tion upon which rested the traditional genera and species, and made apparent the artificial nature of all biological classification which takes into account the extinct as well as still surviving forms of living organisms. But the obliteration of ancient distinctions has by no means terminated here. No absolute or real difference between the living and the not-living can be found upon which to base a natural classification, for the properties and movements which we denote by the term "life" are, according to our best information, not confined to any limited portion of the material world, but are attributes of matter in general. The higher or more complex inorganic forms are evolved from the lower, and, by a continuation of this same process, a complexity is sooner or later attained such that the term "inorganic" is no longer applied, and we call the aggregate organic.

Thus certain biologists, perceiving the necessity of the assumption of cosmical unity, and taking for granted the qualitative identity of the motions and manifestations presented by material forms of all degrees of complexity, refuse to admit the validity or rationality of any classification of these phenomena as living and not-living, but insist upon viewing the whole as a unit, rather than dividing it into sections the limitations of which cannot be marked off. Beginning with the higher so-called living forms with which their science deals, they occupy themselves in the study of those phenomena which are denoted by the term "life," and gradually descending the scale to forms of greater and greater simplicity, they find these manifestations, motions and changes still apparent. Though in ever decreasing clearness, at no point can they be said entirely to disappear, nor, it is believed, would they be found wanting were it possible to extend our observation to the most minute particles, or even to the ultimate atoms out of which the material universe is constructed. This being the case, the denotation of the term "living" is extended beyond its former limitation, and made applicable to each and every constituent particle of the entire universe—the simplest, no less than those of vast complexity which constitute the higher living forms. "A more advanced science than ours," says M. Fouillee, "will find life every where."

But convenient and even necessary as a single appellation to denote what is common to both living and not-living may be on general considerations, separate terms denotative of different grades of the continuity can by no means be dispensed with. Admitting the virtual identity of what we call life and much that we call not-life, we may still insist upon the practical utility of separating them in our imagination by a broad and variable line of demarcation, covering a borderland of indefinite magnitude, and restricting the term "life" to those manifestations displayed by aggregates of relatively greater complexity, even though such restriction be avowedly arbitrary.

There is another plan upon which objects must be classed as living and not-living, a plan which does not conflict with the doctrine of continuity in the least—where the distinction is a real distinction, and where the classification is one of which we must admit the validity—however much we may believe in the universality of life. Every object of which we have any knowledge or conception consists of an aggregate of parts. Where the object is living these parts are mutually dependent, and act in a manner conducive to the welfare of the aggregate as a whole. Even where there is no visible structure and apparently no division of labor, this statement holds good. But with all aggregates of matter the parts are not thus co-operative. Though a believer in "panbiotism" may tell us that a molecule of iron or carbon, an amoeba and a vertebrate are all alike living things, yet he will hardly say the same of a lump of charcoal or a diamond. An object, then, is alive only when its several parts co-operate to promote the welfare of the whole. Objects not coming under this definition must constitute an opposing and correlative class—the not-living.

But, after all, may not this argument for the universality of life, even when thus qualified, be indefensible? It is true that in the present state of our knowledge we are unable to discover a point below which the manifestations of life entirely disappear, or to distinguish these manifestations from those of matter in general. But this does not prove that no such distinctions exist. Not every liquid in passing to a solid state passes through all degrees of viscosity, as do the colloids. On the contrary, the crystalloids apparently pass from the one to the other state by a sudden leap, and, though as yet unobserved, something of an analogous nature may accompany the evolution of living forms from not-living matter, and may have accompanied the first appearance of life.

Here, also, the particles may suddenly assume a definite structural arrangement in the aggregate, and if this be the case, we may expect to find the actions and reactions of the body possessing this structural arrangement of parts to differ as greatly from those of a body composed of like parts not thus arranged as the actions and reactions of a drop of water differ from those of the same aggregate in the form of ice. It is by no means inconceivable that further investigation, conducted under more advantageous circumstances, may result in disclosing such a difference between what is commonly called life and a lower form of molecular energy. And until such investigation has been systematically carried out to the obtainment of definite results, we must be content to remain in a state of uncertainty as to whether life ever had a beginning in time, or whether it is eternal and universal.

IS THE INVENTIVE FACULTY A MYTH?

