THE INNOVATIVE PROCESS

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The history of technology affords ample evidence that inventions are new combinations of familiar parts, and students of the subject have repeatedly emphasized this fact in one way or another. Speaking of Selden's 1895 automobile, Chapin notes that all its essential elements, including its engine, gears, drive shaft, and tires, had already been invented. "It was the integration of these indispensable elements already known into a new working arrangement or pattern that constituted the essence of the new invention."[1] And, as Kroeber says, if we seek the origins of the component elements we find them emerging from still earlier forms: "The more analytically facts are gone into, the more difficult it is to isolate many really basic inventions. More and more do they resolve into combinations of old elements, or into modifications that are reapplications of other old elements. What is new is often a new function, which is culturally significant because it is socially accepted, and which we can name."[2] Stressing the inventor's dependence on the past, Kaempffert, also, draws attention to the composite character of new devices: "It is because they are invariably composed of familiar inherited elements that many inventions seem almost disappointingly obvious when they are first disclosed."[3] Taking the important step of recognizing the extensive inventory upon which an inventor may draw, Hart remarks that, "To create a social innovation is to combine into a living structure elements previously existing in the human organism, the natural environment, and the culture fabric."[4]

It is generally appreciated, then, that inventions are new only in the sense that they are new configurations of old elements. What has rarely been specified, however, is the manner in which these new patterns take shape. Usually the process by which they come into being is hinted at by a term that suggests an organic or a mechanical analogue. It is called a metamorphosis, a mutation, a fusion, a reconstellation, or a truncation, without identification of the elements involved in the alteration or a disclosure of the properties which permit their realignment. In the few such analyses that have been made the conclusion has been that there is more than one kind of process. Thus Kroeber distinguished between invention by stimulus diffusion, reduction-segregation, and displacement;[5] Herskovits between gradual change by the accumulation of small variations and abrupt change initiated by the impingement of unforseen internal and external events;[6] and Linton, along with many others, between basic and derived inventions.[7]

It is the thesis of the present paper that there is more unity in the seeming diversity of element reorganization than has yet been realized by students of socio-cultural change, and that it can be characterized more significantly in its own terms than by resort to an analogy with a mechanical or a biological system. Obviously this unity must reside in the identity of the process by which the reorganization of elements takes place and not in its multiform manifestations.[8] The analysis of a large and unselected sample of cases has led to the conclusion that this process can be described in the following way: it is that mental action by which a detached element of one pre-existing configuration (antecedent) replaces a partially equivalent detached element of another pre-existing configuration (antecedent) to form a third configuration with some properties in common with its antecedents but with others that are peculiar to itself.

An unfamiliar perspective is required in order to recognize the universality of this process. In the first place, it must be granted that a new combination is necessarily a re͟combination. That is to say, before it can occur there must be an analysis of two existing complexes so that a part of one can be united with a part of another. This cannot fail to be so, because nothing exists in complete isolation from everything else. The bonds between familiar things may be physically tenuous or entirely absent; but this is the least important consideration, since physical conjunctions are only one aspect of the interconnectedness which men conceive the universe of their experience to have. A thing, an event, an act, or a thought must be related to another thing, event, act, or thought; otherwise it can have no meaning. That to which it is related may be nothing more conspicuous than its background or setting, no more tangible than a thought; but there is some context from which it is disassociated preparatory to being reassociated.

It must further be granted that the analytic and associative acts which are essential to an invention are mental functions. They are imaginary or symbolic slicings of experience through the medium of ideas about it. It would not be necessary to emphasize this point were it not that in speaking of these processes as they relate to objects it is easy to evoke the image of a mechanical operation. They do not belong to that order of phenomena. Recognizing a rat is an analytic process, for it requires that the animal be distinguished from its environment; but it does not entail any physical manipulation of those referents. Thinking of a rat in place of a lion on an heraldic shield as a symbol of courage and nobility is an associative process, and it likewise has nothing to do with the physical relation existing between the two animals or a shield. This undistinguished invention illustrates the fact that analysis can occur instantaneously; and while it is logically prior to a recombination of the analyzed parts the two can be practically simultaneous. It also illustrates the important point that analysis can take place in the very act of perception without the awareness of the perceiver. As Bartlett says, "although perceiving is rarely analytical or piecemeal in its method, yet it *is* a kind of analysis, since always there are some features of the perceptual situation which take the lead over others. These dominant details are a kind of nucleus about which the rest cluster."[9]

The inventive detachment and recombination of elements is therefore a psychological process and its rules are those of mental and not physical action systems, regardless of how they must conform to the latter if and when they are implemented in material form. The difference between these two realms of action is a matter of everyday observation, and every inventor faces it when he attempts to build a workable model of his mental recombination. Some ideational combinations are physically impossible, others must be modified radically before they can be materialized. Contrariwise, there are innumerable displacements and combinations of elements in the natural world that have no mental counterparts; which is to say that they are not inventions. There are certainly instances when they have been conceptualized for the first time and have had intellectual or practical importance attached to them. Then we have what is commonly called a discovery. But again the newness lies in a mental reorganization of conceptual elements such that one replaces another in a habitually established set. This step is essential whether it precedes or follows the play of physical forces.[10] Nature does not invent and therefore its mechanics should not be confused with the process of creative thinking.

