SCIENCE

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*THE POTENCY OF ENGINEERING SCHOOLS AND THEIR IMPERFECTIONS.**

IT is natural at a time like this to revert in thought to the teaching of engineering in the technological schools of the country, and to ponder on the influence which this teaching produces upon their pupils and upon the economic welfare of the land. I have assumed that some consideration of this question will interest my audience to-day. A discussion of the potency in the body politic of engineering education is particularly appropriate before the school of applied science located under the inspiring heights of your majestic mountains, which afford an unrivaled richness to him who attacks their depths with efforts properly directed by science. Applied science gives you the power of reaching your ore, hoisting, treating and finally smelting it —applied science, which has been taught

* Address delivered before the School of Applied Science of the University of Colorado on November 14, 1902 on the occasion of the celebration of the quarter centennial anniversary of the University.

here and elsewhere to the chemists and engineers of your rugged state.

I am the more ready to discuss this theme here, in the inspiring presence of your mountains and their bracing atmosphere, because you have laid the foundation for, and have the opportunity to build up, a school of applied science (an engineering school) that may stand unexcelled amongst its eastern brethren. True, you are far from the centers of dense population; but the hum of industry is about, and great works are yet to be accomplished before the wealth of your state reaches its highest development; and the engineering school numbering 500 students may be as great as the school that numbers 1,500.

In the building up of your school of applied science, in this, your university, your people must remember that men and money are required. Men who are practiced, and, if possible, great, in two professions—the professions of engineering and of teaching. Money is requisite to pay for the services of these men, and much money for the equipment of laboratories in which they may adequately teach their students—the sons of your state and of its neighbors. In following my remarks, please remember that I bear no mission of instruction to this university; but I make a plea and explanation to those not technically informed friends of the university who may not fully understand, and who desire to know, whence spring the peculiar advantages of technological education and those requirements which demand particularly large expenditures in its adequate support.

During the course of two decades, we as a people have rapidly advanced toward an appreciation of the proper relations of the engineer to his surroundings. The true conception of engineering may be accepted as comprised within the good old definition, 'Engineering is directing the sources of power' (and wealth) 'in nature to the use and convenience of man.' The man who with fullest success follows the profession defined by this keenly conceived sentence must be a man of science, a man of the world, a man of business, and a man who is well acquainted with the trend of human civilization and human aspirations. To make such a man requires the highest thought and effort of the best teaching influences. Michael Faraday (one of the magnificent men whose lives have been dedicated to the commands of pure science) said that it requires twenty years to make a man in physical science, the intervening period being one of infancy. How much more effort must be carefully expended to make a man not only in physical science, but also a man in business and a man in sociology, all in one! Such men are all of the great engineers, measured according to their times; and to them ought to be accorded in their youth the most careful training.

Our engineering college men at their graduation should properly be looked upon as apprentices in the engineering profession. The student must be inspired in college and taught to work for himself in the manner adopted by George Stephenson, when instructing his assistants and pupils. 'Learn for yourselves,' said he, 'think for yourselves, make yourselves masters of principles, persevere, be industrious, and there is then no fear of your success.' The students should be become *thinkers* in college, capable of usefully applying their scientific knowledge therein obtained; and they should be expected to become thorough engineers through experience in applying this knowledge in a manner which may only be gained in an apprenticeship in the industries, similar to the office and hospital apprenticeships of rising young lawyers and doctors.

The methods used at West Point and Annapolis in training officers for the army and navy, and the course of the graduates after leaving those academies, fairly illustrate my point. It is there held that "a man, to know how to teach another man to pull a stroke oar, must get on the stroke oar himself; to be safe as a quarter-deck officer, to give orders for reefing a topsail in a gale of wind, he must himself have reefed a topsail in a wind. To know how to tell a man to ease a weather sheet or to work the gear of any part of a ship, he must have had his practical experience on that same gear. He can not instruct his men properly, he can not command them safely and efficiently, unless he has been through three or four years of hard practical experience, hand in hand with the men in the forecastle. The same thing is true of engineering. No man is fitted to be superintendent (or manager) of a road or works, no man is capable of carrying on large engineering operations until he has had the practical experience which fits him to pass judgment upon what will be the result of the directions which he may give to others."

