

## THE HARDEST THING IN THE WORLD\*

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The hardest work in the world is work that demands an incessant exercise of will power. A band of sailors on a sinking ship may be killed by the labor of pumping, but, in the sense in which I wish to speak of hard work, it is not hard work to pump a sinking ship; nor is it hard work to plow and sow and reap when the alternative is starvation. But to carry on in a course of severe training in a school of science when everything in a superficially easy world invites you to dally, that is hard work, and the only way to make it easier is, as it were, to make it harder.

Our intuition easily bridges the months that intervene between plowing and harvest so that to plow or to starve is as clear to us as a dilemma as to pump or to drown is to the unfortunate band of sailors; but our intuition does not as yet bridge the gap between study and the consequences of study so that the student of science should, above all things, be thankful for the exacting demands of his school, which, though seemingly hard, make his life work much easier.

The sailors will drown if they do not pump, the farmer will starve if he does not plow, and our young men, what will happen to them if they do not study? Fortunately this question has a wide variety of answers for different individuals, but, in general, the choice is to study or to deteriorate, and I, for one, would rather that young men should die than deteriorate in this strangely misleading world of ours.

Everyone knows that young men have a zest for almost any kind of ordeal or test, and everyone who has

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† Dr. Franklin's paper was afterward published in a modified form in his book "General Physics" by Franklin and Grantham, published by Franklin and Charles, Lancaster, Pa.



had experience in dealing with parents knows that many of them are loth to place exactions on their sons. They abhor every kind of test or trial of youth and they multiply youthful indulgences beyond the old-time dreams of paradise. It might be well for us to go back to the terrible ordeals of the Wild Indian. "What? My son to swing on rawhide thongs sewed through the muscles of his breast and back?" asks your smug Joy-rider. Yes, you mere pretense of an aristocrat, yours! You think to place your son unprepared and untried, do you? And the wonder of it is that you can so place him; but his life will be a tragedy if he cannot stick.

Most of my life has been spent as a teacher in a technical school, and teaching is great fun in spite of, or, I should say, in all honesty, partly because of, delinquent students and their softened fathers and tearful mothers. From their point of view, technical education certainly should be ameliorated. How often have I faced a real condition with a young man only to have him and his fond parents take the ground that a favor on my part would alter or even greatly mitigate the stern facts of the case. A sense of humor, alone, is sufficient to fortify a teacher in such a position, but, alas, much more than a sense of humor is needed to keep a teacher sane in face of the widespread abhorrence among civilized men for every kind of ordeal, or test, or trial of youth. No one would wish to go back to the practice of savages in dealing with young men, but the point of view of the softies is hopeless.

Everyone who has had to do with the training of young men in pure and applied science knows that the training involves many exactions and a great deal of severe constraint, and there is, of course, some real distress among our students, a distress that is by no means confined to delinquent students and their over-indulgent parents.

Most of this distress comes from the curtailment of normal instinctive activities which is inevitable when the energies of young men are largely devoted to serious



study. Always we must expect to find a degree of restlessness and a trend towards melancholy among husky young men who cannot hunt, and fish, and play, and make love all of the time; and we must expect moral dangers to come with the almost complete breaking away from old modes of life. What a rich field in which to make use of literature and poetry—and sport! for the fine arts and sports *are* useful because they alone can keep us moderns from reverting to something worse than savagery.

Ernst ist das Leben, heiter ist die Kunst.

The older form of this saying is that "life is short, short and somewhat empty, whereas art is long," but Goethe would have us understand that life is at its worst only serious and trying, whereas art is a flowing river of comfort and good cheer.

A very small part of the distress among our students comes from the fact that a few of them are not adapted to mathematical studies. More than fifty percent of those who enter our technical schools drop out before graduation, and if this high mortality were due to essential non-adaptability it would be a serious thing, but in the great majority of cases it is perversity, not mental deficiency, that is the cause of the mortality. But we should not use the word "mortality" in this connection, for many young men have been killed by being kept in college, and no young man has ever yet been killed by being kicked out. Nor should one speak of "perversity," for it is the God-given privilege of young men to go their own way. No, we should not speak of perversity but merely of unwillingness to study. Even so it is life itself that should draw up the indictment, not one who knows the pain of those who really learn and the grief of those who are not wise.