It is necessary to abandon a mechanical view of invention for yet another reason; namely, that it tends to picture the recombination process as a severing and joining of things at their "natural" boundaries. This is a most misleading conception, for it is precisely in their disregard of conventional units that inventors differ most from their less imaginative contemporaries. They see complexes where others see wholes, or vice versa. Some of them, of course, actually do break things up and reassemble the pieces. Others do not; they do no more than imagine how it might be done. More importantly they envisage partitionings that overlap and intersect object boundaries. They jigsaw their cognitive field in patterns which ignore conventionally established outlines within it. The results are primarily and fundamentally new ideas and not new things. Consequently, they take shape in accordance with psychological principles which have little or no relation to the material properties of objects or to the way in which they behave under the laws of physics and chemistry. Percepts and concepts of experience can and frequently do ignore completely the definition of things established by "common sense" or by the conventionalized procedures of "objective" science--and thus often lead to reinterpretations of the nature of things.

It is easy in retrospect to wonder at the stubbornness or blindness of men that has prevented them from seeing the world structured in a way other than that dictated by custom, and to note how a failure to take a thing out of a familiar context and put it in another has forestalled change. So firmly do things become bonded together by tradition that it requires uncommon insight or rashness to perceive them as complexes composed of detachable parts that remain together only because they have "always" been that way. Sails were the exclusive property of ships--until a forgotten minor genius hitched one to ice skates, a parsimonious board of directors of the South Carolina Railway Company grafted one to a railcar in 1829, and a company in California rigged one to a squat tricycle to initiate the sport of "sand sailing." Kites are for boys--and for eccentric gentlemen like Benjamin Franklin, who used one to capture electricity; and George Pocock, who obtained a patent for attaching one to a carriage in 1826; and an anonymous Solomon Islander, who tied a lure to the tail of one and succeeded in catching fish with it. When Thomas Newcomen built his atmospheric engine--the precursor of the steam engine--he constructed a rocking beam to transmit power from the engine to a pump used to draw water from mines. This cumbersome and inefficient contrivance was adopted by James Watt and others after him for almost one hundred years in the fixed belief that some kind of overhead beam, instead of a direct-acting connecting rod, was essential to the performance of a power-driven machine. For no better reason, and for approximately the same length of time, the cylinders of steam engines were fixed in a vertical rather than a horizontal position, thus contributing to the preservation of the rocking beam tradition and to the inflexibility of the entire complex--which, of course, was regarded as a unit.[11]

As was suggested earlier, such venerable complexes are not held together by bars, bolts, and tubes alone. For centuries horses were harnessed to lordly war chariots, not ridden and not put to the bovine task of drawing carts and plows. They were associated with aristocrats, and therefore with luxury and pomp. They continued to be linked with adventure and sport until relatively recent times. And so it was with bronze in ancient history. It was a costly metal and therefore the exclusive possession of the rich and powerful. It was so firmly entrenched with ritual, heroism, and authority that iron, when it became known in Europe and the Near East, was rejected as a lowly instrument of peasants, ruffians, and barbarians.[12]

When two previously undifferentiated units are analyzed preparatory to their recombination, the parts of each are apprehended as being held together by some specific relationship. These relationships give distinctness to the parts, and they are crucial factors in the recombination process, the reason being that when one part replaces another it assumes the relationship that the replaced part had to its matrix, context, or associate--that is, the remainder of the analyzed unit--regardless of the relationship which the replacing part had to its matrix, context, or associate. The significance of this characteristic of the recombination process must be emphasized because frequently it is precisely the assumption of a new relationship by one part with respect to another that constitutes the most striking feature of an invention. It makes a difference, for example, whether a passenger car rolls on top of rails or is suspended from them; whether air is compressed by or compresses a piston in a cylinder; whether a waterfall causes a wheel to turn or a turning wheel makes a water-lift; whether parents treat their children as equals or as dependents.