By W. H. SMYTH.*

To the ordinary mind a profound mystery appears to envelop the work of the inventor. He is looked upon with a species of awe, as one endowed by nature with what is known as the "inventive faculty," a special organ or sense, having occult capabilities of inspiration and creation; a sort of automatic mental mechanism, needing only that its fortunate possessor should "touch the button" in order that, presto! the desired invention may instantaneously evolve from nothing. In

fact, the great mass of even intelligent people of our age regard a noted inventor as nothing less—and nothing more—than a "wizard." As we go on, we shall see that this extraordinary delusion is shared, not only by the majority of inventors themselves, but in effect by the federal courts having jurisdiction in controversies relating to patents for inventions, as well as by the tribunals of the Patent Office.

The intimate relations which it has been my fortune to sustain with many different inventors through a long period, and my own experience in a capacity which may perhaps be regarded as that of a professional inventor, have led me to adopt certain views as to the nature and qualities of invention, and the mental processes of which the completed invention constitutes the tangible result, which in many respects are widely at variance with those which have heretofore found general acceptance. Whatever may be thought of the correctness of these views, it may at least be affirmed that, when formulated into a working hypothesis, they have enabled inventions to be conceived and worked out with no less certainty and accuracy of results than are common in other departments of science in which the phenomena and processes have been investigated, classified, and subjected to fixed laws. They have further led to the belief that not only is the popular conception of the mental operation of invention a wholly erroneous one, but that what is loosely termed the "faculty of invention" is one which is just as much capable of acquirement by proper instruction and cultivation as any other: in short, that, like carpentry or shoemaking, it is nothing more or less than an art.

If these conclusions be well founded, it is at once apparent that they tend to bring within the scope of scientific methods one of the most important departments of human endeavor, and one which, even in its present chaotic condition, has perhaps been the most important of all agencies in the advancement of modern civilization.

I hold that that which is commonly termed the "inventive faculty" is nothing more than a combination of certain mental faculties with which every rational human being is endowed to a greater or less extent—namely, visualization, memory and reason.

The mental process involved in making an invention is analogous to that employed by the child in building with his toy blocks. Conceiving the idea of building some sort of house, he first arranges those which he thinks most suitable for the foundation, and continues by selecting from his store of blocks of various shapes and sizes those which he finds best adapted to form the various parts of the complete structure he has in mind. So, too, the inventor selects from the store of elementary mechanical parts or combinations with which memory has furnished his mind those which he regards as available for his purpose. The child builds and rebuilds, he changes a block here, and removes or adds a block there; so does the inventor, although in his case the mental operations of selection and arrangement are often so quickly and so automatically performed as to escape even his own observation. The material, too, with which the inventor works is infinitely better adapted to its purpose than are the blocks of the child with their unchangeable shapes and dimensions. It may be hard or soft, hot or cold, pervious or impervious, transparent or opaque, elastic or rigid, fluid or viscous; in short, it may be regarded as infinitely plastic, though possessing every other inherent quality known in nature or art.

When confronted with a defect in his structure, the child is compelled to laboriously select from his heap of blocks, critically examining each one and trying its effect as a part on the whole; but the inventor's mass of material is of a much more manageable character. In an instant the panorama of memory is unfolded, and he makes his selection—a process which may be repeated not merely once, but a hundred times, while the hand of the child would be faltering over a single block. Among this material the mind of the inventor works as a modeler in infinitely plastic clay. With such facilities and such material why should not great results be accomplished? On the contrary, would he not be a bungler indeed who under these conditions should prove to be incapable of producing a worthy result?

Why, then, do we find the Patent Office at Washington to be a vast storehouse, filled with every conceivable form of foolish, silly, illogical, and useless contrivance? Why this immeasurable waste of money, time and effort in the production of useless rubbish? Why is it that the very name of "inventor" has become a synonym for an irrational and crack-brained enthusiast, and a title which the originator of an important or valuable device no longer cares to accept? The reason for this state of affairs is not far to seek.

Let us again revert to our illustration of the building block, and add to the other conditions under which the child is compelled to work one more which is necessary to complete the analogy. Let us assume the blocks to represent, not only the actual things from which the inventor's conceptions have been derived, but his mental conception of those things. A very strange state of affairs now arises, which is due to the difference between the concept and the reality. It is as if the instant a block were picked up for use it should, wholly unperceived by the child, assume a distorted shape—the cube, for example, being no longer cubical, or the cylinder no longer cylindrical. The extent of the distortion, being a variable quantity, may range from an almost immaterial difference to the assumption by the cube and cylinder of the characteristics of each other, to say nothing of infinite possibilities of error in all other directions. Such an imagined distortion of the shape of the blocks is more than paralleled in the distorted mental impressions of exterior objects existing in the mind of the ordinary untrained observer: in fact, it is only the few who observe with even approximate accuracy, and still fewer who have the capacity to retain a correct mental impression of that which they have observed. Let the ordinary person attempt to make a drawing of, say, a round topped table. After a careful examination, he will probably proceed to draw to the best of his limited ability a circle, and next, with more or less accuracy, the legs, ending upon a horizontal line intended to represent the floor. Now mark, the circle has been drawn, not because the impression of a circle has been made upon the retina of the draughtsman, and so on his mind, but because he knows, or thinks he knows, that the top is

circular. The fact that the legs rest upon the horizontal floor is quite sufficient to justify the delineator in his belief that he sees that which is not to be seen, and he represents it accordingly.

