that it was now so far advanced in this country that it needed no further support. It seemed to me to be regrettable that such opinions could be held anywhere. I mentioned this statement to my friend, Karl Thomas, of Leipzig, a former pupil of Rubner, and he comforted me by saying, "Why, the whole of life is metabolism."

[1] Delivered before the Piersol Anatomical Society, the University of Pennsylvania, Philadelphia, February 28, 1930.

A celebrated clinician once elaborated and published a wonderful interlocking endocrinological scheme regarding diabetes. About one out of four of his guesses was right; the other three are now in the receptacle devoted to scientific rubbish. And we witness year after year false interpretations of physical phenomena, because a younger generation has arisen which does not know and apparently does not care to know what the old masters knew of the phenomena of metabolism. It is too much trouble to learn about it. The younger generation wishes to do a few metabolism experiments of its own and to draw conclusions without any knowledge of the background of accumulated evidence which may render the conclusions invalid.

Rubner, during the war, lamented the clamor of those Germans who demanded the production of a super-bread, for he knew of work done fifty years before, which even educated physicians had forgotten,

which precluded the possibility of producing a super-bread.

I would like to dwell for a short time upon the life of Liebig,[2] whose activities were largely responsible for the development of modern metabolism research, as founded in large measure by his pupil, Carl Voit. For the lessons of Liebig's life seem likely to be forgotten in the standardization and mechanized control exercised over American education to-day. So if you will bear with me, we will look backward a hundred years and more.

In 1803 Liebig was born in Darmstadt. He was one of seven children. His father sold oils, paints and dyes. When he was fourteen years old his school teacher complained of his inattention and asked what he would ever become. Liebig replied that he would become a chemist. The laughter which followed this remark caused him to leave school. He sought apprenticeship to an apothecary in the neighboring town of Heppenheim. He learned all he could learn in that environment in ten months and, on returning home, indicated to his father improvements which he could make in his business. At the age of seventeen he went to the University of Bonn to be under Kastner, then the most celebrated chemist in Germany, and he followed Kastner to Erlangen when the latter moved thither.

In a letter written to his parents from Bonn he says:

> I take great pleasure in my studies. The more I understand, the greater my satisfaction. I have begun to realize how little I know, and how much I must learn before I can say, I know something. Please do not forget to send me money.

His typical father writes him from Darmstadt, "Give thyself trouble to learn thoroughly, and practice diligently Latin and French."

And the typical son again, "The most necessary Christmas present which you, my dear parents, can give me, what can it be other than money."

Kastner proved inadequate for the aspiring young student. Liebig has told how Kastner related to the class that the moon had an effect on the clouds, because the moon became visible when the clouds dissolved. But Kastner had the wisdom to recommend this brilliant young man to the Grand Duke of Hesse-Darmstadt and to advise that money be provided so that he could study in Paris. We would to-day call this a traveling fellowship. Through the finance minister, Schleiermacher, Liebig was given a modest sum for his expenses. He traveled to Paris by stage coach at the age of nineteen. At first the small-town lad has a confused impression of the delirious life of a great city, but he writes to Schleiermacher:

> In no other country do the sciences develop so wonderfully as here and this is because of the highly developed mathematical sense of the French scientists, which causes them to reject all useless hypotheses. Gay-Lussac handles the subject of chemistry in a way which shows his complete mastery of it, and Thénard does the same. Experiments are made with lavish expenditure of material. The government spends money freely for such purposes.

Both Thénard and Gay-Lussac had been pupils of Berthollet, who was a pupil of Lavoisier.

Writing more intimately to Walloth, a friend of his own age, he says:

> Behold in me a salutary metamorphosis! The lectures of Gay-Lussac and Thénard have transformed science from an old nag that one has only to saddle in order to ride into a horse with wings which is always trying to escape and which I am constantly trying to capture. I thought I worked in Darmstadt, but here my daily song extends from seven in the morning until midnight and I have pleasure in it. Paris is now much more agreeable to me. Days pass like hours at home . . . and I look sorrowfully forward to the time when I must leave it.

A little later, in a letter to his parents he tells how he has made an interesting discovery. An acid arises from the action of nitric acid on alcohol, and this acid unites with metal oxides to form the fulminates of mercury and of silver. He discovers similar salts of copper, iron and zinc which indicate the exact composition of the substance. The French have been puzzled by these things for a long time. His thesis has been written, Thénard and he review it together and then they walk to the Académie des Sciences. Since Thénard is president of the Académie, he is unable to read the paper, so Gay-Lussac reads it. Liebig brings with him the newly prepared salts and presents them before the Académie. In spite of the rather long thesis there are interruptions of applause. Gay-Lussac and Dulong append their signatures to the following memorandum incorporated in the minutes of the Académie: "Because of the new experiments described in this very remarkable piece of work, we entertain the highest hopes concerning the talents of the author."