Relationships are extremely varied in their nature, as varied in fact as the human mind can conceive them to be, for they are mental constructs. There is no external source for their apprehension, no stimulus for high, low, first, more, less, or any other conceptual connection between the sensory elements of our experience. That which we call the relation between things is a mental contribution to the external situation. It is an interpretation. And yet it inheres in the nature of the stimulus and is immediately knowable. Spearman lists this property of the mind as one of his three cognitive principles. He calls it "the eduction of relations," by which he means that the presentation of two or more stimuli at once and spontaneously tends to evoke a knowing of the relation between them.[13] It is an unmediated and an inseparable aspect of the apperception of things.

Despite their importance we have a very underdeveloped terminology for the identification of relations. This is owing partly to their indeterminate number and the shadings which they are conceived to have. It is also owing to our bafflement when we attempt to isolate clearly those relations we feel to be present. Some of our everyday experiences involve very complex sets of relationships which we sense but cannot express: the relationships between a parent and his child, between a moving automobile and the pavement over which it moves, between a politician and his constituents, between the legs and body of a running animal. We do grasp such relationships, even if intuitively and fleetingly. An appreciation of their significance is necessary in order to comprehend the range of inventive recombinations, for they constitute one control on the number of patterns that are possible.

It is evident that when an inventive recombination occurs the elements of the new combination directly or indirectly become substitutes for the elements of the original combinations which they have displaced by their union. If AB is one pre-existent analyzed combination and XY the other, one invention made possible by their recombination would be XB. In that case X displaces and therefore substitutes for A and at the same time B displaces and substitutes for Y. But it makes a difference whether X or B is the <u>active</u> substituting element because of the relationship factor. If X is the <u>active</u> displacer then it joins B in the same relationship as did the displaced A. If, on the other hand, B actively displaces Y it assumes Y's relationship to X, and that can result in a totally different XB. There are therefore two possibilities for the formation of the XB combination. The same holds true for the combination of A and Y. In addition to these four possibilities there are just two others. One occurs when both X and Y replace and substitute for A and B with the assumption of the relationship between A and B; the other when both A and B replace and substitute for X and Y with the assumption of the relationship between X and Y.

These six patterns exhaust the possibilities of the XYAB paradigm and it is believed that all inventions, as well as many creations that are not generally considered to be such, conform to one or another of them. The maximum of six is established by the relationship factor acting in conjunction with one other control. This is the inventor's conception of equivalence or similarity, for substitution takes place in accordance with his apprehension of a common factor in a pair of parts of existing combinations. In other words, recombinations are not made in random fashion; they result from the substitution of one thing for something like it. X is substituted for A because, as conceived by the inventor, it has something in common with A. Hence it is natural that there should be a substitution. Similarly for Y and B.[14] Their common properties may be physical, or functional, or abstract. They may be generally accepted as such; or, as sometimes happens, the perception of them may be attributed to the insight of a genius; or, as more often happens, they may be regarded as fantasies of amusing, absurd, frivolous, or even a dangerous people. Frequently equations are made below the threshold of what is considered to be inventive simply because the identity of X's and A's or of Y's and B's is taken for granted, as when one wheel is substituted for another wheel, their admitted differences being ignored by common agreement. This is precisely the juncture at which a division is often made between "significant" and "insignificant" inventions, and the reason why, as Kaempffert says, "many inventions seem almost disappointingly obvious when they are first disclosed." It is also why there is a lack of agreement on what constitutes an invention. The process itself is a routine, commonplace event. All of us resort to it daily. If we do not have a hammer available when we need one we use anything like a hammer that we have at hand; it may be our fist, a stick, a stone, or a shoe heel. Our impression of newness in what we call an invention is a function of the degree of similarity that we accord the substitute with reference to that for which it substitutes. And it is obvious that the measure of similarity is individually and culturally variable. Sometimes an inventor's conception of a resemblance and therefore of the possibility of a substitution is so "far-fetched" that he is regarded as a crackpot; in other instances his equation is so obvious that neither he nor anyone else thinks of him as an inventor.

The displacement occasioned by a substitution inevitably entails the discarding of the former contexts or associates of both of the replacing elements as far as that invention is concerned. Thus the union of the X and B of the XYAB paradigm automatically detaches them from A and Y. This of course does not mean that they will never again be associated with A and Y. What normally happens in a successful invention is that the elements it displaces continue to exist as alternatives. In some instances they retain that status indefinitely, particularly if they have an advantage over their new competitor under certain circumstances; in other instances they become obsolete and in time are forgotten entirely. These side effects of an invention may be regarded as desirable or undesirable; they may be deliberate or unforseen; they may be "gains" or "losses" depending upon one's point of view.

