4

Theories of Creativity

Creativity is common to a great number of endeavors, both scientific and artistic. The flash of creative insight experienced by an engineer engaged in invention is very similar to that felt by the poet as he finds just the right word, the mathematician in discovering the solution to a difficult proof, the musician engaged in composition. The methods used to stimulate creativity are also similar for all disciplines. Psychologists have been interested in the creative process, the creative personality, and methods of inducing creativity since the time of Freud. Out of this interest have arisen theories of creativity, and a composite personality of the creative person.

Before any studies were done by psychologists the only material available on the subject of creativity was of an autobiographical nature. The important information contained in these studies is that creative ideas come from outside the realm of conscious thought but that creation is not merely inexplicable inspiration. It involves a lot of effort and applied skill on the conscious level. [15] The following are thoughts of Mozart, Tchaikovsky, and Poincaré on the subject of their own creativity:

> When I am, . . . entirely alone, and of good cheer; . . . it is on such occasions that my ideas flow best and most abundantly. Whence and how they come I know not; nor can I force them. Those pleasures that please me I retain in memory, and am accustomed, I have been told, to hum to myself. . . .
>
> All this fires my soul, and provided I am not disturbed, my subject enlarges itself, becomes methodized and defined, and the

whole, though it be long, stands almost complete and finished in my mind, so that I can survey it, like a fine picture or beautiful statue . . .

What a delight this is I cannot tell: All this inventing, this producing, takes place in a pleasing lively dream" [15, p. 55].

Generally speaking, the germ of a future composition comes suddenly and unexpectedly. If the soil is ready—that is to say, if the disposition for work is there—it takes root with extraordinary force . . . and finally blossoms. . . . The great difficulty is that the germ must appear at a favorable moment, the rest goes of itself. It would be vain to try to put into words that immeasurable sense of bliss which comes over me directly a new idea awakens in me and begins to assume a definite form. I forget everything and behave like a madman. . . .

Dreadful indeed are interruptions. Sometimes they break the thread of inspiration for a considerable time. . . . In such cases cool headwork and technical knowledge have come to my aid. . . . It is a great thing if the main ideas and general outline of a work come without any racking of brains, as the result of that supernatural and inexplicable force we call inspiration" [15, pp. 57-58].

Most striking at first is the appearance of sudden illumination, a manifest sign of long, unconscious prior work. The role of this unconscious work in mathematical invention appears to me incontestable, and traces of it would be found in other cases where it is less evident. Often when one works hard at a difficult question, nothing good is accomplished at the first attack. Then one takes a rest, . . . and sits down anew to the work. During the first half hour, as before, nothing is found, and then all of a sudden the decisive idea presents itself to the mind. It might be said that the conscious work has been more fruitful because it has been interrupted and the rest has given back to the mind its force and freshness. But it is more probable that this rest has been filled out with unconscious work and that the result of this work has afterward revealed itself to the geometer" [15, p. 83].

SELECTED THEORIES

Psychologists have only very recently turned their research efforts toward development of a theory of creativity, although some speculation went on previously. All theories are not based on the idea of inspiration arising out of the subconscious and preconscious mind as a result of some sort of transfer of a problem from the consciousness to lower mental states where it is mulled over until magically solved; although, this is the theory to which I subscribe and which is presented later. E. W. Sinnot [15] claims that, although some new ideas appear to arise almost spontaneously, there is a second major method, that of creativity by direct frontal assault. In this method the widest possible array of facts and ideas are collected and then a search is made for previously unseen relationships between these facts and ideas. Much of Edison's work was done in this manner. He often collected little known inventions of others and assembled them into inventions of his own. Sinnot also suggests that creativity is related to the ability to pick out important facts and ideas from the vast collection stored in the mind. This is because of the mind's organization of information into categories.

At the extremes of psychology are the stimuli-response theorists and the cognitive theorists. Both these schools of psychology have developed theories of creativity. The stimuli-response theory suggests that creativity is the formation of associations between stimuli and responses which are not normally associated. Creative people are particularly skillful at connecting aspects of their environment which on the basis of experience do not seem to belong together.

The cognitive theory holds that the creative individual organizes everything into categories on a subconscious level as do all individuals, but the creative person's categories tend toward divergence rather than convergence, and as a result of this divergence the creative person can recognize relationships which would not otherwise be apparent [15].

Still another theory of creativity is advanced by C. R. Rogers. Rogers states that creativity is the emergence of a new idea caused by the interaction between a unique individual and the events, people, and circumstances of his life [15]. As already indicated by every one of the inventions discussed to this point, each person's special skills and/or circumstances certainly do influence the contributions he or she can make. According to this theory, certain conditions must be present in the creative person and certain conditions must be present in the creative person's environment. Their coincidence is somewhat a matter of luck but the more talented the individual and more varied his or her experience the more likely the coincidence will occur.

The theory of creativity that seems most plausible and useful to me is taken from a book by Koestler [16]. It seems plausible because it conforms to my personal experiences and useful because it clearly indicates what must be done to increase creativity.

A basic tenet of the theory is that all creativity has the common characteristic that a relationship is seen to exist between two entities which are not previously recognized as being connected. This is true even if the creative act is merely the construction of a good joke. The thought progress can be shown diagrammatically by Figure 4.1. The vertical plane represents an area of thought and all the ideas one would normally associate with that area of thought. As our mind scans the limits of that plane there are no surprises; we might even say that any train of thought contained therein is "common sense" and familiar to those "skilled in the art." However, suppose there is another plane of thought not obviously connected to the first to which our mind might jump and in doing so get the solution. This is represented by the horizontal plane. Koestler calls this jump "bisociation."