After the reading Alexander von Humboldt, the celebrated traveler, who has just returned from Italy after long absence from Paris, a man about fifty-five years of age, approaches the young man and, without revealing his identity, talks with him for nearly an hour and then invites him to dine with him at a restaurant in the Palais Royal, where he tells him who he is.

[2] The author is especially indebted to his friend, Dr. Margaret B. Wilson, for the source of material contained in "Briefe von Justus Liebig nach neuen Funden," 1928, sold at the Liebig Museum at Giessen; and to Pettenkofer's well-known "Gedächtnissrede des Dr. Justus Freiherr von Liebig" (M. von Pettenkofer, "Populäre Vorträge," Braunschweig, 1876, No. III) delivered in 1874, a few months after Liebig's death.

The outcome of this adventure is that Alexander von Humboldt persuades Gay-Lussac to take Liebig into his laboratory where he can receive direct instruction from the greatest of living chemists. At that time Gay-Lussac refused to receive young men. But Humboldt knew from personal experience what it meant to work with Gay-Lussac; they had analyzed atmospheric air together in 1804. Liebig related to Pettenkofer that when Gay-Lussac and he discovered an especially beautiful fact or accomplished successfully an especially difficult analysis, they danced around a table together, the boy of twenty and the older boy of forty-five.

While residing in Paris Liebig received his doctorate degree in 1822 from the University of Erlangen because of two years of work under Kastner. The thesis was on the subject of the fulminate of silver. In it the errors of others were exposed and his own views were clearly expressed in a style of which he was to become a master.

At the close of Liebig's period of education in Paris, Alexander von Humboldt wrote concerning him to Liebig's patron, the Grand Duke Ludwig, as follows:

> We are fortunate in having with us in Paris one of your subjects, whose superior talents, whose vast knowledge of chemistry and whose sagacity of spirit have attracted the lively interest of the Institute of France. Dr. Liebig unites these qualities with gentleness of character and grace of manner, most unusual among scientists of his age. If my feeble voice carries any weight with your Royal Highness, I beg you to continue your special protection of Monsieur Liebig. He will become a professor who will honor our country, and I am positive that profound gratitude, which will also be shared by my colleagues in the Academy, Gay-Lussac, Thénard, Dulong and Vauquelin, will be extended toward a sovereign who will deign to honor one so especially talented.

Through the influence of this letter Liebig, at the age of twenty-one, was appointed professor of chemistry at the University of Giessen without consultation with any members of the faculty. His laboratory was first established in an old military barracks. It is needless to say that the young professor received very little support from his colleagues.

Writing to Schleiermacher to thank him for a small contribution from state funds toward fitting up living quarters above his laboratory, he says:

> The desire always to retain your regard and good-will prevented me from doing many things in Paris which would now disturb my peace of mind, and was a constant stimulus to try to understand and to investigate the branch of science which I had chosen as a calling. Besides this I have you to thank for the opportunity, on account of which I am fortunately able to make the knowledge then acquired live, and to make it useful for the Vaterland. I have to-day received renewed proof of your truly fatherly benevolence. . . . It makes me sad to think that I have not the skill to express my thanks otherwise than in words. Do not disdain these thanks which come from an agitated and honest heart. It will always be my earnest endeavor to preserve your satisfaction with me.

Liebig had a clear idea in mind, that he would personally instruct other young men in chemistry after the manner that Gay-Lussac had instructed him. He first gave his pupils ideas to work out, and then, when they could think for themselves, stimulated them to do so.

German biographers state that before Liebig the German professors generally adopted the attitude that they were not to unbend to the students and tell them their best thoughts. This was along the lines of Goethe when Mephistopheles says to Faust:

> Das Beste, was du wissen kannst,
> Darfst du den Buben doch nicht sagen.

Liebig reversed this and said, "All that I can do I will make the pupils learn also."

Students flocked to Giessen from Germany and then from all parts of the world, as many as twenty at a time being received. All the dialects of Germany and all foreign tongues were to be heard in the laboratory. Each student felt that he was living a life lofty in purpose, that he was serving science, that he was a pupil of Liebig!