In those instances on which we have relatively complete information all the characteristics of the inventive process that have been described are clearly present. A good example comes from the fusions between automotive and man-powered vehicles during the 1890's. The earliest safety bicycles were too cumbersome to have wide appeal, so their manufacturers set about reducing their weight and the friction of their moving parts in all ways possible. They introduced ball bearings, tubular frames, wire spokes, pneumatic tires, and thin wheel rims. But, by the end of the century the bicycle began to lose its appeal so its designers turned their attention to its competitors, the steam, electric, and gasoline driven carriages. Into these vehicles they built their familiar tubular frames, chains, sprockets, and ball bearings, sometimes with little or no modification. Thus, the first Locomobiles (formerly "Stanley Steamers") offered to the public in Washington, D.C. in 1899 were equipped with bicycle wheels.[15] If we apply the symbolism adopted above to this example, X would be a horse drawn carriage body, with its heavy wooden wheels Y; A would be a bicycle frame, and B its wheels. XB would then be the invention with respect to this particular feature of the Locomobile; Y the abandoned wagon wheels (which Daimler and Selden retained in their first gasoline wagons); and A the by-passed bicycle frame that was eliminated from this strain of powered vehicles. The wheel substitution and other evidences of the crossing of bicycles and buggies appeared in such automobiles as the Benz of 1885, the Franklin of 1903, the Haynes of 1895, and Henry Ford's first, as pictures of these vehicles clearly show.[16] Meanwhile, marriages were being contrived between gasoline powered vehicles Y and bicycles B that bore issue in some form of "motorcycle" XB through the substitution of the motor X of the automobile for the pedal and foot power A of the bicycle. The details of this new breed of vehicles show unmistakable signs of their mixed parentage. There was, for example, the Hitchcock Quadricycle which carried a car seat for two mounted on the frames of two bicycles and was driven by a two-cylinder "naphtha" engine.[17]

Speaking in more general terms, horses X, taken from other tasks Y, have replaced men A in turning millstones, presses, waterlifts, and treadmills B. On treadmills the X's have replaced other sources of power A to drive mine pumps, railway cars, boats, and--if a Frenchman in 1825 had had his way--an airship B. Waterwheels X have relieved both men and beasts A in the operation of millstones, bellows, and machinery B; and in turn have given away to steam and electric power (new X's). At the end of the last century, compressed air X, acting on a piston B, substituted for steam A in a variety of devices ranging from railway engines to rock drills and it became a strong competitor with electricity. Then at about that time a temperamental upstart, the gasoline engine X, moved in to power the universe of rolling, floating, and flying objects B in place of steam, electricity, and air as well as the labor of men and beasts A.

It may readily be conceded that this replacement formula expresses well enough the inventive process in many instances, especially those in which a part of an earlier invention substitutes for a part of another; but how about the "really fundamental" ones? It is easy to see that one form of power has substituted for another, but how was the first step taken to harness power, and how did it involve a double analysis and a recombination? The answer to these questions all bear directly upon what has been said earlier about the nature of analysis.

Innumerable people have known that vapors emitted from crevices in certain parts of the earth are inflammable. About 1684, John Clayton verified reports of this phenomenon in Lancashire and then proceeded to produce such a gas himself. Conjecturing that there was a relationship between the gas, the earth's heat, and the coal deposits in nearby mines, he applied heat to coal B placed in retort X--in which alchemists had boiled and roasted an indefinite number of Y's--as a substitute for the earth A. Then, in a second step, he caught the released gas X in a bladder B, formerly used for many A's, instead of letting it escape into the atmosphere Y. He punctured the bladder with a pin, brought a candle flame near the vent, and so produced the precursor of gas lights and burners.[18]

Following Torricelli's announcement in 1643 that the atmosphere exerts a pressure at sea level approximately equal to that of a thirty-inch column of mercury there were a number of attempts to devise an engine to put this pressure to work. The problem was to create a vacuum into which a piston would be forced by atmospheric pressure. In 1654 von Guericke constructed a pump B which would draw air X instead of water A from a closed container.[19] In 1680 Huygens suggested that gunpowder be used instead of a pump to create a vacuum. The engine he built for experimental purposes consisted of a cylinder and a piston, the latter being attached to a counterweight. A small charge of gunpowder was exploded beneath the piston, thus forcing it to one end of the cylinder. Most of the gas generated by the explosion escaped through valves; as the remainder cooled the piston moved into the vacuum thus created and in doing so raised the counterweight.[20] Denis Papin, who was Huygens' assistant, was dissatisfied with the imperfect vacuum created by this method and turned his thoughts to steam as a substitute for gunpowder. In 1690 he reported his reasoning in these words: "Since it is a property of water that a small quantity of it turned into vapour by heat has an elastic force like that of air, but upon cold supervening is again resolved into water, so that no trace of the said elastic force remains, I concluded that machines could be constructed wherein water, by the help of no very intense heat, and at little cost, could produce that perfect vacuum which could by no means be obtained by gunpowder."[21]