Four years is but a small part of Faraday's period required 'to make a man' in the physical sciences, and in so short a period (which is the duration of the engineering college course) only the foundations of the engineer (the *man* in science, business and sociology) can be laid. "There is a great difference between reading and study; or between the indolent reception of knowledge without labor, and that effort of mind which is always necessary in order to secure an important truth and make it fully our own," said Joseph Henry; and the engineering college course should be bent toward such a complete and true presentation of thorough science and truth that the student is incited permanently to secure it for himself and make it fully his own—and he may then put it to valuable use in future practice. "It is not enough to join learning and knowledge to the mind; it should be incorporated into it."

The engineering college graduate should be a fertile and an exact thinker, and a man of value upon his graduation; but he can not come to his highest fruition until years thereafter. The speaker would gladly be judged of the success of his teaching by the success attained by his students after years of practice in their profession, but let no judgment be passed (as is so often done in some colleges) upon the basis of wages received during the year after graduation. Our engineering college teaching may be properly condemned if it does not plant those methods of thought which will grow more valuable with the years, and, indeed, become most valuable only after the mature development of the individual.

The engineering course should not be too formal or limited to the expository methods used of old in instruction in classics. Professor Tait speaks the views of the scientist when he says: "It is better to have a rough climb (even cutting one's steps here and there) than to ascend the dreary monotony of a marble staircase or a well-made ladder. Royal roads to knowledge reach only the particular locality aimed at, and there are no views by the way. *It is not on them that pioneers are trained for the exploration of unknown regions.*" The truth of this proposition has been discovered of late years by even the most ardent classicists, and those of us who are called upon to teach men in every one of whom must be developed a certain spirit and power 'for the exploration of unknown regions'—we who meet this unique problem, untrammeled by traditions and strongly aided by the influence and examples of the old engineers, should most fully appreciate and adopt this precept of a great mathematician and philosopher.

To the engineering student in college the laboratory is of inestimable value. In it he can learn the true relations between science pure and science applied. He can learn to reason true, from cause to effect. His mind may be developed less trammeled than in the class-room, and the inspiration to independent thought may be more readily given deep root. 'Every branch of engineering is becoming more firmly rooted to the scientific bed rock upon which it rests,' and the engineer must be a man of scientific methods, besides being a man of business. He must have learned with the scientist that the price of success is constant, concentrated effort. All this can be taught better in the laboratory than in the class-room. A spirit of indifference which may be readily bred in the class-room, and which is ruinous to success and happiness in life, can not exist in the laboratory that is properly administered. "Genius is nine parts character. The prize is to him who dares, not merely to him who can." *In the laboratory the student may be inspired to dare.*

It must not be thought that I do not give adequate place to the class-room lecture and the text-book recitation. The laboratory work should be carried on in unison with and fortify the work of the class-room. A power may be had through it which can not be gained in the more formal meetings, and I would have at least one half of the time allotted by students to the study of applied science spent in properly supervised laboratories.

The subjects taught are not of so much importance as the effect to be gained in the students' powers, but certain branches lend themselves particularly to the desired end and admirable laboratory equipments in those branches are essential to every fully successful school of engineering. Here the budget of the university is affected. It requires large sums of money to equip, maintain and administer such teaching laboratories, and only few (very few) of the greater engineering schools have yet approached a satisfactory point therein. In this state of great mineral wealth, that has been, and is still more largely being, developed through the knowledge of the engineer, it is reasonable to hope that some public-spirited citizen of ample means will adequately endow the engineering laboratories of this, the university of his own state, so that they may take and hold due rank with the best.

But some of you may say, "What is the benefit to the body politic of the expensive laboratories in our midst? We admit the benefit to the students who personally enjoy their advantages, but is their effect more far reaching?" Most assuredly their effect *is* more far reaching—it reaches to the uttermost limits of the industrial progress and prosperity of the land. In this nation the industrial pursuits are engineering pursuits, and each betterment of clear perception amongst the engineers goes to strengthen the roots of our whole national life. He who truly ponders the question of modern civilization can not but admit that its best and kindest features rest immediately upon the foundations of scientific discovery and invention, and that the engineers and their works constitute the most mighty human force now moving society. Let us think of a few of the engineering feats of the century gone by:

George Stephenson, in 1829, after painfully developing the locomotive, won the Rainhill contest, and the preeminence of steam locomotion over draft animals was established before the world. Here was the christening of that civilization which rests upon the ready communication between the people.