Kestin [17], following Koestler, gives a simple but excellent example of this moment of insight. As a boy he was challenged by the problem of drawing a right triangle when given two lines; one being the hypotenuse, C, and the other, H, being the distance from the right angle perpendicular to the hypotenuse as shown in Figure 4.2.

His first approach was to draw a right angle having sides of indefinite length. Then he attempted to visualize the hypotenuse sliding with ends attached to the right angle's sides until a position is reached which would give the correct length of H and the required relationship of it to C. Numerous trials could establish the triangle—at least to a close approximation—but that was not an acceptable solution. The next morning the problem appeared on a quiz. Kestin visualized it in a different orientation as shown on the left in Figure 4.3. He had seen this orientation before, related to a theorem of geometry that states that the angle sub-

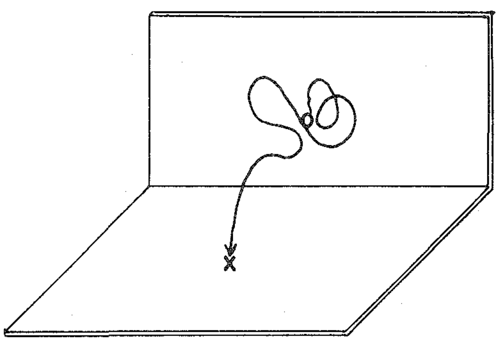

Figure 4.1 Intersecting planes of thought.

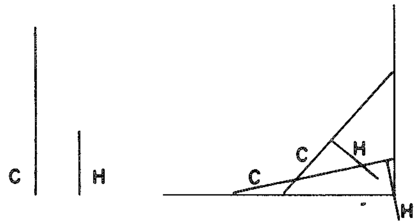

Figure 4.2 Kestin's first attempt to solve the right triangle problem.

tended on the diameter by a point on the circle is a right angle. The reorientation resulted in the jump to recall a theorem that did not occur to him during the previous evening's study. However, once the connection was made the exact solution was easily obtained; in fact, that construction even defines the maximum height the right triangle can have, namely, $H_{max} = C/2$. For the young Kestin this was an invention.

In his extensive treatment of this theory of creativity [16], Koestler cites the invention of the printing press as an example of this moment of insight, this association between two planes of thought which in this case existed but remained unassociated for hundreds of years. He states that letters testify that Gutenberg had long engaged in many attempts to improve the old art of printing. The art of making playing cards and pictures of saints by rubbing cards on engraved woodblocks was well known and the art of making coins by striking a die dated back many centuries. However, these skills were not adequate for printing a book. In that application the method needed to apply more composition with each impression and the pressure applied to the paper with precision.

Gutenberg took part in the wine harvest. He wrote, "I watched the wine flowing and going back from the effect to the cause I studied the power of this press which nothing could resist" [16, p. 123]. At this mo-

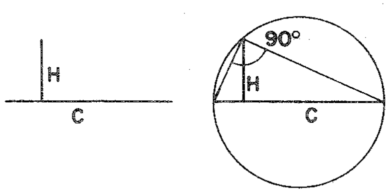

Figure 4.3 The perfect solution to the right triangle problem.

ment it occurred to him that the same, steady pressure might be used to press type to paper and then remove the type straight away from the paper to avoid smudging. Thus, the result of having a person skilled in printing, who had recognized the need to improve the process, witness an operation that seems totally disassociated, wine making, resulted in one of the most important inventions of all time. It does not matter that the process had been developed in China sometime earlier. For Gutenberg it was a totally creative act and for Western civilization it provided a new era for information storage and universal distribution.

The intersecting planes of thought shown in Figure 4.1 take on clearer meaning if the concepts involved in Gutenberg's invention are identified on each plane. This has been done in Figure 4.4. There are some factors which are common to wine making and printing by press. These define the line of intersection between the two planes. If such common requirements are identified as the inventor seeks a solution the bisociation usually follows. In both planes there are also many other things or concepts which are pertinent only to one or the other. These lie far off the line of intersection as shown by the few named; paper, ink, grapes, bottles, and kegs. As Gutenberg viewed the action of the wine press the insight that the same basic mechanism would be appropriate for a printing press was accomplished instantly.

Perhaps it is a bit difficult to fully appreciate how great a jump in thought was required by Gutenberg's invention. Remember that there were no books, pictures, or the many other ways we have to transmit in-

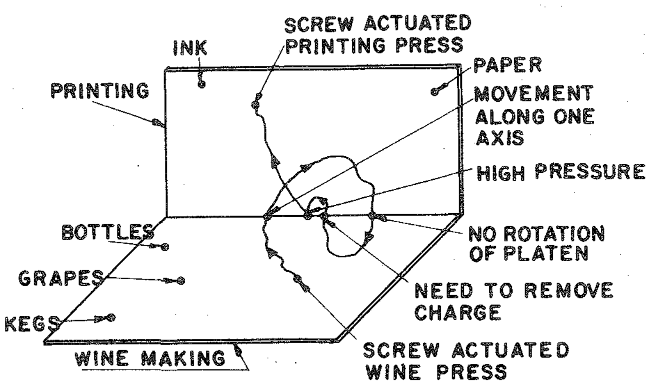

Figure 4.4 Intersecting planes of wine making and printing.

formation. It is conceivable that Gutenberg had never seen a screw before or, even more likely, that he was completely unaware of its mechanical advantage before he saw the grape juice gush from the wire press.