Think of a man, no matter how quick in perception or how logical in mind, but with his memory stocked with erroneous conceptions like these, often not even rising to the dignity of caricatures of the external objects which they are assumed to represent. From such a mass of mental material is it conceivable that it would be possible to produce anything whatever which when completed should bear any logical relation to real things? Most certainly not; such a production could only find its fit place among the aggregation of abortive refuse which already encumbers the cabinets of the Patent Office.

The field of invention extends far beyond the narrow limits which custom has assigned to it; ingenuity and invention may be and are manifested, not alone in the works of the mechanic, but in those of the musician, the poet, the author, the lawyer, the physician or the theologian. But, alike in the case of these and all other inventors, a certain mental equipment is an indispensable requisite to success. There must exist, first, an unerring and accurate perception of those similarities and differences which are fundamental in their nature; second, the capacity to distinguish the pertinent from the fortuitous in the particular problem under consideration; and third—and this applies particularly to the mechanical inventor—the ability to clearly visualize, so that he may examine his structure as it progresses, and may select and, if need be, adapt the elements he selects from his store to the end that they may be co-ordinated with that structure.

The process of mind which I have termed "visualization" is curiously exemplified in an incident which I will give as nearly as possible in the language of the narrator:

"I have on several occasions surprised myself, so to speak, in the act of going through a mental operation which for want of a better name I will call 'manualization'—that is, using mental hands to manipulate mental material. This has only occurred, so far as I can recall, on occasions when I have been struggling mentally with some aggravatingly refractory problem of mechanical detail, which, though really no more than a pretty little puzzle, has concentrated my attention until the entire mental effort was focused on the rebellious point in strained and intense abstraction, the incomplete portion being in clear and sharp visualization. Then slowly, and as if with great effort, two hands would be laboriously pushed into view, and would take hold of the unfinished part and twist and shape it until it assumed a form adapted to the desired end. Then, like a flash, the strain would relax, the apparition vanish, and I would perceive myself to be a relieved, but exceedingly tired, individual. The visualization, including the hands, would still remain in mental view for possibly a second or two after the completion of the work."

If it were true that the so-called "faculty of invention" is something unique and apart from other forms of mental activity, it would certainly seem as if its manifestations must be so characteristic as to be at once recognizable. Such, however, is by no means the case. Is it not a most suggestive fact that, while the question of the presence or absence of "invention" has constituted the sole and only issue in thousands of contested cases which have been passed upon by the Patent Office and by the federal courts, not one of these august tribunals has ever succeeded in laying down a definition of that which constitutes invention? Listen to the observations of a learned judge of the Supreme Court of the United States:

"The truth is, the word [invention] cannot be defined in such a manner as to afford any substantial aid in determining whether a particular device involves an exercise of the inventive faculty or not. . . . In a given case we may be able to say that there is present invention of a very high order. In another we can see that there is lacking that palpable something which distinguishes invention from simple mechanical skill."—*McClain v. Ortmeier*, 141 U. S. 419. Is not this condition of mental confusion readily explicable, in view of the suggestion contained in the title of this paper?

Professor Robinson, perhaps the leading authority to-day, at least in the United States, upon questions of this kind, says: "The mental faculties employed in the inventive act are the creative, not the imitative faculties. An invention is the product of original thought. It involves spontaneous conception of some idea not previously present to the mind of the inventor. Industry in exploring the discoveries and acquiring the ideas of others, wise judgment in selecting and combining them, mechanical skill in applying them to practical results—none of these are creation, and none of these enter into the creative act. Only when the mind of the inventor originates an idea new to himself, if not to all the world, does he call into exercise his own inventive skill, and perform the mental portion of the inventive act."—*Robinson on Patents*, vol. i, sec. i, par. 75