Joseph Henry, engineer by nature and education, scientist of renown, perfected the electromagnet, adapted it for signalling purposes, and taught the world how to operate it at a distance. The fruits of this single application of electromagnetism, brought to commercial perfection through the efforts of the then derided Morse and the brilliant Graham Bell, have twice revolutionized the commerce of the world and incalculably advanced its civilization.

Through the brilliant and daring Ericsson, one of those mighty acts of Providence that sometimes occur in the guise of miracles was wrought in Hampton Roads for the preservation of independence and liberty amongst the race.

These examples from the last century are sufficient to serve my purpose of illustration. The progress of the new century bids fair to magnificently exceed the past.

The engineers of the world may be thought of in connection with three classes:

The scientific followers after principles and inventions.

The plodding constructors and originators of structures.

The engineering plungers and promoters.

The first are to-day by far the greatest, and their preeminence grows with each application of new discoveries to the use and convenience of man. But we must not fail to give proper honor to the faithful workers of the second class, who founded the profession and are yet its mainstay; or to lend due admiration to the brilliancy and daring of the third class.

In the first class are found such names as Rankine, Lord Kelvin, Werner Siemens, John Hopkinson and Joseph Henry, to whom I have referred. In the second class stand Telford, Stephenson, Gramme, Corliss and many others of renown; while James Watt stands as a link between them and the first. The third class lists such men as the admiration-compelling Ericsson, Bessemer, Holly and Morse.

These men, who have so largely contributed their part of blood to the living strength of the industries, whom I have selected to represent the past in engineering, are giants in beneficent influence upon the growth of civilization and the development of the wealth of the world. Their lives will be felt until the name of the nineteenth century is blotted from the memory of man. Each has played his part. The industry-promoting Bessemers more immediately increase the wealth of the world; the steady Telfords and Stephensons contribute much to its permanent comfort and convenience; but the scientific discoverers of principles and engineering inventions appear to lend the most far-reaching influence to the world and its civilization. Let us see what foundation of knowledge now exists upon which such men may base their work.

With all the effort of the centuries since the days of Gilbert and of Bacon, when the validity of experimentally proving natural laws was firmly established, we have really advanced but little towards the heart of nature's secrets. The material progress of the world depends largely upon improvements in our methods of utilizing what we now think of as three factors:

1. The properties of material matter.
2. The characteristics of energy.
3. The characteristics of intellect as found in organic life.

We are yet profoundly ignorant of the ultimate character of either matter, energy or life. Experiments seem to indicate that we may find the clue to the mystery of the first two, but it is yet impossible to assert whether, in our present state, we may reach an entire understanding of their true character. Experimental investigations often become increasingly difficult as we approach the goal of ultimate truth, and the final attempt to press into the citadel of a cardinal truth may cost more effort than all of the approach through the outer works.

However, we have gained a store of knowledge about materials, energy and organic life, and have organized it in such a way that it seems to point to a few great, generalized facts. We apparently have learned that nature is never idle, but that she is a persistent worker with a steady, cumulative activity in which there is ever a unity and no discontinuity; that there is an ever-present 'dovetailedness' as Dickens, I think, put it. Nature's activities are not isolated and independent of each other, but are apparently all in intimate relation, and governed by the same all-pervading fundamental laws. This is the foundation on which the engineers of the present century have to work. Meager as it is, it is far in advance of that occupied by their predecessors of one century ago.

Of fundamental laws we seem to have proved two—the law of the conservation of energy, as it is called, and the law of organic evolution, which controls the development of life through the 'survival of the fittest.' I spoke of these as proved, and so they have been as far as they relate to the problems of our daily life; but they have been rather deduced by inference, as far as the universe at large is concerned, than established by demonstrations. The law of evolution has been so widely discussed in type and speech, that I may assume on the part of each of you some knowledge of its doctrine, and I will at once pass on.