It should also be mentioned that Gutenberg's work did not stop at that moment of bisociation. That was the beginning of intense effort to improve the ink and to develop movable type suitable for the press [18]. This activity probably involved subsequent lesser inventions or it may have been skillful engineering and research. It is not unusual for the insight to an elegant solution to act as the motivation for prolonged and intense effort to complete the invention.

AN ORDINARY EXAMPLE

It is appropriate that I present an example more closely related to the type of problem likely to be encountered in product design. In the early 1950s I was involved in a product development that resulted in my first invention. The overall problem was to develop a residential-type circuit breaker which would occupy only half the space of the one then produced by the client company. The width of the unit in production was 1 in.; the new one was to have two devices in a 1-in., molded plastic case.

Circuit breakers are a very appropriate product to consider because overall they involve most of the engineering disciplines. Figure 4.5 shows one of the many designs used. The case of thermosetting plastic involves chemical engineering, the silver-tungsten contacts and the special alloys which have high mechanical strength as well as high electrical conductivity involve metallurgical engineering, the manual control and displacement amplifier involve mechanical engineering, and the overcurrent sensor combines electrical and mechanical engineering problems. The device must be inexpensive and yet reliably interrupt the electric current when it exceeds the current rating of the wire which the circuit breaker is designed to protect.

All circuit breaker mechanisms involve a latch (parts 46 and 47 in Figure 4.5) which disengages in response to excessive values of current through the device. To provide a means of tripping on a modest overload, most designs have a length of bimetal (17, two metals of dissimilar thermal expansion side by side) which is heated by the current and the resulting movement is used to disengage the latch. However, that process is too slow for high-current overloads and so magnetic forces are used to cause disengagement. The decision was made to have the design of the

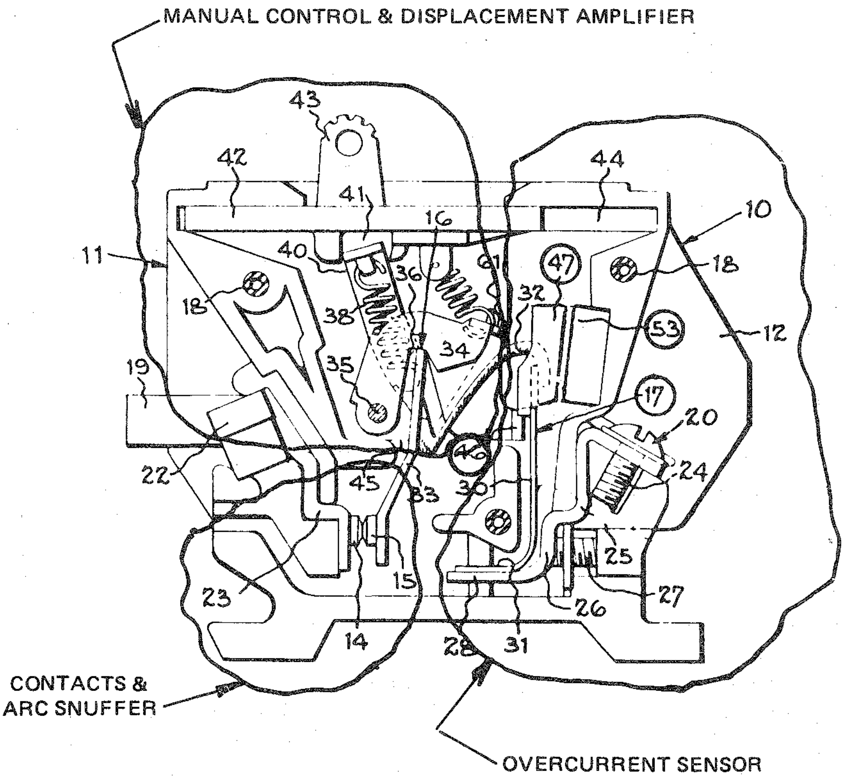

Figure 4.5 The interacting elements of a circuit breaker (U.S. Patent Office).

miniature device similar to the one already in production to benefit from the manufacturing processes and skills which had been developed for it.

The design problems encountered in reducing the size of components were minor until the magnetic circuit was considered. The unit in production used two U-shaped steel pieces, one, the latch (47), which was welded to the bimetal, and the other, the armature (53), which was held stationary in depressions molded in the circuit breaker housing. A magnetic field was produced in the two steel pieces and the intervening air gaps by the electric current which passed through the bimetal and then to a flexible conductor as shown in Figure 4.6. The latch was pulled into the armature by the magnetic field during high-current overloads.

The armature was made in a U shape so as to present a short air gap when the latch is in position to hold the trip mechanism and yet not to hinder the latch movement as the bimetal continued to flex due to the current during the arcing period which usually follows separation of the contacts. If bimetal is restrained from moving when it is hot its internal forces can exceed the yield strength and distort it. This changes the circuit breaker calibration.