Consider the wonderful capacity of the Wild Indian for long continued and strenuous effort in hunting and raiding. Surely the Indian is not as lazy as he appears to be in his Agency Home on a Reservation! And everyone knows that our young men are not stupid, although



it is as difficult to persuade our young men to study as it is to persuade Agency Indians to plow, and for exactly the same reason. Studying, and especially the studying of science, is as new to us as plowing is to Indians. The great-grandfathers of most of us could not even read and write, and it is absurd to expect college boys to study because they like to study or because they have an instinctive appreciation of the necessity of studying. No, carrying on in college must depend mainly on the will-to-study based on a conviction of its necessity, and this conviction must come from the friendly counsel of older men and be reenforced by a sustained demand on the part of the college. We are not concerned here with Newtons and Pasteurs and Einsteins. The emergence of such men from a hunting and fishing and farming ancestry is a thing no one pretends to understand, and it is even doubtful if "carrying on in college" has much to do with their emergence.

But, people ask, is study, especially the study of science, a necessity? Certainly not, if there is any alternative; and, of course, there is an alternative. Imagine a never-to-be-escaped human need of a twenty-foot arm. What age-long development and what infinite pains of birth! It is easier to build a steam shovel. This no one will deny, and it means that mankind is now bent decidedly, for better or for worse, towards what is called social inheritance as opposed to organic inheritance; but social inheritance has its pains, also, as many know who burn the midnight oil:

Woe to those who are young.  
(Weh denen die Enkeln sind.—Goethe.)

It is a common belief that youth means carefree joy, but this blissful state is for childhood only. The divine quality of youth is not freedom from care but enthusiasm, and as enthusiasm has in the past led young men to the terrible sacrifices of war, so enthusiasm alone can lead young men to accept the increasing burdens of preparation and training which civilization demands. Woe to those who are young!



How shocking to substitute a materialistic appreciation of steam shovels for a tender-minded love of science for its own sake and to look upon study as a dire necessity rather than a pure delight. But study is a distressing thing to most young men. Let us face the fact, for nothing but facts can help us in our dealings with young men. You can fool all of the people part of the time and part of the people all of the time, so it is said; but not young men, they never can be fooled at all.

And many people ask, is an exacting constraint really necessary in the teaching of physical science? It certainly is, constraint and not a little coercion, and it would be a great boon to education if some understanding of this fact could be given to all men. Everyone feels the constraint of the physical necessities of the world in which we live, and, although in one way this constraint is more and more relieved by the advancement of science, in another way it grows ever more and more exacting. It is indeed easier to cross the Atlantic Ocean now than it was in Lief Ericson's time, but consider the Discipline of the Shop and above all consider the Rules of Machine Design! Even the hardy Norsemen never knew anything as uncompromisingly exacting as these.

Every person with whom I have ever talked, old or young, theorist or practitioner, student-in-general or specialist in whatever line, everyone, I say, has exhibited more or less distinctly an attitude of impatience towards the exactions of the precise modes of thought of the mathematical sciences.

There, alas, the spirit is constrained  
And laced in Spanish corselets.  
(Da wird der Geist euch wohl dressiert,  
In spanische Stieffeln eingeschueurt.—Goethe.)

It is no wonder that easy-going believers in liberal education have always looked with horror on the sciences, as softened men and women look upon work. Liberalism means freedom, and liberalism in education has been defined as "the freedom of development in each individual of that character and personality which is his



true nature." This I accept in the spirit of optimism, believing men's true natures to be good; but there is a phase of education which has little to do directly and a very great deal to do indirectly with character, and I call attention to this conception of liberalism in education as an incomplete conception which to a great extent excludes the sciences. There is a condition in education which is the opposite of freedom, for the teaching of the physical sciences is a mode of constraint and a constructive discipline without which no freedom is possible in our dealings with physical conditions and things. *The study of elementary physical science is a reorganization of the workaday mind of a young man, a reorganization as complete as the pupation of an insect, and an exacting constraint is the essential condition of this reorganization.* As complete as the pupation of an insect! The body of a caterpillar is dissolved into formless pulp, and the body structure of the butterfly develops anew from a central nucleus very much as a chicken develops in an egg. Few, if any, of the body organs of the caterpillar carry over into the butterfly.

There is a kind of salamander, the axolotl, which lives a tadpole-like youth and never changes to the adult form unless a stress of dry weather annihilates his watery world. Ordinarily he lives always and reproduces his kind as a tadpole, and a very funny looking tadpole he is, with his lungs trailing as feathery tassels from the sides of his head; but when the aquatic home of the axolotl dries up he quickly develops a pair of internal lungs, lops off his tassels, and embarks on a new mode of life on land.