The law of conservation of energy asserts that energy can not be created nor destroyed. We may transform energy in any manner within the compass of our intellect, but we finish with the same amount of energy as we started with. We may transform the chemical energy of coal, by combustion in a boiler furnace, into heat energy, and this may be utilized to 'raise steam.' The energy in the steam may be transformed into mechanical energy by means of a steam-engine, and this into electrical energy by a dynamo. The electrical energy will be less than the original chemical energy because some of the heat has gone to contribute warmth to the surrounding air and solid bodies, but the available electrical energy added to all of this heat (which has not been destroyed, mind you, but continues to exist as heat) *makes a sum which exactly equals the original chemical energy in the coal.*

Another fundamental law has been ordinarily accepted as governing; this relates to matter. You all know that matter is apparently indestructible. Transform it as we may; change, by combination, the matter which we call hydrogen and that which we call oxygen into that which we call water; again, combine this with metallic sodium to form caustic soda; again, form other combinations or compounds—through them all we have apparently transformed matter without gain or loss, and hold the same mass at the end of our transformations as we held at the beginning. The chemists have been making a very thorough study of this idea for years past, and they do not seem convinced that it represents a universally applicable law; but for all present purposes of the engineer it may be safely accepted.

In accordance with these laws relating to matter, energy and life, and their myriad corollaries, the professional engineer must carry on his work through the discovery of scientific principles and their useful combinations. Invention is no longer a mere question of designing a working machine. That may now be safely left to the skilled mechanic; while the engineering inventor must discover new combinations of scientific principles and give them applications that are useful to man, in order that they may more perfectly contribute to the support of the race. Men must be educated for this purpose in our schools of applied science. This education can not be efficiently gained without the help of the schools.

Again, new principles must be discovered and great laws deduced, and contributions must be levied from them for the support and advancement of the race. It has long and justly been regarded a signal achievement to discover an important phenomenon or principle in science, and the discoverer has been stamped a learned and great man. It is still a signal achievement to discover, but the discoverer may add luster to his fame in our time by directing the application of his discovery to the service of mankind, so that no undue delay may be suffered to occur before it too contributes to the welfare of civilization. These men also may be most effectively educated in our schools of applied science.

The motive force of progress and civilization at the opening of the twentieth century is infinitely greater than at the opening of the nineteenth; largely due to discoveries and the world's slight education in science; and the possibilities following great discoveries are equally increased. Carrying this education of the people in applied science to its farthest limit must accentuate the progress, bringing with it those trains of good that follow in the wake of broader intelligence and wider opportunities. Every industry, every line of transportation or system of intercommunication, every branch of useful endeavor, has profited by the growth of scientific teaching and the work of the engineering schools; and civilization, which spreads, fattens and grows great through transportation and intercommunication between peoples, has been the gainer. Manifestly the influence of the schools of applied science is vastly greater than the effect directly produced on their individual students.

Consider the growth of our own people! The nineteenth century opened while the meridian crossing the center of our population bathed half its length in the Atlantic Ocean. Now it approaches its baptism in the Mississippi. The opening of our fertile domains, of which this tells the tale, is a story of transportation and intercommunication—the steam railroad and the electromagnetic telegraph, applied science allied with vigilant energy.

Much was formerly preached of a discord between theory and practice in engineering, and the old specter has not yet been laid for some. But no such discord ever existed except in the minds of the unlearned who failed to see that it was the finger of truth which washed away their rule of thumb; and with even them it existed only as the suspicion arising, as Bacon says, 'of little knowledge.' Even this phantom was laid in 1855 through an admirable address by the learned engineer, Professor Rankine, whose discoveries added much to engineering practice, and whose early death was so deeply mourned. After tracing the development of meager scientific knowledge and mechanical practice amongst the ancients, Professor Rankine makes the following observations:

"As a systematically avowed doctrine, there can be no doubt that the fallacy of a discrepancy between rational and practical mechanics came long ago to an end; and that every well-informed and sane man, expressing a deliberate opinion upon the mutual relations of those two branches of science, would at once admit that they agree in their principles, and assist each other's progress, and that such distinction as exists between them arises from the difference of the *purposes* to which the same body of principles is applied.