It is easily seen from Figure 4.6 that the magnetic circuit pieces, 47 and 53, required four thickness of material plus clearance to ensure unimpeded motion. The magnetic pieces needed to be 16-gage steel (1/16 in. thick) to provide a sufficiently low reluctance path for the magnetic flux during short circuit. Thus, with a 1/32-in. clearance on each side, a total of 5/16 in. would be required to accomodate the magnetic pieces. The minimum thickness of the plastic sides and center piece for proper curing was to be 1/16 in. each, leaving a mere 3/32 in. within the total 1/2-in. width of the circuit breaker for the bimetal to which the latch was to be welded. This was not sufficient width for the bimetal. Thus, the problem was well defined. The design sought was one which would pull the latch away from the trip mechanism by magnetic force during high-current overloads but then immediately allow continued movement in the same

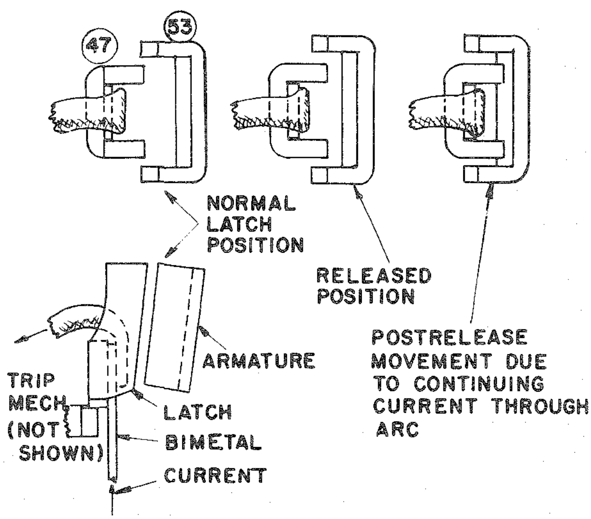

Figure 4.6 The electromagnetic tripping unit of a circuit breaker.

direction as the bimetal continued to flex. Furthermore, it must allow the bimetal to be at least 3/16 in. wide.

A number of rather prosaic ideas occurred. For example, the armature could be flat and mounted on a leaf spring. This would eliminate two thickness of metal and allow the bimetal continued movement during the arcing period by bending the thin spring. Abutments would be used in the plastic housing to restrain the armature from moving to the latch rather than the other way around. This and other ideas were rejected for various reasons and the vexing problem of designing the magnetic circuit held up development for several weeks. Then, one Saturday morning when I was alone in the office and deeply involved with the problem the bisociation took place (although I did not know of Koestler's theory at the time). I began by comparing the sought after magnetic circuit to typical design of a current relay. There, a light armature carrying a contact is pulled toward a stationary contact by a strong electromagnet. The thought occurred to me that if I were to suddenly block the movement of the armature the heavier electromagnet would be pulled to it. I used my hand against the edge of the desk to simulate the action. The straight fingers represented the armature, cupped palm the latch, and the knuckles a hinge. All that was needed after that moment of insight was to adapt the dimensions to the small size to fit the circuit breaker. As shown in Figure 4.7, the need for the U-shaped armature was eliminated. The flat armature is mounted on the latch by a hinge and is carried unimpeded in the direction the bimetal must flex. This construction allowed the bimetal to be 3/16 in. wide.

The unit was used for many years in the client's product. It was convenient to manufacture and reliable.

JANUSIAN THINKING

A kind of creative leap that has been recognized is named after Janus the Roman god, whose two faces permitted him to look in opposite directions at once. "Janusian thinking" consists of actively conceiving two or more opposite or antithetical concepts, ideas, or images simultaneously, both as existing side by side and equally operative or equally true. An account written by Einstein in 1919 [19] describing his development of the general relativity theory gives an example of this type of thinking. He drew an analogy between the need for relative motion between a magnetic field and a conductor if electromagnetic induction is to take place (the conductor must "cut" the magnetic flux lines for voltage to be induced)

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CIRCUIT BREAKER

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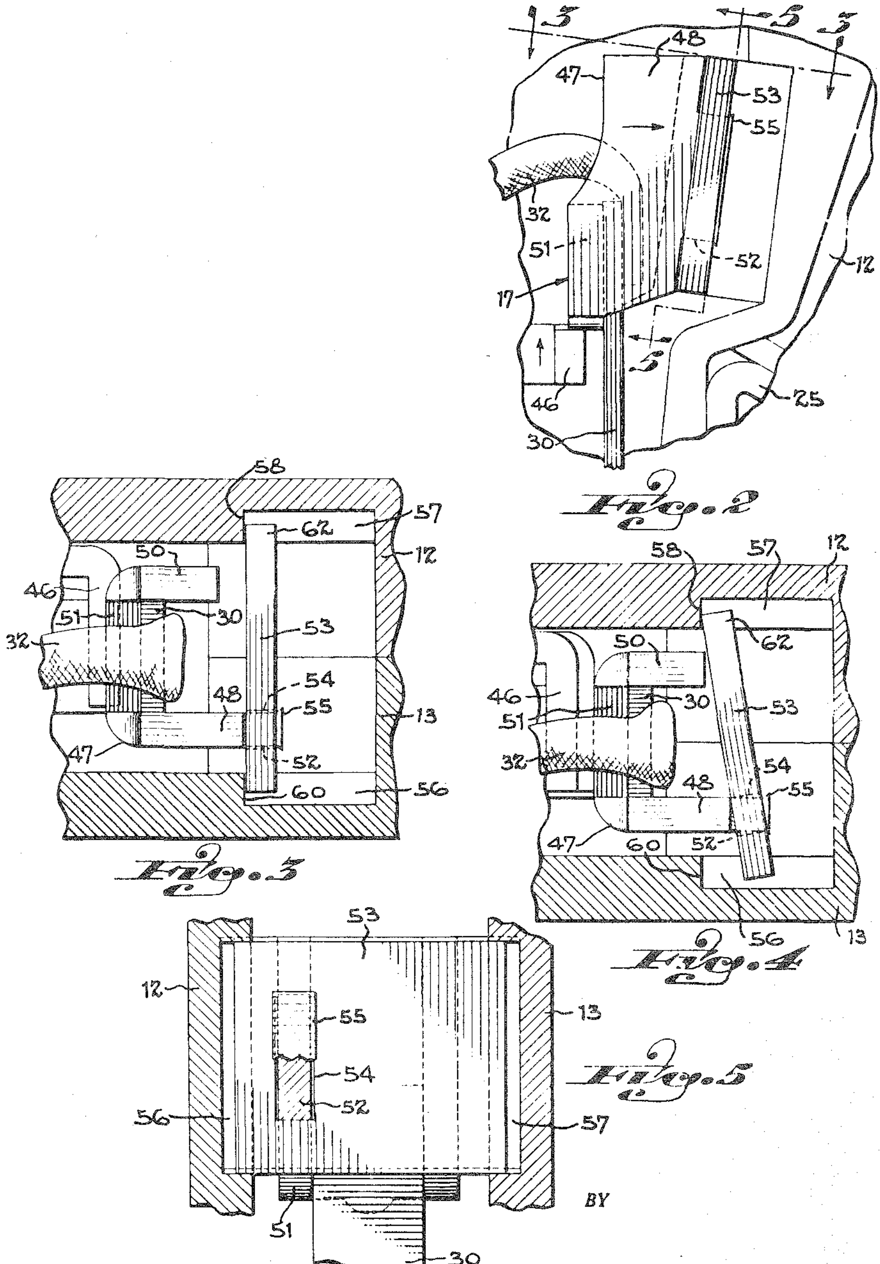