Papin constructed an atmospheric engine based on this reasoning and demonstrated its ability to raise a counterweight in the presence of the members of the Royal Society in London. There is some doubt as to whether Thomas Newcomen knew about this scientific toy, but in any event he constructed a heavy-duty replica of Papin's laboratory exhibit and put it to work pumping water X from mines instead of raising blocks A. It thus replaced horses on treadmills, and in time, through Watt's efforts, became a steam engine.

Huygens' experiments with gunpowder suggested the use of its explosive force as a source of controlled power, and apparently efforts were made to construct such a machine, using gunpowder and other unstable compounds, throughout the seventeenth century. Despite these early attempts the internal combustion engine came after the steam engine and was developed as a substitute for it. In 1799 LeBon built a workable machine powered by exploding coal gas. In 1859 Lenoir substituted benzene for gas and at the same time substituted his piston and combustion chamber for the comparable elements of a steam engine. His invention "closely resembled a horizontal double-acting steam engine, with a cylinder, piston, connecting-rod, and a fly-wheel, in which the gas merely took the place of steam, the mixture being fired by means of an electric spark passed between two points inside the cylinder at the appropriate moment."[22] Lenoir took the further step of mounting his engine B, which until this time had been secured to a stationary base A, on a carriage or a wagon X as a substitute for horse or steam power Y, thus producing the first vehicle driven by an internal combustion engine.[23]

As these examples are intended to show, all the elements of the ABXY pattern are present even in the most fundamental inventions, but at times some of them seem to be absent because they are taken for granted; or because preexistent connections between A and B or between X or Y seem remote or inconsequential; or because the XY or AB bonds are so intimate that it is difficult to see how analysis could be involved. The fact that steam and gasoline engines were anchored to stationary bases before they were put on wheels may seem too obvious to mention; yet the dissociation of the engine from its immovable base constituted a major departure from tradition and few men even thought of it, or if they did they rejected the idea as impractical. It is even more difficult to distinguish two events or to isolate two attributes or states of a thing; and it may be equally difficult to appreciate that this, too, is an analytic process. When James Watt invented his steam condenser he did not separate one part of the Newcomen engine from another part. Instead, he analyzed the machine into its two phases--heating and cooling--and substituted a separate cylinder, acting solely as a condenser, in place of the steam-reducing phase of the single Newcomen cylinder. Likewise when he went on to invent a real steam engine, instead of the atmospheric reactor bequeathed him by Newcomen, he did not physically separate one end of the Newcomen cylinder from the other, but distinguished between the air and steam pressure phases in it and substituted steam for air, thus making both ends of the cylinder the same and creating a double action piston powered on both strokes by steam.[24]

It is not uncommon for parts to be substituted for wholes. All that is necessary is that they be considered to be equivalent for the purposes at hand. This happens regularly with abbreviations of words and acts. It has given license to the writing of "Washington, D.C." instead of "Washington, District of Columbia," to the ending of letters by some people with "I am, sir, your obedient servant, etc., etc.," and to a man's touching his hat instead of tipping it to a lady. It is this same process that Kroeber has called invention by reduction-segregation. One example that he gives is the development of the alphabet out of a mixed pictographic-ideographic-phonetic system of writing. The Egyptians used such a mixed system in which a word was spelled out phonetically and reiterated by an ideogram "as if to make sure that one representation would be read if the other were missed."[25] The alphabet is believed to have evolved out of this system or one like it, possibly among a neighboring Semitic people, by the elimination of all but phonetic symbols. If this is indeed true the process was one of substituting a part, the phonetic element, for the whole of the ideographic-pictographic-phonetic complex that previously was considered to be necessary, upon the realization that the part was equal to the whole and could therefore function independently in place of it. Our writing "thot" instead of "thought" offers a parallel.[26]