The first part of Liebig's program was the establishment of accurate methods of analysis of organic compounds, methods in vogue to-day after a hundred years. He discovered the dibasic organic acids; he discovered chloral and named it; he made aldehyde from alcohol. He called it "aldehyde" because it was alcohol dehydrogenated. The name created laughter. He could have called it Gay-Lussacin without disturbing the then existing scientific world (Pettenkofer). Liebig, with his devoted friend Wöhler, discovered that benzol was just as constant in many different chemical compounds as arsenic was in the inorganic world. Berzelius was so happy over this that he suggested the name *Proin* for the new radical after a Greek word meaning "the dawn of day." Leibig's publications numbered two hundred on the most varied subjects. Their exceptional quality make the number astounding (Pettenkofer).

Liebig, who had been creating the science of organic chemistry, of which he was the supreme exponent, published in 1840 a volume entitled "Organic Chemistry, Its Application to Plant Physiology and to Agriculture," and then in 1842 appeared his celebrated "Animal Chemistry, or Organic Chemistry Applied to Physiology and Pathology." The wide sweep of his intellectual attainments led the way into such different fields as modern biological chemistry and the modern dye industry.

To read our daily newspapers one might conclude that the dye industry created organic chemistry. To believe that would lead to the conclusion that the steel industry created inorganic chemistry. Liebig himself has pointed out that such conceptions belong to the uneducated mind of the masses and that placing dyes on wool does not belong in the same category as the mastery of chemical research.

The growing world influence of Liebig stimulated one Samuel W. Johnson, the son of a Connecticut farmer. Young Johnson wrote his father in 1849:

> When I behold myself outstripped by others simply because they have the means, I am strongly tempted to repine at the partiality of fortune, but when I read of the achievements of Davy, Faraday, Klaproth, Liebig, Berzelius and a host of others who have elevated themselves from poverty to the highest stations and shed a halo of glory upon their own names and the age that has produced them by their zealous self-denying struggles after truth, how am I encouraged to tread cheerfully the path of science, though alone and exposed to the sneers of the vulgar and the ignorant. . . . Affectionately the same old sixpence, S. W. JOHNSON.

Johnson was then nineteen years old and was teaching school at Flushing, Long Island. Finally, after five years of testing the son, the father gave him in cash the equivalent of what he had given his other children in farm lands, animals, houses and barns. Thus Johnson was enabled to go abroad when he was twenty-three years old, to study with Liebig and to bring home with him those ideas which established first the Connecticut Agricultural Station and later its counterparts throughout the Union.

It is curious to record that in 1849, the same year that Johnson wrote so appealingly to his father, Liebig wrote that if the revolutionary tendencies of the time brought a blood bath at Giessen, they would go to America and found a German university there. These were the days which drove Carl Schurz and Abraham Jacobi to the United States.

Liebig believed with Lessing that talent consisted essentially of work and will power. The industry within his laboratory was prodigious. Liebig was a rare example of one who knew from boyhood what he wished to do. Addressing Thénard in 1841, he says he had had no other introduction to him in Paris except his love of study and his fixed desire to profit by his teachings. His associate, Pettenkofer, says that Liebig's power lay in the nature of his being, in attributes which no man can acquire but which are inborn. He had endurance, diligence and good methods. He had a sharp penetrating understanding coupled with a restless, active imagination (without being in the least a dreamer). These attributes were intimately and harmoniously blended. Mental concentration on concrete problems played the greatest part in the scientific achievements of his life. Liebig himself has told us that the quiet and the freedom from interruptions in the small town of Giessen enabled him to accomplish what it would have been impossible to do in a large city. However, his work at Giessen became so arduous, he tells us, that constant ill-health embittered his life. After his removal to Munich in 1853 his health improved, he could eat and sleep like other men, which had not been true for many years. He took no more students into his laboratory, and the glory of his life was in the past, in the twenty-eight years spent at Giessen. Others were carrying out his methods in a manner which made Germany supreme in chemical knowledge.

On his sixtieth birthday he makes a memorandum that his reception in Paris bordered on the miraculous. He says he has observed that when any one possesses a pronounced talent this awakens in all men an irresistible desire to contribute to its development. All help, as though they had counseled together to do so. But talent can be successful only when it is united with a definite constancy of purpose. Unfavorable external obstacles to the development of talent are small in comparison with those which lie in the man himself; for just as a natural force, be it ever so powerful, is ineffective in itself unless reacting with other forces, so a man who learns without trouble, one who has inherited definite intellectual gifts and preferences, can succeed only after he has learned a great many other things at the cost of greater effort than other people may have to make to acquire the same knowledge. For that reason he agrees with Lessing that talent is work and will.