Figure 4.7 An improved electromagnetic tripping unit for thin circuit breaker (U.S. Patent Office).

and a similar need for relative motion to observe a gravitational field. Thus, Einstein noted, for an observer in free fall from the roof of a building there exists in his immediate vicinity, during his fall, no gravitational field. If the observer releases an object (neglecting air friction) it will remain at rest with respect to him and he with respect to it. The idea of a body being in motion and at rest at the same time are the antithetical concepts which Einstein used in his development of relativity. This was described by Einstein later as the happiest thought of his life.

The connection between two planes of thought that involves a seeming contradiction requires an especially high level of creativity. Black's development of negative feedback shows elements of Janusian thinking. The concept of reducing the output of an amplifier by introducing a fraction of it with negative phase relationship into the input is easily understood; but the reduction in distortion as a consequence is contrary to intuition. The improvement of the circuit breaker just described also involves this way of thinking. The solution occurred when I visualized the light-weight, hinged armature being pulled to the latch, being abruptly stopped, and the energy stored in that moving piece being delivered through the connection of the hinge to the member that was pulling it. During that moment, the two parts reversed roles and the trigger mechanism escaped.

In the referenced paper [19] the statement is made that Janusian thinking is not bisociation. It is described as a logical postulating of what on the surface seems illogical. Note however, that Einstein used a principle of the electromagnetic field to establish a principle of the gravitational field. He had found one connection between the two phenomena (or their associated planes of thought) and spent most of his life in an attempt to establish more. Janusian thinking is not bisociation but can lead to it.

BLOCKS TO CREATIVITY

Notice that in Figure 4.1 the looping mental activity on the vertical plane indicates a temporary hesitation to the bisociation. Such temporary blocks are normal. However, under some circumstances such blocks can permanently prevent the necessary connection between the two planes of thought. How do such blocks arise? Kubie [20] argues that there is no single cause but all can be lumped under the term *neurotic*. He cites examples of persons whose research went awry because of deep-seated emotional problems which caused prejudice, compulsion to spend mental energy on criticizing associates or proving a preconceived notion. On the other hand, a person who is at peace with himself because he understands whatever conflicts exist and can put them aside is free of this unwanted mental burden. The brain is free to act as a communication center processing bits of information on what Kubie calls the conscious, preconscious, and unconscious levels. On the conscious level a person deals with a subject in terms of communicable literal ideas and realities. On the preconscious level, he processes data at an extraordinarily rapid rate and with great freedom, assembling and disassembling many diverse patterns. On the unconscious level, without realizing it, a person uses his special competence and knowledge to express those needs indicated by his innermost concerns and his emotions. To the extent to which unconscious processes dominate the mental activity, the effective use of his preconscious thought process will be channeled to those problems. Not only are the products of preconscious thought vulnerable to distortions from the unconscious levels, the stream of activity itself must be protected from the same influences because creativity depends upon its free flow. The preconscious processes operate best when they are not restricted by the conscious and do not suffer interference from the unconscious. Perhaps you have experienced the technique of "sleeping on" a problem of deep concern with the happy result that the solution was obvious as you awoke the next morning. The activity of the preconscious does not depend upon our being alert or even awake.

There is another research report that gives insight to a cause of mental blocks. Hyman and Anderson [21] report tests whereby colored slides of familiar objects, such as a fire hydrant, were projected upon a screen and subjects tried to identify the object while the picture was out of focus. Gradually the focus was improved in discrete stages. The striking finding is this: If an individual wrongly identified an object while it was far out of focus, it had to be brought to a significantly better state of focus for him to correctly identify it than for others who had made no appraisal at all. A general statement would be that it takes more evidence to overcome an incorrect hypothesis than to establish a correct one. Or in words easier to remember, a false start can produce a mental block.

This discussion was included here to provide a positive basis for advice on improving creativity, not to worry you with the thought that inventing is difficult. First, since the preconscious is directed by your emotions, you must really want to invent to do so. Second, you must recognize those concerns that may redirect your preconscious activities—even against your will—and learn to set them aside. Third, learn to study the problem but do not decide too quickly on the mode of attack. More will be said about this later.