There is a further involvement that must be taken into account to appreciate the generality of the proposed pattern of analysis and recombination. This is the fact that parts and functions of living organisms, including man, are often key elements in the ABXY paradigm. This has been implicit in much of what has been said about the substitution of machines for men and animals, but there are other aspects of the process that deserve particular attention. A very considerable part of our technology has come into being through man's efforts to protect, strengthen, or maintain the physical or mental potentialities with which he is equipped as a member of the human species. Paleolithic men had a very limited stock of artificial devices. In the main, they used their own bodies to contend with their environment, but they did employ sticks and stones as substitutes for their fists and teeth in battering and crushing their way to survival; and they used fire and caves as substitutes for an inadequate body covering. There have been thousands of inventive steps in between those elementary substitutions and the complicated machines that we use today to master our enemies and our environment; but there has been an unbroken continuity, one step building on others which preceded it. Many modern inventions have as their purpose the restoration of body parts or functions that have for some reason failed us. In this category would fall our prosthetic devices: artificial limbs, eyes, teeth, and hair, as well as our eyeglasses and hearing aids. Then there are the prophylactics and curatives which guard us from death and disability by substituting for deficiencies in our organic apparatus--stimulants, vitamins, enzymes, and tranquilizers.

Some organic substitutes are made to look like the part they are to replace, but this is by no means necessary, and often a better substitute can be contrived if formal resemblances are ignored. After many centuries men who had visions of flying finally abandoned attempts to imitate the flapping of bird's wings and made their airfoils rigid. John Fitch's model of a ship driven by a steam engine imitating the rowing action of galley slaves was somewhat more realistic, but not so successful as the paddle wheels adopted by other inventors of his day.[27] All that is required of a substitute is that it have something in common with that which it replaces; and this need be no more than the capacity to produce the same ultimate result. Adding machines and typewriters bear little resemblance to our brains or limbs, but do accomplish some of the same purposes.

Many body substitutes strike the public as ridiculous or impious tinkerings with nature. Among the more innocent invaders of the human domain in the last twenty years have been U.S. patents issued for an automatically released ammonia spray to keep the drowsing motorist awake; kits of snore stoppers for heavy sleepers; an automatic wiper for eyeglasses and for vanity case mirrors; weighted ice cubes to keep their chill away from the lips of highball drinkers; an electrically heated toilet seat; and a headband with a prong in front to hold the cigar of a preoccupied card player.[28] All of these manifestations of progress have drawn their elements from other contexts and are designed to substitute for some attribute or function of the human organism through an equation of their effects.

As might be expected at this point, no significant distinction can be drawn between inventions which involve people and things and those which involve people only. Departures from custom with respect to interpersonal relations, communications, eating habits, and other traditional patterns of behavior originate with the equation and substitution of an analyzed part of one habitual unit of behavior with the analyzed part of another, just as with things. It is not usual to speak of novel--and sometimes shocking behaviors--as inventions; but inasmuch as the process by which they are conceived is the same as for new combinations of things, it is convenient and appropriate to have a term which will comprehend all instances. Innovation is a suitably neutral term and it will be employed throughout the remainder of this paper when no distinction is intended between the conception of new things, acts, beliefs, or ideas.

Some years ago the linguist Edwar Sapir pointed out that Americans are gradually abandoning the word "whom" in favor of "who."[29] That is, in those instances in which our language traditionally demands an expression such as "Whom did you see?" Americans who know that this is the "correct" form, but who insist on saying "Who did you see?" are consciously replacing "whom" A by its equivalent "who" X in the context of "did you see?" B instead of retaining it in its proper context, such as "was that man?" Y. The substitution of "who" for "whom" is an implicit admission of their equivalence for such speakers, and the equation can be substantiated by questioning. There are, of course, many people who do not know that tradition dictates a difference in usage for the two forms of this pronoun. They are not innovating, but simply following the new tradition.

Coded communications of all sorts clearly follow the pattern of equation and substitution. In these instances, as when a number "stands for" a letter of the alphabet, the equation is arbitrary; that is, it is made such by definition. Similarly with gesture languages, shorthand transcriptions, and the many forms of gibberish such as pig Latin. Slang and teen-age expressions are innovations which are more directly comparable with the "who" for "whom" substitution in that the replacement of a customary expression by a new one is an individual departure which may or may not become popular.

Strange as it may seem, imitation is innovation, for when it happens one person identifies himself X with another person A and instead of doing what he is accustomed to do Y he does what his paragon B does. The reason this seems to be anything but innovative is that in many instances no one questions the equation of the one person with the other. But there are numerous occasions on which the equation and its consequences are considered to be scandalous, presumptuous, or ridiculous. In this category would fall children behaving like adults and vice versa; natives incongruously garbed in alien finery; social climbers and passers of class boundaries--not to mention outright imposters.