If the above extract does not embody the popular conception of the nature and attributes of invention referred to in the first paragraph of this paper, I am at a loss to know what meaning is to be attributed to it. I take direct issue with the propositions laid down by Professor Robinson, and contend that the very qualities, faculties, and acts stated by him to be foreign to invention are those which constitute its very essence. It is assumed that something is created in the mind of the inventor; that something which had no previous existence is spontaneously generated there. On the contrary, I say that the mind of the inventor is a selective mental apparatus, in which material gathered from the outside is re-arranged and adapted to new uses, and that this is nothing different from the normal operation of the human mind in all other operations. If this is not true, and if invention in fact is something other than this, then I can only say that the possibility has been demonstrated that, by the exercise of those faculties of the mind which are "foreign to invention" and those only, results may be produced which are absolutely undistinguishable from "invention of a very high order." If, on the contrary, my contention is well founded, and there is really no such thing as the so-called "inventive faculty," and if the act which we call invention is nothing more than the normal result of the operation of mental en-

* From the Engineering Magazine.

downments of which all are possessed in a greater or less degree, it must logically follow that, inasmuch as our mental faculties are admitted to be no less capable of cultivation and improvement than our physical faculties, the power of invention or the capacity to invent may be improved and strengthened. It further follows that the operation of these faculties, like other processes, must be capable of being reduced to a definite system, governed by well defined laws, with manifest advantage in respect to economy of time and effort and certainty of result.

Despite the unscientific and haphazard way in which these important results are attempted to be reached, we boastfully speak of the present time as the "Age of Invention." To me the past and present ages, as respects invention, seems ages of pure empiricism, which bear to the future and real "Age of Invention" much the same relation that the last century bears to the present in respect to theoretical and applied science.

Examine at random any one of half a dozen lines of mechanical invention; one striking characteristic, common to almost all, instantly arrests the attention; they present nothing more than a mere outgrowth of the manual processes and machines of earlier times. Some operation, once performed wholly by hand tools, is expedited by some device which enables the foot as well as the hand to be utilized. Then power is applied; the hand and the foot operation, or perhaps both, are made automatic, and possibly, as a still further improvement, several of these automatic devices are combined into one. The fundamental basis is the old original hand process, and hence, except in the extremely improbable event that this was the best possible method of accomplishing the result, all the successive improvements are simply in the direction, not of real novelty, but of mere modification and multiplication.

This inevitable tendency of the human mind to follow along well worn grooves of habit serves to explain the reason of a fact often noticed, namely, that the most radical and important departures from old methods, by which many of the industries of the world have been completely revolutionized, are nearly always originated by persons wholly ignorant of the accepted practice in the particular industry concerned. There is no conservatism so unyielding as that of the specialist. It is one of the most insidious enemies which the inventor has to encounter; it is so easy to take things for granted, to let well enough alone. It is this and other considerations of no less significance that I have in mind when I say that the Age of Invention is not yet; we see only its vague and ill-defined fore-glimmer.

The ideal invention is as positive as a geometrical demonstration: hence the actual invention should at least be the logical mechanical complement of the condition incident to the operation to be performed; it should be the logical answer to the problem which has been set, and should change only when external conditions change. Therefore an improvement on an invention should be of rare occurrence. The true and complete solution should be reached in the first instance.

I cannot close this line of argument without insisting upon the fact that the first and most important prerequisite to invention is an absolutely clear insight into and comprehensive grasp of all the conditions involved in the problem. My own experience leads me to believe that this prerequisite alone constitutes nine-tenths of the work of invention, and that the remainder, in most cases, practically invents itself, or, to be more accurate, flows therefrom as a logical sequence.

And now, if it be admitted that invention is not an impalpable and indescribable "something," but that, on the contrary, it is the result of wise judgment and trained mechanical skill co-operating to select, combine and apply observations and conceptions already accumulated, what then?

My answer to this is two-fold, inasmuch as it necessarily implies two radical and far-reaching departures from existing conditions. The first change should consist in eliminating from patent law and patent practice the conceptions which attach to the words "invention" and "invented," and in substituting therefor the ideas embodied in the words "discovery," "discovered," "produced," "thought out," "reasoned out." The mere change of phraseology would in itself go far to put an end to the existing maze of confusion incident to the determination of the ever recurring question whether a given device does or does not involve that undefinable "impalpable something" which the law says is the indispensable requisite to patentability and would restrict the whole scope of the inquiry to the comparatively simple questions of novelty and utility. The second and by far the most important change should consist in the inauguration of a science of invention with all the attributes which that phrase implies. Impressed as I am with the transcendent importance of this branch of the subject, I venture to offer such suggestions as have occurred to me, in the hope that others more competent may be induced to take the matter in hand, and give it the consideration which its importance warrants.