"If this doctrine had as strong influence," continues Rankine, "over the actions of men as it now has over their reasonings, it would have been unnecessary for me to describe so fully as I have done the great scientific fallacy of the ancients. I might, in fact, have passed it over in silence, as dead and forgotten; but, unfortunately, that discrepancy between theory and practice, which in sound physical and mechanical science is a delusion, has a real existence in the mind of men; and that fallacy, though rejected by their judgments, continues to exert an influence over their acts. Therefore it is that I have endeavored to trace the prejudice and practice, especially in mechanics, to its origin; *and to show that it is the ghost of a defunct fallacy of the ancient Greeks and of the mediæval schoolmen.*"

Enough has been said to illustrate my point. The influence of schools of applied science is vast and far-reaching, and every dollar spent in the establishment and maintenance of well-considered schools not only returns abundantly to the states in which the schools are centered, but their usefulness may extend to the nation and the world at large. Patriotism now needs no better object than the founding of such schools.

We may now justly turn to enquire into the character of the education for the individual that may be derived from such schools. Herbert Spencer names in a sentence the true criterion by which to judge of the adequacy of an educational process, and I can not refrain from a quotation: "To prepare us for complete living," says he, "is the function which education has to discharge; and the only rational mode of judging of any educational course is to judge in what degree it discharges such function."

Here arises the query, What is complete living? Spencer answers this, but we may each likewise answer for himself out of his personal consciousness and experience: An education for complete living includes training the faculties of self-preservation, the faculties of self-support, the faculties of proper parentage, the faculties of proper citizenship, including the betterment of our political and social relations, the faculties of properly enjoying one's leisure and lending enjoyment to others. Education, to use the words of Huxley, 'ought to be directed to the making of men,' and must include 'things and their forces, but (also) men and their ways.' We can not, we must not, cultivate one to the exclusion of the other.

The study of science and its applications, in the atmosphere of our better engineering schools, certainly lends largely to each of the faculties and powers which are required for complete living. It has been asserted that it lends more immediately to the earlier and less disinterested ones; but this assertion I must deny. The profession of the engineer demands a creative imagination cultivated to the sober, clear sight which sees things as they are; and a quick appreciation of the effect of sentences and their combinations; which make him akin to the creators of art and literature, and give him in large degree the more disinterested faculties named. I am willing to yield to no one in an appreciation of art, literature and music as an element of the highest importance in the education which goes to relieve the strain of an over-arduous professional existence and to smooth the relations between fellow men; and I can not but regret that these liberal branches must be omitted from the curricula of the engineering schools. But I also can not fail to remember that an education in applied science brings keenness of perception, and recognition of truth and beauty, to its average followers, from which springs an appreciation of art and literature and music which rivals that produced in the most gifted product of the literary colleges. "With wisdom and uprightness a nation can make its way worthily, and beauty will follow in the footsteps of the two, even if she be not specially invited."

Of all the intellectual faculties which we cultivate through education, the most useful is the faculty of sound and mature judgment; and of all, this is the one most often deficient. Here the laboratories of applied science are strong in their influence for good. That man who follows the laboratory courses in one of our well-administered engineering colleges and goes forth without improvement in his faculty of judgment and a quickening of his executive powers is an unworthy son of man. The force of straight thinking can not be over-estimated. 'Victory is for the people who see things as they are without illusion, who do not take phrases for facts,' and straight thinking is one of the gifts derived from the engineering laboratories. The engineer's duties require that he shall possess this most important of mental attributes; and fortunate it is for the profession, for it makes of every great engineer a man of greatness. Do you question this statement? If you but enquire of the past you will find it proved. Amongst no class of men is found a broader sympathy with humanity and a more liberal view of the progress of the race than is exampled in the lives and works of the great engineers, and none have been better or nobler citizens.

Yet, withal, it must be a matter of concern in the technological schools lest the lines be drawn too close, and the students become absorbed in an ungenerous, over-earnest pursuit of details. Breadth of view may be sacrificed unless our teachers be men of ripeness and power, and the students learn through them that each element in the life of the 'complete liver' has of itself an intrinsic merit. This fear of a belittled outlook for some of our students, whose ambitions or mental aspirations may have never been stirred in their pre-college days, would be dissipated could the personality of each teacher in the schools of applied science include that rare combination of mellow scholarship, clear scientific perceptions and engineering common sense which we occasionally meet and which a few colleges rejoice to retain in their midst.