Novel behaviors may originate not only through person for person substitution but through the equation and substitution of situations traditionally considered to be different. Not long ago the funeral of a famous band leader was attended by a display of jubilation that most Americans feel should be reserved for a joyous occasion. Oddly enough from their standpoint, that was the sentiment of the mourners too. It was a joyous occasion. A more consequential instance of situational equation occurred in the 1920's when a University of Illinois football player decided to become a wrestler. He resorted to the flying tackle in the ring, as he was accustomed to do on the football field, and so initiated the lunging strategies of hippodrome wrestlers today.[30]

The copying of objects, like the imitation of people, involves the innovative process and it therefore inevitably produces something new. No matter how diligent the copyist, his replica X will depart in some manner from his model A, the degree of acceptable deviation being controlled by X's suitability in context B. Such reproductive variation is not confined to things but appears in news reporting, rumors, songs, and artistic designs. It is most striking when the copying takes place across cultural boundaries, for then different conceptions of equivalence are juxtaposed.

The acceptance of something new, since it is imitation, operates by the same equation-substitution process as does the conception of it. Hence diffusion, acculturation, and assimilation are different manifestations of the same phenomenon. Diffusion is acceptance and acceptance is diffusion, the one term being conventionally applied to the description of a collective response to something new, the other to an individual reaction. Psychologically there is no difference, and in both instances the accepted thing undergoes modification in transmission. This fact can be overlooked only if we arbitrarily treat some modifications as trivial, or if we ignore the change of context and association that necessarily occurs when an idea or thing is adopted by one person from another. It follows from this that stimulus diffusion is not peculiar in producing inventions. All diffusion does.[31]

The categorical syllogism is a form of reasoning based on two premises which contain three and only three terms between them. It is a means of inference by which a relationship between two of the terms is deduced through the elimination of the third term which is common to both premises: all spiders are poisonous. This insect is a spider. Therefore this insect is poisonous. Translated into the symbols of the innovative formula this can be stated as A is B. X, whatever else (Y) it may be, is A. Therefore X is B. This is the form that many arguments take, and it is the basis for many beliefs and theories, and the experiments that are sometimes undertaken to prove them. The members of the Indian Shaker Cult assert that medicine heals sickness; their rituals are medicine; therefore their rituals heal the sick. In the middle ages it was believed that a lodestone could attract an estranged wife to her husband as it did bits of metal. It is not easy to fathom the basis for the equation of iron filings and alienated wives, but the same may be said of many novel ideas. Possibly some of Benjamin Franklin's contemporaries felt the same about kites and church spires. At any rate he found enough similarity in them to test his premise that lightning was an electrical spark leaping to earth through an elevated conductor. Most anthropologists believe that the ancestors of the American Indians must have arrived in the New World by way of Bering Sea. They reason that a primitive people without sea-going vessels and a knowledge of navigation would not have been able to cross the Atlantic or Pacific Oceans. The first immigrants to America were such a people; therefore they could not have reached America by traveling across the open sea.

Inventors with a serious purpose have often labored to produce something that their contemporaries regard as a ludicrous contraption. It is not surprising, then, that other innovators have adopted the same formula to create something which they think is funny and hope that the public agrees with them. Hence, we have inventors of chin-driven fans for gum-chewing secretaries and crank operated boxing gloves to be used for pounding the bottom of catsup bottles--again the familiar pattern of substituting an X for an A. Slapstick comedians, punsters, and cartoonists regularly resort to this formula, even though they may not be aware of it as such. Their appeal lies in the incongruity of their XB associations, which means the oddity of equating X with A. Whether this be considered an infantile form of humor or not, examples of it are not lacking in our literary classics. Witness Mrs. Malaprop's prescription for the education of a young lady: "Observe me, Sir Anthony, I would by no means wish a daughter of mine to be a progeny of learning: I don't think so much learning becomes a young woman; for instance, I would never let her meddle with Greek, or Hebrew, or Algebra, or Simony, or Fluxions, or Paradoxes, or such inflammatory branches of learning--neither would it be necessary for her to handle any of your mathematical, astronomical, diabolical instruments. But, Sir Anthony, I would send her, at nine years old, to a boarding school, in order to learn a little ingenuity and artifice. Then sir, she should have a supercilious knowledge in accounts;--and as she grew up, I would have her instructed in geometry, that she might know something of the contagious countries. . . ."

So far an attempt has been made to select illustrations of innovations requiring only one substitution. In many instances, however, innovations are made by equating and substituting some Y for B as well as X for A. The particular Y that is substituted may not have been previously associated with X. In any event, by replacing B it comes to be joined to X in the same relationship that originally linked A and B. This double substitution produces what may be called an analogy. Theoretically this pattern of innovation is at least as common as is the one involving a single substitution and in practice it may be more so. It certainly predominates among mechanical inventions, the reason being that in order to combine X with B it is usually necessary to alter B so that it more nearly approximates the physical properties of Y before the new combination is workable.