The following should form, in part, the basis of a scheme for the cultivation of invention:

- (1) Accurate and methodical observation.
- (2) Cultivation of memory, including the faculty of association.
- (3) Cultivation of clear visualization.
- (4) Logical reasoning from actual observations.

Particular importance should be attached to accurate observation, inasmuch as this is the indispensable foundation of all real education.

With the above considerations in view, a course of training in which the following exercises are included has suggested itself to me:

First. Drawing from simple objects, not copies, under the following conditions: The object to be carefully examined, then removed and a drawing made wholly from memory; this is to be repeated until the last effort depicts the object as correctly as if drawn directly from it; each successive drawing to be on a separate sheet and removed from view while the succeeding one is in progress; when considerable proficiency has been attained, more complex objects to be substituted and the time interval increased; the class of objects to have as wide a range as possible; as proficiency increases, the time allowed for preliminary observation to be shortened, until the briefest possible glance at an object shall be sufficient to impress its appearance clearly upon the mind, the power of visualization becoming so highly cultivated that at any future time the image may be called up and reproduced with absolute fidelity of detail; as a modification of the foregoing, drawing objects from description, oral and other.

Second. Other exercises of the same general character, with or without the aid of drawing, having reference to other characteristics than form, as, for example, material, structure, and function.

Third. The solution of problems pertaining to the construction of the sample object, its manufacture and improvement, together with the discovery of means for the accomplishment of definite ends. These are, of course, merely suggestions, the scope of which may be extended and modified almost indefinitely. It may perhaps be objected that, while the first and second of the exercises above suggested might have the effect of cultivating the mental capacity for accurate observation, retentive memory, and clear visualization, the third would often prove to be beyond the scope of the ordinary mind. That such is not the case I am able to show by citing as an example the invention of an actual machine of no inconsiderable utility, for the purpose of assembling fruit cans in the process of manufacture. For convenience of description the experiment is thrown into the form of a colloquy.

Q. Of what shape is a fruit can? A. Cylindrical.

Q. What is the principal peculiarity of the cylindrical form? A. Roundness.

Q. What does this adapt it to do? A. Roll on a plane surface.

Q. To provide means of conveying cylinders a short distance in the simplest manner, how would you proceed? A. Make an inclined plane.

Q. Then, to convey bodies and heads of cans to a place to be operated upon, what would you provide? A. Inclined planes.

Q. Suppose you had to unite two pieces of stove pipe in the usual way, how would you go about it? A. Hold them carefully opposite each other; then shove them together.

Q. Suppose you had to unite many such pieces of stove pipe in lengths of two, and to do it quickly? A. Fix something that would hold them opposite each other, and then shove them together.

Q. Now, with regard to the tops and bottoms of fruit cans; how would you assemble them? A. The same as stove pipes.

Q. How is that? A. Let them roll down into something which will hold them in line with one another, and then shove them together.

Q. How will you make room for the next cans? A. Let the finished cans roll away.

Q. How would you instruct a mechanic to build your machine? A. Make three inclined runways, one for the can bodies and one on each side for the covers. At the lower end of the runways, make something that will hold these three things in line with each other. Then fix something that will push all three together, and make a runway for the finished cans to roll away.

Will any one deny that the above course of reasoning is not within the capacity of an intelligent boy of twelve years of age, or that a mechanic skilled in the construction of such machinery could not build a practically operative can-heading machine from the above specification?

A course of instruction such as I have attempted to outline would serve to confer upon all capabilities now enjoyed only by the few, and would give to them such capacities for dealing with novel and unexpected problems and conditions as would vastly increase the productive capacity of the community. Language fails me in attempting to express my sense of the vast importance and urgent necessity of systematic culture and education in the direction which I have indicated. The science of invention should take its place as the first study in the kindergarten, and the test of proficiency therein should be the last one to which the student should be subjected before leaving his "Alma Mater" to struggle with the ever new problems which will surely confront him in actual life.

It requires far more than the necessarily brief space which can be allotted to a magazine article to treat this subject in the manner which its importance demands, but I trust that enough has been said to show that such a course of training, if generally adopted, would vastly increase the dominion of man over the forces of nature, and immeasurably hasten the advent of the real age of invention.