Something similar to the change that overturns the world of the axolotl seems lately to have come upon the world of men, for our modern age of science and organized industry is like a stupendous drouth in its effect on the fine arts and on all the fine old ways of living. Millions of men do, however, continue to live as tadpoles, and those who develop beyond the tadpole stage must meet the great stress of dryness with a quick and respon-



sive inward growth. The study of science is indeed an "inward growth" or what we may call "making up one's mind" in the sense of adjusting one's mind to a new order. It is the formulation and burning-in of precise ideas and exact definitions, the development of mathematical method, and the building up of elaborate points of view.

Nothing is so essential in the physical sciences as precise ideas, because nothing else so effectively opens the mind for the perception even of the simplest things and nothing else serves so effectively to hold things in mind. The necessity of precise ideas; herein lies the impossibility of compromise, the necessity of constraint. One *must*\* think so and so, there is no other way. And yet there is always a conflict in the mind even of the most willing student because of the narrowing influence which precise ideas exercise over our vivid and primitively adequate sense of physical things. This conflict is perennial, and it is by no means a one-sided conflict between mere crudity and refinement, because refinement ignores many things. Precise ideas not only *form* our sense of the world in which we live, but they *inhibit* sense as well, and their complete and unchallenged rule would indeed be a stress of dryness.

All theory, my friend, is somber, gray!  
And only the tree of life is green.  
(Grau, theurer Freund, ist alle Theorie,  
Und grün des Lebens goldener Baum.—Goethe.)

What is physical science? Surely we must have in mind some kind of an answer to this question if we are to understand why the study of physical science is important and why it cannot be made easy; but a formal definition would be utterly useless, it is very much better for our purpose to note two extremely remarkable things concerning physical science.

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\*It is to be remembered that we are speaking of physical science. How ridiculous it would be to say to a young Shakespeare You must think so and so; there is no other way!



(a) The first of these things is that we have learned to place highly complex and wonderfully penetrating interpretations upon the almost unthinkable meager data which we obtain directly through our senses, interpretations which are far beyond the range of the native intelligence of the most gifted men. An astronomer, for example, *looks at a speck of light* as it crosses the field of his telescope and he *listens to and counts the beats of a clock*, noting the time of day when the speck of light crosses the center of the field. He then *looks at and counts the lines on a finely divided circle*, noting the angular distance of the speck of light above his horizon. All this he does three times in succession because he is mindful of a complicated set of equations which contain six unknown qualities (counting the beats of a clock three times and counting the finely engraved lines three times gives him six numbers\*). Then, proceeding to interpret his data, he calculates when the speck of light (a comet) will be nearest the sun, how far it will then be from the sun, how fast it will be moving, and when it will return, perhaps a hundred years hence. This kind of forced interpretation is the usual thing in physics and in chemistry, and to the uninitiated the experimental data seem to be absurdly meaningless and inadequate.

(b) The second of these things is that we have learned how to exercise over physical things a kind of rational control which very greatly transcends the cunning of the most skillful mind. A generation or two ago most useful things and most of our control over nature depended solely on manual skill, but a modern steamship or a Bell Telephone System is produced and operated chiefly by rational planning. Manual skill is, as it always has been, vitally important in the plastic arts and in music, and laboratory research now goes far beyond old-time manufacturing in its demand for manual skill; but what does manual skill have to do with the running of a

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\* Eddington has semi-humorously called physical science a "schedule of pointer readings." See Chapter XII of *The Nature of the Physical World*. A. S. Eddington, Cambridge University Press, 1928.



phonograph or with the operation of a radio receiver? We seldom think of manual skill in connection with modern things.

Francis Bacon long ago listed, in his quaint way, the things which seemed to him to be most needful for the advancement of human knowledge or power, and, among other things, he mentioned "A New Engine, a help to the mind as tools are a help to the hand." Unquestionably the most important aspect of modern physical science is the aspect in which it constitutes a realization of Bacon's idea. Physical science does certainly constitute a New Engine which helps the mind as tools help the hand, and it is this New Engine which is responsible for all *forced interpretation* and all *rational control*.

This New Engine is in part a mechanical structure. Consider, for example, the carefully planned and elaborate arrangement of apparatus which is set up and used in every experimental study in the laboratory and in every kind of engineering test. Experimental data, or pointer readings, which are as meager as the astronomer's data, take on meaning and bear a complex interpretation because of this arrangement of apparatus. Or consider the carefully planned series of operations of solution, reaction, filtering, drying, and weighing which are always carried out in chemical studies and tests. The experimental data of the chemist are as meager as the astronomer's data and they take on meaning and bear a complex interpretation because of the carefully planned and executed operations, and a group of operations is essentially a mechanical structure.

The New Engine is also in part a logical structure, that is to say, a closely reasoned body of mathematical and conceptual theory.