The teaching force of an engineering school should ideally be made up of engineers—men who have seen some years of successful practice (and preferably continue to hold some practice), who are held in esteem for such by their brethren in practice; but who have a joy in the quiet life of the scholar which is traditionally associated with the colleges, and who may thus be contented when outside of the immediate tide of engineering production. Yet the teaching of engineering is a question of pedagogy rather than of the engineering profession, and it must be dealt with with this clearly in view. Here is one source of many profound imperfections in our existing schools. I venture to say that it is the exception rather than the rule when a teacher in a school of applied science has given any consideration to the tenets of psychology and pedagogy, upon the due application of which depends much of his success in properly impressing his students. These teachers are doubtless no greater offenders than their brethren in the so-called colleges of liberal arts, but in this is found no palliation for the offense. Fortunately, a goodly proportion of the older ones amongst the devoted men who are contributing their blood and brains to the welfare of the engineering schools are often endowed with a natural sense of fitness in the processes of education, and the younger gain due appreciation of methods from association with them. Yet I must regret to say that proposals relating to the curricula of the technological schools are frequently offered, which unpardonably violate every tenet of good teaching.

This condition ought not to exist, and it can not continue after the truth has seized hold: that these schools are facing a teacher's problem, which must, indeed, be met by engineers with all of the directness and power of the engineer's best efforts—but that the problem can not be solved as one solely relating to the engineering profession.

It is sometimes thought that men who can not make a success in business life are just right for teaching. This is entirely wrong, and the idea should not be admitted for a moment in any modern technological school. The discontented man who has made a failure in business life will certainly make a failure in teaching engineering. Engineering colleges should avoid 'men who are fools in working,' even though they are 'philosophers in speaking.' Enthusiastic men are wanted; they may be young men, if needs be, but they must be paid well enough so that they may take places as self-respecting members of the engineering profession, and they must be properly chosen with respect to their qualifications. These men must be good professional engineers; they must possess power and satisfaction gained from engineering research, and from attainments in other lines than those of purely professional acquirement; but sound teaching is their work of first importance. It is very difficult to teach well, but that is no excuse for admitting poor teaching into the engineering schools.

The problem in the engineering colleges is rendered more complex by the character of the curricula, which require that the students shall follow for a period what may be denominated preparatory science instruction before they enter upon the truly professional work. In the latter, at least, the teaching should be largely by inspiration and suggestion.

The process of gathering, organizing and assimilating knowledge by each student should, as Spencer suggests, be as far as possible a process of self-evolution. If a professional student will not follow his work with zest and satisfaction, it is a thankless and doubtful task to force him to it. The best method for the teacher in professional subjects (but the method of all methods difficult to follow without abuse) is indicated in Kipling's verse:

> "For they taught us common sense,—
> Tried to teach us common sense—
> Truth, and God's Own Common Sense
> Which is more than knowledge.
> * * * * * *
> "This we learned from famous men
> Knowing not we learned."

The engineering colleges are at fault in not more fully developing the initiative, the enterprise and the executive powers of their students, though this is a difficult part of the task of 'making a man.' But that thing must be done in order to make successful industrial engineers. It can be done largely by influence, by the character of the treatment of the students, and by the sort of ambitions that are put into them. It can be done in some degree by the selection of the work assigned to the curriculum, but the subjects studied are of less importance than that the students learn,

> "Truth, and God's Own Common Sense."

The teacher must remember when he tries to teach by inspiration, even though his time and method be wisely chosen, that he may expect to receive in the class-room some hard blows to his self-regard and his esteem for his teaching. He may pour stimulating thoughts over his students day after day for weeks, and finally find that few have taken root. He may even be brought to that state of desperate depression that is illustrated in one of Turgeniev's novels when its hero, Dmitri Rudin, failed to succeed in his post at the university. The engineering teacher—provided he is sure of his time and method—may take heart by remembering this: that if every stimulating thought presented to his students, whether relating to professional applications of theoretical principles or directly to the development of initiative, self-reliance and executive powers—if every stimulating thought took root in every student's mind, those minds would become over-burdened cyclone centers of thought; and if one real thought takes root from time to time in each student's mind the teacher may be truly satisfied.