The editor of the Engineer, London, comments on the foregoing, as follows:

We reproduce from the pages of our United States contemporary, the Engineering Magazine, a remarkable article by Mr. W. H. Smyth, who asks, "Is the inventive faculty a myth?" Of course before any attempt to answer this question can be given, we must understand in what sense Mr. Smyth uses the words "inventive faculty." It is not quite clear that he has precise views on the subject himself. He gives Professor Robinson's words in the sense of a definition. Professor Robinson says "an invention is the product of original thought. It involves spontaneous conception of some idea not previously present to the mind of the inventor." To put this, and indeed the commonly adopted view of the matter, into other words, it is assumed that the inventor is endowed with certain gifts, thanks to which he is able to produce new mechanical combinations simply by directing his attention to the subject. The combinations suggest themselves to him. They are in a way to be regarded as inspirations. Now Mr. Smyth will have none of this. He argues that the work of invention is in no sense or way spontaneous, and that an invention is nothing more or less than the result of a very simple process of reasoning brought to bear on known facts. The principal importance of the subject is to be found in the effect given in construing patent specifications to the words "invention" and "inventor." Pushed to its legitimate conclusion, Mr. Smyth's argument comes to this, that there is no such thing as an invention which is a good subject for a patent; that, in fact, no one is essentially an inventor to the exclusion of others, and that any given mechanical end can be attained by any man or woman who has been trained to form accurate mental pictures. We believe that Mr. Smyth is quite right in some of his conclusions, but we are very far from agreeing with him all around. In this country, at all events, it has long been admitted that there are two special types, or

classes, of inventor and invention. That is to say, there is the inventor proper, and there is the man who "schemes" or reduces to a practical form the ideas of the inventor. Occasionally both characteristics are combined in one individual. It appears to us that Mr. Smyth ignores altogether the existence of the inventor and holds that all so-called inventions are only the result of scheming.

Now it cannot be disputed that the part played by the schemer is of transcendent importance in the mechanical world; but the schemer cannot, and does not, do everything. Let us take, for example, the case stated by Mr. Smyth—assembling the tops, bottoms, and middles of tin cans. He tells us how it may be done, and asks, Is the work of "invention" in this case greater than any small boy of twelve could accomplish? In this particular instance no great strain is imposed on any one's inventive faculties so far. But an attempt to reduce the idea of the inclined plane, the holder and pusher, etc., to practice, would very soon be found to involve difficulties which might call for a very strong effort of invention. In order that the machine may be a success, it is necessary that all the can bodies shall be round, that they shall all be of precisely the same character, and that they and the lids shall be held accurately in the same place. For see how thin a tin can is and how thin is the flange of the lid. The smallest want of adjustment of the parts to each other would lead to their destruction. It may be said, of course, that the schemer—the draughtsman who designs the machine—could take care to provide for this by making the parts of the machine very accurately. But is it not obvious a far better result could be achieved by the adoption of such arrangements that there would be no necessity for minute accuracy; the machine being so far automatic, or endowed with mechanical intelligence, that it would always assemble the parts properly, whether they were all identical in shape or dimensions or not? Now we maintain that to confer this automatism on a machine may be a distinct act of invention very largely partaking in its nature of inspiration. But outside of this positive action, as we may term it, of the faculty of invention, we have another, which is yet more important, and concerning which Mr. Smyth is wholly and strangely silent. We refer to what may be termed the art of rejection. There are in many cases several methods of attaining a given end. One of these will be better than the rest, and ought to be used. Now we maintain that in numerous cases the selection of the best method is effected by the inventor in a way and for reasons that he does not understand in detail and cannot explain in words. The selection is the result of what we have before now called mechanical instinct. And that the mechanical instinct is not the result of training is proved by the circumstance that many admirable inventions have been made by outsiders, so to speak. Every one who has any practical acquaintance with mechanical engineers and their work will no doubt call to mind various instances wherein mechanical instinct does good work, the inventor or designer arriving at a result without being able to understand the process of reasoning by which he got it. It must be admitted, we hold, that while certain types of inventive work can be done to order, others are distinctly original. It is quite possible for many, if not all, fairly educated people to write verse by following certain rules; but it is given to very few to write poetry.