A German biographer, quoting Shakespeare, says of him:

> His life was gentle; and the elements
> So mix'd in him, that Nature might stand up,
> And say to all the world, *This was a man!*

The story of Liebig's life carries its lesson to us to-day. American philanthropy is building great buildings for education, greater buildings than the world has ever seen. Those who visited this country last summer in connection with the XIII International Physiological Congress marveled at them and at their equipment and went home and wrote about it. We are building great comfortable homes for the students in our colleges; we are planning pent-house apartments for the internes in our hospitals. But who is concerned with the material welfare of the professor? The answer is, virtually no one. No pent-house apartments are thought of for him. And what are we doing to pick out the exceptional young man and develop him? To this question it may be stated

that the National Research Fellowships initiated by the Rockefeller Foundation on the advice of the former professor of experimental medicine at the University of Pennsylvania, Dr. Richard M. Pearce, have done a vast amount of good (written the day before Dr. Pearce's death). It is said that privately endowed universities can not undertake this task. However, we might also welcome a return to the older method of the personal touch of Alexander von Humboldt, which magnified Liebig's opportunities, of the personal interest in him of the Grand Duke, and of the "truly fatherly benevolence" of Schleiermacher. The supporting influence of these three enabled a brilliant young man to shed undying glory on his country.

For the most part this personal touch is lacking in this America of ours. Money is given, and that is thought to suffice. The money is devoured by buildings and then by the routine necessities of running them. But support should be given to the education of brilliant young men who will work, support which follows through to the end. Work is the surest criterion. If a young laboratory man, be he ever so brilliant, spends his time at his desk at best indulging in philosophic thought, it is wise to get rid of him entirely, perhaps through removal into another environment which incites him to work. It is easy enough to distinguish between the workers and the drones. It is easy enough to distinguish between brilliancy and stupidity. But there is very inadequate machinery to give exceptional education to the brilliant worker. Not only this, but one should also remember that the most highly gifted professors, unless they have private means, lead lives of self-inflicted poverty.

It was believed at Yale at the time of Liebig that chemistry, like virtue, should be its own reward.

At the present time we should be alert to the fact that our over-organized university machinery is not producing as many real scientific men of the highest intellectual caliber as our material resources, if not our national pride, justify. German universities have always been able to fall back upon state funds when aid is needed, because the universities there are considered to be a part of the glory of the state itself. This attitude is too little appreciated in our own country.

The modern furor about changes in the curriculum matters little. The most important fact is that the student, before he begins to think, must have something to think about. And this involves learning not only what he likes and what is easily acquired, but also, according to Liebig, a great deal that he does not like at the expense of his will power.

Carl Voit was a physiologist with a physician's training, and he was able to give more of a physiological interpretation to the problems of metabolism than was Liebig. Pettenkofer and Voit built the first respiration apparatus for the determination of metabolism in man. Voit determined the metabolism in human diabetes and in leukemia as early as 1866. He always taught that one case carefully examined gave more information than the statistical array of hundreds.

In our own country metabolism work has been carried on largely as an extension of the German background. F. G. Benedict, Boothby, DuBois and I have been greatly interested in the subject. Recently, Richardson, Loebel and Shorr have been using the Warburg apparatus for the determination of the metabolism of thin slices of living isolated tissue. Just as in the case of a man placed in the respiratory calorimeter, the respiratory quotients of the isolated tissue vary with the food provided in the surrounding medium. When glucose is added to the medium, the respiratory quotient and the intensity of oxidation both rise, thus manifesting the phenomenon of the specific dynamic action of burning carbohydrate just as it occurs in man.

Recently these same authors have been investigating the respiratory phenomena of the tubercle bacillus. DuBois said the other day that he could map out a ten-year program for work along these lines.

So it becomes apparent that each generation of workers approaches a clearer appreciation of the phenomena of metabolism. It is far from complete. It is only through joyous work that it will be carried on, through work so rewarding that it would make one feel like dancing around a table, just as Gay-Lussac and Liebig did. It will be finished only when a knowledge of life itself is complete.

Sir James Jeans, in his recent book, "The Universe around Us," says that if one takes the height of a large Egyptian obelisk as the measurement of the time since the birth of the earth out of the mass of the sun, then the life of man on the earth would be represented by a penny on the top of the obelisk, and the time during which man has been civilized, or 5,000 years, would be represented by the thickness of a postage stamp. He estimates man's probable future in terms of additional time to exceed the height of Mont Blanc put on top of the penny and adds:

> As inhabitants of the earth we are living at the very beginning of time. We have come into being at the fresh glory of the dawn and a day of almost unthinkable length stretches before us with unimaginable opportunities for accomplishment. Our descendants in far-off ages, looking down this long vista of time from the other end, will see our present age as the misty morning of the world's history. . . . By what light we have, we seem to discern that the main message . . . is one of hope to the race and of responsibility to the individual—of responsibility because we are drawing plans and laying foundations for a longer future than we can well imagine.