These two structures, the mechanical and the logical structures of physical science, do indeed constitute a New Engine, and the teaching of physical science is the incessant rebuilding of this New Engine: (a) by developing the logical structure in the minds of young men,



(b) by training young men in the use of instruments and in the performance of ordered operations, and (c) by exercising young men in the application of these things to the phenomena of physics and chemistry at every step and all the time, with every possible variation.

That is, of course, an exacting program, but the only alternative is to place young men under Jules Verne where they never will be called upon to DO anything. There young men need not be troubled by exactions, for they can follow their teacher pleasantly on a care-free trip to the moon, or, with easy improvidence, embark on a voyage of twenty thousand leagues under the sea!

"Superiority to fate  
Is difficult to learn.  
'Tis not conferred by any,  
But possible to earn,  
A pittance at a time,  
Until, to her surprise,  
The soul, with strict economy,  
Subsists 'til paradise."

One does not like to particularize too much concerning a poet's meaning, but Emily Dickinson refers, no doubt, to the superiority to fate which resides in character; but I refer, at this juncture, to another kind of superiority to fate, the kind that comes from the control of nature to the uses and needs of men.

Physical science has nothing whatever to do directly with purely human things, but it keeps some ambitious men very busy and it allows more men to be lazy than could ever before indulge in laziness since the world began! It not only tells us nothing as to the meaning of life, but it permits many men to live without developing the strength of character which alone gives real meaning to life! Something essentially anti-religious has certainly come to us with the advancement of science. What is it?

One hurtful influence of science is a widespread popular misconception, a false belief in its completeness and universal adequacy. As Woodrow Wilson said in his sesqui-centennial address at Princeton more than thirty years ago, a strange gas has somehow escaped



from our laboratories, and, become noxious in the great out-doors, it is poisoning the world. Another hurtful influence of science, strange as it may seem, has come from its quick and almost universal bounty.

Idolatry is the worshipful contemplation of anything from a point of view which makes the thing false, and the most distressing idolatry the world has ever known is the modern, popular science-worship which pays no tithes and takes no pains. It is our Great Religion. Its catechism is science teaching which abhors exactions, its litany is the semi-serious wail of regret of the easy college graduate that a silver-spoon smartness was not transmuted by a pleasant college course into what he conceives the talents of its priest-hood to be, and its creed is the belief of every spineless parasite\* who thinks exultingly that science is the building of steamships to carry him where he has no need to go, of railways to bring him things he could better do without, and of airplanes to carry quickly his letters which would not lose in meaning if their time of transit were to take a thousand years! Most people think of science in terms of its results, chiefly, indeed, of results which facilitate joy-riding of all kinds including every phase of easy and luxurious living and orgies of near-thinking. And these are the Beatitudes! Blessed is the Joy-rider, for he sees his God; and thrice blessed (thank God!) is the Joy-rider's world, for there no one will ever run amuck!

No! Science is Finding Out and Learning How. Its greatest gift to those of us who live inside of its frontiers is an understanding of the things that surround us and of the things we have to do, and its price is pains.

Science is finding out and learning how, but its bounty has fascinated the crowd, who, neither paying nor achieving, adopt a scale of material values for everything in life with a consequent neglect of human quality and a

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\* Note that he has, as yet, no character, and his superiority to fate resides in the material comforts which come to him willy-nilly from the socialized applications of science. What are we going to do with him?



denial of human value in everything. We have a wisdom of easy plausibilities, a religion of mechanical beatitudes, a theology of universal indulgences, a jurisprudence which will hang no rogues. All of which means that we cannot discern worth or unworth in anything, and least of all in men; whereas nature commands us, at our peril, to distinguish worth from unworth in everything, and most of all in men. Our real problem now, as always, is "Who is best man?" And the fates forgive much—forgive the wildest, fiercest, and cruelest experiments, if fairly made in the settling of that question. Theft and blood-guiltiness are not pleasing to the gods, and yet the favoring powers of the material and spiritual worlds will confirm to you your stolen goods and the noblest of voices will applaud the wielding of your sword if only your robbing and slaying are done in fair arbitrament of the question "Who is best man?"

But if we refuse such inquiry we come at last to face the same question wrong-side upwards, and all our robbing and slaying must be done to find out "Who is worst man?" Who is worst man? Alas, considering our wide order of inverted merit, that is a difficult question; and its decision is mere Denial!

"Ich bin der Geist, der stets verneint!  
Und das mit Recht: denn alles, was entsteht,  
Ist werth, dass es zu Grunde geht."—Goethe.