It may be argued that the mechanical engineer has only certain so-called mechanical powers—as the lever, the screw, the pulley, and the inclined plane—to deal with, and that the most he can do is to combine these, or some of them, to attain the required end. But this is not the whole truth. The screw may be used, and is used when we do not want to gain power. The lever may be used, as in the compensating beam of a locomotive, when the arms are equal and the loads the same at each end. The inventor is very far from being tied up in this way. Mr. Smyth insists that there ought to be but one way of attaining a given end. The invention "should be the logical answer to the problem which has been set, and should change only when the external conditions change. Therefore, an improvement on an invention should be of rare occurrence. The true and complete solution should be realized in the first instance." This passage ignores the dominant effect of the power of prudent selection. In order to prove its soundness, it would be necessary first to prove that there can be only one correct solution to any given problem. A whole host of problems suggest themselves, however, which obviously and logically do not admit of a single answer. Take, for example, the question of haulage on tramways. The problem is extremely simple, but it admits of at least half a dozen solutions. How is it possible to say that any one is better than others? Water has to be forced under pressure into countless steam boilers. Is any one save a salesman prepared to prove that any given pump or feed apparatus solves the problem of feeding boilers better than any other? It is only necessary to state the proposition in this way to show how untenable it is. While speaking of feed pumps we may mention an instance of invention of the type that may be regarded, we think, as akin to inspiration; we refer to the feed pump used with the Belleville boiler. It has long been known that direct-acting steam pumps with a single cylinder and pump and a slide valve are liable to stop when running slowly; the slide valve blocking the steam port before the stroke is completed, while there is no momentum to keep the piston going. It is for this reason that all single cylinder pumps without flywheels have two sets of valves, the main slide valve being worked not directly by a tappet, but by steam. For more than thirty years inventors have been struggling with this problem, and have got no nearer its solution. Indeed, in some modern forms of water meter the equivalent of the old Cornish tumbling bob has been used. Apparently every available device has been tried without success; yet in the Belleville feed pump the whole problem has been solved in the simplest possible way, and the engine, although it has a slide valve worked by a tappet, will run at a stroke a minute as well as at twenty or thirty. The whole secret lies in opening a little relief valve at the end of each stroke, which permits a small quantity of water to flow back to the suction side. Theresistance is thus removed, and the steam in the cylinder completes the last half inch or so of the stroke under any circumstances. It may be said that this solution of the pro-

blem was quite obvious. The fact that it was not used till now is sufficient answer to such a contention.

But there is still another side to the question as yet not touched on. What shall be said of the inventors who to a large extent invent a want and then satisfy it? Such very largely was the electric telegraph. It cannot for a moment be said that the world wanted it when Ronald, or even Wheatstone, began their labors. It had not entered into the mind of the commercial world that telegraphic communication was possible, yet the moment these men discovered that certain results were possible they at once invented, so to speak, a want for them. Is not this something more than a mere logical mechanical process of combining wheels and springs and levers to fold envelopes, let us say? If it be denied that such work as that of Watt or Stephenson, or Wheatstone or Wilde manifests genius, it is difficult to understand in what genius consists; but it is certain that such inventive work as Mr. Smyth contemplates involves no display of genius whatever. We have not, however, a word to say against his contention for the cultivation of the faculties of observation. The reason, indeed, why so many young men fail in life as engineers is that they do not keep their eyes open. Curiously enough, the method of training recommended by Mr. Smyth is identical with that pursued by Robert Houdin, the celebrated French conjuror, in training his son; who became, we are told, so great an adept that it was enough for him to glance at

HYDRAULIC SWING BRIDGES, NORTH SEA CANAL.*

FOUR hydraulic swing bridges cross the canal, three near Rendsburg and the fourth near Taterpfahl, about three miles from the Brunsbüttel lock. A fifth bridge, which takes the railway traffic over the Eider near Rendsburg, is a swing bridge worked by hand. They all cross straight reaches of the canal. Two of them turn through a right angle, the other two through angles of 70°.

It will be seen from the illustrations that there are four piers, one large and three smaller ones, to each bridge, two for the transverse and three, again counting the central pier, for the longitudinal position.

These piers leave a clear waterway of 160 ft. width, projecting somewhat from the slopes, which deep draught vessels have to avoid in any case.

The road swing bridge (Fig. 1), which lies a mile to the west of the railway bridges (Figs. 2 and 3), is normally closed, while the railway bridges are, as a rule, left open. The latter describe arcs of 70°, the former a right angle. The power houses are on shore, the gear and the operating levers on the bridges, the latter in signal boxes, and the arrangements are such that the line signals and the hydraulic levers interlock one another. When a train is signaled, the bridge cannot be opened. Unless, therefore, a vessel steam right into a closed bridge, no serious accident can occur.

the center the bridge is pivoted in a bearing fixed to the top of the central ram or plunger, the axis of the bearing lying at right angles to the axis of the bridge. In the lowered position the bridge further rests with three steel edges on strong flat steel chairs (Fig. 4) bolted to the central pier. When the bridge is to be turned, the whole structure is first raised by about 7 in. The counterweight in the tail end makes the structure tilt slightly, so that the rollers at the far end of the tail sink upon the rail, fixed to the arc of masonry (Fig. 1).