One of the most obvious blocks to creativity is caused by our education. This occurs because we become prejudiced that our particular area of engineering, the things we are expert in, is somehow the best. Electrical engineers look for the elegant solution only in terms of electrical devices or phenomena, mechanical engineers look to mechanical devices, and so forth.

A personal experience gives a good example of this prejudice. One of my patents involves a toy that was developed years ago incidental to Cub Scout activity. This is shown in Figure 4.8. It is a teeter-totter made of a bar magnet (27) which is positioned over a coil of wire (17). The pivots of the magnet (26) are slightly above the center of gravity of the rotating member. The coil is connected to a D-size battery (19) through a momentary contact switch (contacts are 22 and 23). When the switch lever (20) is pressed, the teeter-totter will rotate a bit but one closing of the switch does not accomplish much movement. Successive closing done in rhythm with the teeter-totter motion can increase the kinetic energy enough to completely turn the teeter-totter and its two occupants through a full revolution. The operation takes the same sense of timing that a child needs to "pump" a swing. The difference is that the toy requires only hand movement, not body movement.

After a toy manufacturer expressed interest in the device the decision was made to apply for a patent. During the initial meeting, the patent attorney asked if a similar play action could be gotten by a mechanical toy. I hadn't even considered that but immediately responded that it could not and even if it could it would not be as much fun.

I refused the first offer I received and in time learned how difficult it is to sell a toy. Toy manufacturers did not feel comfortable with coils, magnets, and low-friction pivots. On the other hand, plastic parts are their stock and trade. Several years after my patent was issued a toy appeared which could have been derived by analogs from mine (I am not implying that it was). This used a plastic bean pot mounted on pivots with center of gravity slightly below the pivots. A measure of plastic beans was provided to pile on the flat top of the pot. Each bean so added raised the center of gravity of the pot and bean system until the potential energy was sufficient to overcome pivot friction, rotate the pot, and "spill the beans." That is what the toy was called. It enjoyed a number of successful years.

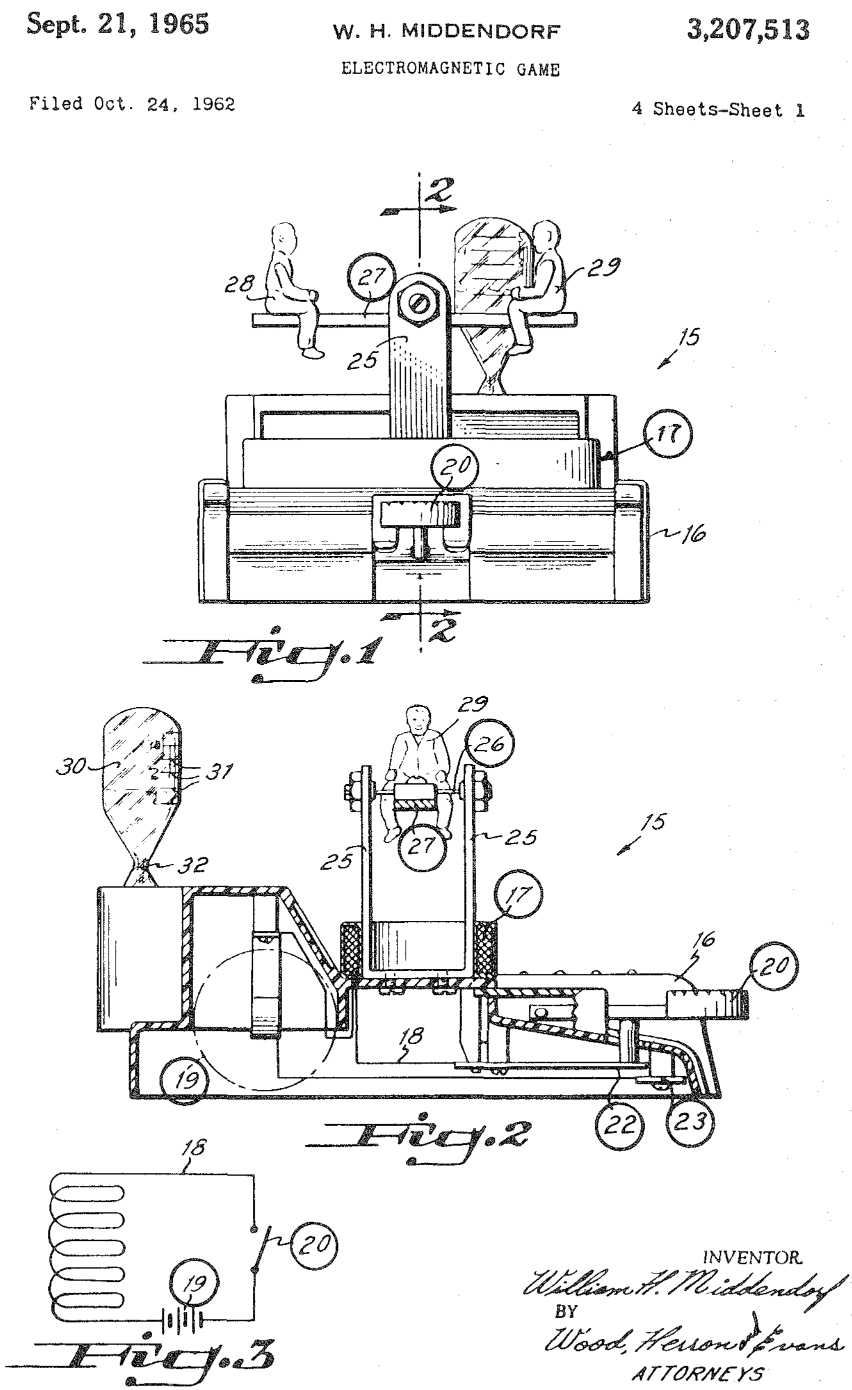

Figure 4.8 An electromagnetic game (U.S. Patent Office).