I have already suggested that the question of professional instruction in the engineering schools is entangled with the problem of leading the students through a course of preparatory science looking towards the professional studies. The medical schools may and largely do escape this responsibility by requiring their students to pursue a liberal college course before embracing the professional courses. The existing plan of the medical schools is ill-advised when viewed from the engineer's standpoint, but we hope that some inviting plan may yet result from the proposals made by several great university presidents in respect to coordinating the liberal and professional college courses. We would gladly welcome the old-time college course and the old-time preparatory course, especially as far as they made men of vigorous thought who could spell and cipher; and we now gladly receive and encourage all students who have been willing and able to complete an academic college course before entering upon their technological studies.

Broadly, however, until there arises such an advantageous plan of coordination which may be adopted with advantage to our students and to the profession, the engineering schools will continue, as heretofore, to instruct their students for four years immediately following the high-school course—the first two years being largely filled with mathematics, chemistry, modern languages, drawing and other subjects leading to the professional studies of the engineer. These students come freely to the college at an age between seventeen and twenty, equally immature in mind and body—and one part must not be trained at the sacrifice of the other. "It is not sufficient to make his mind strong; his muscles must also be strengthened; the mind is over-borne if it be not seconded."

Montaigne puts it very gracefully: "It is not a mind, it is not a body which we erect, but it is a man, and we must not make two parts of him." A prime requisite to success in life 'is to be a good animal,' and the engineering schools must look after the bodily and social welfare of these entering students in a way that is not required of the medical school with its course largely recruited from the liberal college. These students should be encouraged to enter into the various interests of the life around them, especially of the college life, including its social affairs and its athletics and gymnastics. The extra responsibility which thus rests upon the teacher in the engineering schools equally increases the effect of the influence with which his personality affects his students. The latter is a recompense that every lover of teaching will willingly make sacrifices to obtain.

My discussion of my subject has been brief, though, perhaps, as long as your desire. I have tried to show you that the wide influence of the engineering schools is of two branches: First, a direct effect exerted through the graduates extending the useful applications of science to the advantage of man (which is the effort of every true engineer); second, an indirect (but equally important) effect resulting from the admirable education disseminated amongst the people. And I have pointed out not only elements of great educational strength, but also some sources of weakness in the schools. It has been my particular wish to bring to your mind some image of the potent influence for good which has been in the past, and still more may be in the future, borne on the body politic by these schools, and to impress you with the desirability of bringing to their support the same bountiful endowments that are now justly flowing to the support of the medical schools. I trust that I may have interested you and that I may have reached, in some degree at least, my object.

In the course of my remarks I have had frequent occasion to use the phrase 'applied science.' You must not mistake me. Applied science is not something set off by itself and differing from 'pure science,' so-called. Far from it. It is pure science, if you wish, pursued in the stimulating, nutrient atmosphere bred of the belief that all scientific knowledge returns to its possessor great good in proportion to the advantages which he, through it, brings to mankind. Such an atmosphere is to be found in many of our medical schools and, I hope, equally in our engineering schools.

DUGALD C. JACKSON.

UNIVERSITY OF WISCONSIN.

*STAMENS AND PISTILS ARE SEXUAL ORGANS.**

THE statement in the above title will be received by some of my hearers with wonder that so obvious a matter should need any discussion, while by others, especially those versed in the modern morphology, it will be met by emphatic dissent. Yet I am convinced of its truth, and venture here to rise in its defense.

The discussion of the subject is not new. Professor L. H. Bailey, in SCIENCE for June 5, 1896 (reprinted in his 'Survival of the Unlike,' page 67), defended, with his usual clearness and vigor, the application of the sex-terminology to stamens and pistils; and he was answered in the same journal for June 26 by Professor Barnes, who maintained the strictly morphological view that the sex-terminology should be restricted to the gametophytes, or so-called sexual generations, within the pollen grain and the embryo sac of the ovule. Recently this morphological view has again been emphasized by Professor Ramaley, in SCIENCE for June 20, 1902, and he puts the case in its extreme logical form when he says: "The stamens, therefore, can not be male organs, nor the carpels female organs. * * * There are no such things as male and female flowers, nor flowers which are unisexual or hermaphrodite." This view I hold to be an error, for the reasons which follow.

To prevent misunderstanding it should be said at the outset that there is no difference of opinion as to the morphological facts involved. We all agree that the contents of the embryo sac when it is ready for fertilization, and of the pollen grain when in the corresponding condition, are the gametophytes, the precise morphological equivalents of the prothallus or sexual

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