In Fig. 3 only the square iron plates to which the rail is bolted can be seen; these plates are cemented into the brickwork; the rail is of the ordinary type.

At first wheels with slightly beveled faces were employed. These conical wheels have been replaced by two others, also cast steel, ground straight on their faces. On the Taterpfahl bridge, which differs in several respects from those at Rendsburg, wheels with rounded faces have been adopted. Each of these two wheels, whose shafts deviate very slightly from the horizontal, is supplied with two small auxiliary rollers, which come into play when the bridge oscillates, and which have been found very useful. These rollers are solid, while the big wheels, which have a diameter of 4 ft. and a width of 8 in., are hollow.

The extreme end of the arc is borne by two small pillars in the water. The photograph of which Fig. 1 is a reproduction was taken before the canal had been

HYDRAULIC SWING BRIDGES, NORTH SEA CANAL.

a jeweler's shop window and then repeat the number and name of every article in it. As we have said at the outset, Mr. Smyth has written a curious and interesting article. The views he advances are original, at least in the sense that they have not before been printed. We admit that very much of the so-called invention of the world is not invention at all, but scheming pure and simple—not worth a patent and not entitled to one. It is probably not very easy to draw the line between scheming and invention; but we think that if we say that scheming produces a result by a consecutive act of reasoning from given premises, the whole process being well understood by the schemer, and that the inventor produces a given result by a mental process the precise nature of which he is unable to explain, we shall not be far from the truth. Mr. Smyth has not touched on this aspect of the question. But that is no doubt because he holds that all inventions have been and must be the result of well understood logical processes of deduction, which may be taken to prove that he has never really invented anything himself.

THE oil of tobacco found in the stems of long-used pipes, or obtained by distillation at a red heat, is one of the most active and powerful poisons known to the chemist. A single drop will often cause death in the case of a dog or cat.

The bridges weigh about 600 tons. The road bridge, illustrated in Fig. 1, is heavier than the railway bridges, represented in the diagrams, Figs. 2 and 3. In the latter instance the track rests on the top of the structure, which consists of two main girders, inclined to one another, the distance between them being 8 ft. at the upper booms and almost 15 ft. at the lower. The total length, 325 ft., is divided in the ratio of 3:2, the longer end being the lighter; the shorter, or tail, end is weighted with brick ballast. Part of the tail end is covered with a wind apron of corrugated iron, which equalizes the wind pressure on the two arms. In the road bridge, the two main girders stand vertical, 20 ft. apart, leaving a high road of 18 ft. width. The raised footpaths, 4 ft. wide, are carried by brackets fixed outside the main girders; the switch box is also outside these girders, above the central pier. The roadway is supported by cross girders, on which longitudinal girders are placed; secondary cross girders resting on the latter receive a double layer of boards.

On the railway bridges the last 35 ft. of the rail track nearest the shore rest on a slide. When closed, both ends are supported, the longer end lying on the intermediate pier, B, from which separate girders take the roadway on to the shore, a distance of 62 ft., and the shorter end resting on a small pier 12 ft. from the other shore (Fig. 2). At

widened to its full extent, and so does not represent the present appearance. The nose end of the bridge, which during the swinging deflects visibly by about 4 in., comes to rest on two similar small piers, striking against two steel buffers in the same plane. The cylinders in which these buffers move are filled with diluted glycerine, the chambers being provided with small ports, through which the liquid is forced when the bridge is approaching the pier. Heavy counterweights, one for each buffer, afterward press the buffers out again. When turning, the bridge rests on three supports, the two wheels and the bearing of the central pivot. The bridge is now lowered until the nose also finds its support. During this motion two contact fingers of brass bear against a vulcanite plate with a horizontal contact strip of platinum. The closing of this circuit rings a bell in the lever box. The turning of the bridge was designed to be accomplished in two minutes. The railway bridges take on an average 109 seconds, the road bridge, for which 130 seconds are allowed, a little more. Most of this time is occupied in the vertical motion. Before the opening of the canal, when it will be remembered, public traffic was not permitted beyond Rendsburg, that is, on this section, the bridges were turned some forty times every morning. The closed bridges leave a headway of 10 ft. or 15 ft.

When swinging back, the bridge again strikes buffers and makes a signal contact; the position of these

* From Engineering.