CHARACTERISTICS OF CREATIVE PEOPLE

As in all areas involving human endeavor, there is no complete agreement by investigators concerning the characteristics of creative people. Fortunately for our purposes, it is only necessary to consider the less controversial aspects.

According to D. W. MacKinnon [15] the creative individual enjoys esthetic impressions; has high aspirations; values independence and autonomy; is productive; has a high intellectual capacity; genuinely values intellectual matters; is concerned with his own adequacy; is dependable and responsible; has a wide range of interests; is ethically consistent; appears socially at ease; enjoys sensuous experiences; is critical, skeptical, not easily impressed; is candid in dealing with others; is talkative; and is generally introverted especially when engaged in creative activities.

Frank Barron [22] gives the following description of a creative scientist:

1. High ego strength and emotional stability
2. A strong need for independence and autonomy, self-sufficiency, self-direction
3. A high degree of control of impulse
4. Superior general intelligence
5. A liking for abstract thinking and a drive toward comprehensiveness and elegance in explanation
6. High personal dominance and forcefulness of opinion, but a dislike of personally toned controversy
7. Rejection of conformity in thinking (although not necessarily in social behavior)
8. A somewhat distant or detached attitude in interpersonal relations, though not without sensitivity or insight; a preference for dealing with things or abstractions rather than with people
9. A special interest in the kind of "wagering" which involves pitting oneself against the unknown, so long as one's own effect can be the deciding factor
10. A liking for order, method, exactness, together with an excited interest in the challenge presented by contradictions, exceptions, and apparent disorder

To these summaries, I would add that creative persons usually have ability and willingness to explore tenuous connections between only remotely connectable things. While the vast majority of such attempted connections lead to nothing useful, occasionally one yields a novel and useful insight into the problem at hand.

A very important characteristic for creative persons dealing with shape, composition, or physical interaction is the ability to visualize constructions in the medium in which they work. For example, the skilled artist must "see" the final picture before it is produced so as to evaluate the effect of every brush stroke. Earlier in this chapter Mozart was quoted as saying that "it stands complete in my mind so that I can survey it like a fine picture. . . . " Similarly, the interior decorator must visualize the results of choosing a certain sofa with certain rugs and drapes placed in a certain room. No one could earn a living as a decorator if he needed to see the choices in place before being able to decide whether or not the room would have the desired appearance.

Some designers work with systems or devices that require ability very nearly that required of a composer. They must be able to visualize relationships among ways of displaying information rather than things. The electronic circuit designer belongs to this group. A clear mental picture of component characteristics is required so that the effects of choosing one transistor over another or one circuit connection over another is readily apparent. Other designers work with systems or devices that require ability more like that of the artist or interior decorator, i.e., they must evaluate the effects of spatial relationship among materials of various shapes and of forces or potentials. Likewise, proper mounting of electronic components to provide adequate ventilation requires the ability to visualize spatial relationships. Thus, there are variations in the requirements to visualize, depending upon the job to be done.

A creative person does not hesitate to think unconventionally. On the other hand, a truly creative person does not select the unusual just because it is different. It must also be elegant. It is relatively easy to invent new devices or systems if being unusual is all that is required. For many years a popular satirical cartoonist with an engineering education named Rube Goldberg drew ludicrously complicated systems that accomplished useless or trivial results. There was creativity in the humor of the cartoons but certainly not in the invention of the systems. In fact, it was particularly unflattering in the 1930s and 1940s to call a design "a Rube Goldberg."

A creative person has a tendency to be dissatisfied with the products within his field. This is a natural consequence of being creative. So many alternatives are evident to the creative person that some other design flashes to mind as being more desirable. This characteristic is important because it may give you some insight into your potential as an inventor. Have you ever remade a new device, improvised to fix something that was broken, or simply made do with what was at hand to accomplish a certain task?

One of my students offered a good example of this. He had acquired a poster and wanted to hang it in his room without using masking tape. Surveying what he had available he used a safety pin as shown in Figure 4.9. He was careful to penetrate only half the thickness of the cardboard backing. The safety pin hanger worked as well as anything he could have purchased.

Last, a creative person maintains enthusiasm about his work, often in the face of disappointment. Creating something new requires full involvement of the skills of the inventor. Half-hearted participation will likely produce nothing of value. Those who lose interest quickly simply do not last long enough to invent. Furthermore, the inventor usually takes great pride in his own accomplishments. If a person does not really care whether or not he produces, the effort necessary to produce will not be maintained. Pride in accomplishment is a vital motivation.

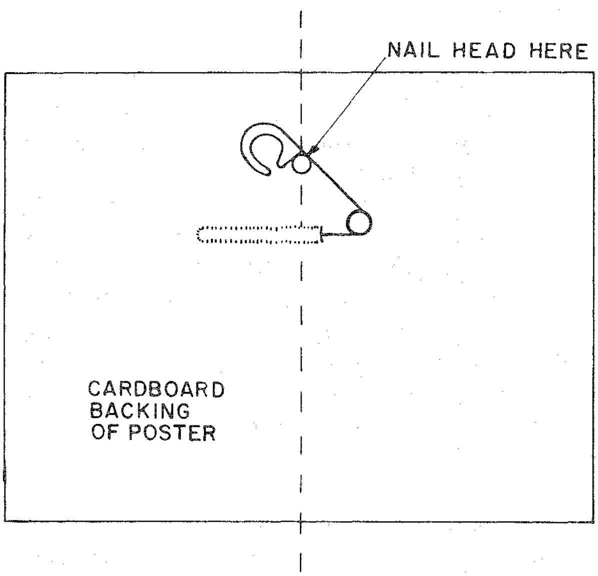

Figure 4.9 A student's improvised poster hanger.

CREATIVITY AND AGE

The effects of age on creativity was addressed in a book by H. C. Lehman entitled *Age and Achievement* [23]. In this study Lehman tabulated the number of creations within five-year intervals by his subjects, calculated the average number of creative contributions in each age bracket, and plotted the average number of contributions against the age brackets. His study covered many fields, such as chemistry, mathematics, fiction writing, and so forth. The interesting finding was that there is a certain range of ages, extending from the late 20s to the early 40s, which seems to hold as the period during which creative persons make the maximum number of contributions. Each field has its own particular range, which is shorter than the composite.

In the category of practical inventions Lehman shows that, based on 554 contributions by 402 inventors who were deceased at the date of his publication, the mid-30s are the most likely years for invention. The frequency of occurrence fell off almost as rapidly between the ages of 40 to 50 as it had risen between 20 and 30. Nonetheless, the data included some inventors younger than 20 years of age and some nearing 80. When comparing the most productive years of inventors born prior to 1750 to those born between 1830 and 1850, his data show that both groups enjoyed maximum output in their mid-30s but the earlier group remained much more productive between 35 and 65.

As to quality of contributions, Lehman shows that the 40 greatest inventions of modern (1953) times by 35 inventors occurred most often when the inventor was 32 years of age. The frequency of occurrence falls off even more sharply at less or greater age for this select group than it does for the larger group of "practical" inventions.

Lehman's findings have been substantiated by Bromley [24], who tested 32 men and 32 women in each of four age groups and graded ideas they generated as common or unusual. The youngest group with average age 27 had the largest number of ideas and the largest number of unusual ideas. The total number decreased somewhat with age but the most significant decrease was in the number of unusual ideas, especially in the oldest group whose average age was 72. The number of unusual ideas contributed by that group was less than a third of the number contributed by the youngest group.

Lehman [23] cites 16 possible causes for the decrease in contributions with age. However, these do not indicate a decrease in ability to be creative with age. Rather, a redirection of interest and effort seems to be the major factor. For example, he lists preoccupation with the larger affairs of successful men, less drive, decline in health and vigor, and neglect in staying abreast of the ever expanding state-of-the-art. Staying abreast of the state-of-the-art is, of course, more difficult as the change in technology accelerates. This was true in the comparison of inventors born before 1750 and those born before 1850. The ever changing technology is even more evident today.

These reasons given by Lehman for the decrease of invention with age is not subtle lessening of the ability to create but merely the obvious changes in the strength and available time one would expect to occur with age and success. Further, it must be remembered that those findings are statistical and cannot be applied to any one individual to predict his or her limits of creativity. This point is well emphasized by a list Lehman includes of 92 well-known older persons who made very great contributions when more than 70 years of age. Also, it has been noted that an effective stimulus for continued contribution is for the creative individual to deliberately change his field of endeavor.

INDIVIDUAL VS. GROUP EFFORT

For many tasks, team effort is accepted as being much more productive than the sum of the effort of the individuals. Does this hold for creativity? The theory advanced by Koestler [16] shows the advantage of group involvement as well as the major reason the group may not be successful.

As to the advantage, there is no doubt that the varied education and experiences of a group will increase the probability that the appropriate combination of ideas are stored in the minds of the participants. The problem is that the search for these tenuous connections of seemingly unrelated things cannot take place between two minds. They must be contained in one. There is a possibility, of course, that in exchanging ideas someone will describe just what another needs to establish an appropriate connection and, with further conversation, the group will arrive at the point of invention. There are indeed valid multiple-inventor inventions. However, they are probably rarer than the patent listings would indicate. Names are often included to avoid conflict or to reward those who brought the invention to a successfully engineered product whether or not they were true participants in the invention.

It is easy to speculate that Gutenberg had acquaintances who were familiar with wine making and had discussed the need for improving the printing process with them. However, his description was insufficient to direct the thoughts of the acquaintance to the force of the wine press and the description of wine making by his friend was not vivid enough to make the connection obvious to Gutenberg. Then suddenly, when Gutenberg saw the process, the similarity leaped to his consciousness.

There are other reasons that groups do not perform to their full potential in view of the extensive availability of knowledge and experience. This has to do with the tendency to be less interested in full dedication of oneself when a member of a group than when acting alone. An individual will spend extra hours thinking about the problem, work enthusiastically on it, and plumb the depths of the preconscious to find a solution. Members of a group are more likely to do what is necessary but not much more.

Data collected by psychologists [25] show that groups get more solutions to problems than do individuals but not more per member, and dividing the problem among individuals and adding all the answers gives an even higher total. Groups tend to correct each others mistakes, so the group judgment reduces quantity but improves the average quality. Individuals produce more good designs and also more bad designs. However, the truly bad designs are usually recognized as such and discarded. It is better to base your company's products on a small number of truly good designs than on a larger number of good but lower quality designs produced by group activity.