Analogies are innovations not only because Y has never before been related to X as it is in consequence of the double substitution, but also because neither X and A nor Y and B are ever identical, only alike in some respect. The over all result is that the form of AB is preserved but the content or substance may be markedly different. Innovations of this kind are made throughout the gamut of things, theories, beliefs and behaviors. In the history of science Faraday's demonstration of electromagnetic induction, leading to the invention of the electric motor, generator, and transformer, was based on two analogies between the parallel and reciprocal effects of magnetism and electricity. He confirmed Oersted's discovery of the intimate relationship between the two phenomena and reasoned, first, that if magnetism A could induce magnetism B, then electricity X could induce electricity Y; and second, if a fixed electrified coil A could rotate a pivoted magnetized needle B, then a fixed magnet X could rotate a movable electrified coil Y.[32] Ohm's demonstration of the nature of the flow of electrical energy through a conductor was based on analogy with Fourier's demonstration of the nature of heat conduction. Just as the flow of heat A through a metal conductor is proportional to the difference in temperature B between its ends, so the flow of electricity X is proportional to the pressure (voltage) differential Y between the ends of its conductor.[33] General theories are derived in this way--the so-called inductive method--from repeated observations on a series of reaffirming XY's; and they end up with a statement about the relationship between the common features of all X's and A's and all Y's and B's to the disregard of their particularistic and distinguishing properties.

With respect to things rather than theories, Lenoir's gas engine was analogous, even in its details, with a steam engine. It was just different enough (as Y is to B) to run on gas X in place of steam A. Westinghouse's railway car brake was a miniature piston and cylinder Y like that of a steam engine B, but activated by compressed air X instead of steam A.[34] Cayley's glider was modeled on a bird's body with inorganic wings X and a tail Y instead of the bones and muscles of their counterparts (A and B.)[35] The wings and tail of this device were analogous because they represent a retention of form along with a replacement of substance. This is an extensively exploited formula for innovation. It accounts for all the counterfeits, fakes, ersatzes, and imitations that, whether contrived for deception or not, look like something which they are not because they retain the interpart relations but not the materials of their prototype AB. Also conforming to it are a varied assortment of translations and transpositions, as when a musical score is "arranged" by the introduction of novel embellishments on its X's and Y's while retaining the relationships (melody, rhythm, tempo) between the original A's and B's. Similarly for the substitution of content (sense data) in communication systems, as when a message is transmitted in Morse code, not by the tapping of a telegraph key, but by light flashes or tape perforations.

The origin of the commissioned form of government provides an example of an analogy in the field of institutional innovations. In 1900 Galveston, Texas was struck by a hurricane and tidal wave which so severely disrupted facilities that the bicameral city government was unable to discharge its responsibilities. During the crisis a committee of businessmen undertook to find a solution to the administration problem. They proposed that a commission of five persons (X) be appointed to govern the city (Y) as nearly as possible as a board of directors (A) manages the business of a corporation (B). It is reported that they "did not at the time realize that they were inventing a new form of political structure."[36] This is a significant observation, for it means that these men, like thousands of other innovators before and after them, were unaware of their role simply because for them X was A and Y was B. It is also significant that these innovators were businessmen, for that fact throws light on their choice of a prototype AB. In other analogies the source and nature of AB is more apparent: In 1949 a Chicago attorney founded Divorcees Anonymous; in 1923 Ohrbach's clothing store in New York instituted a "cash and carry" plan; and in 1951 the Oklahoma City Police Department established a charge account system for a select list of traffic-law violaters.

Parodies, burlesques, and ballets are analogies. So are the numerous items in the proliferating business of pet care whereby owners--or alert entrepreneurs--identify dogs, cats, and other creatures X with their masters

A to pave the way for pet hospitals, hearing aids, tranquilizers, crutches, eyeglasses, tooth brushes, motels, powder rooms, cocktail bars and horoscopes--all Y's that are not quite the same as their B counterparts for human use. From the area of deliberate humor comes such analogical creations as a cartoon depicting a cave man spanking his child for "defacing" a wall of their home with a drawing of a woolly mammoth that is one of a kind now highly prized as examples of prehistoric art.

If the differences rather than the similarities between X and A and between Y and B are emphasized in a double substitution the result is what may be called a parallel instead of an analogy. In these innovations it is still the similarities between X and A and between Y and B which bring them into conjunction, but at the same time their differences set them apart. Their novelty lies in the fact that their XY components are different from AB and yet they are linked by a relationship that is transposed from the AB prototype. XY may already exist as a unit, in which case it is then paired off against AB as an alternative or as an insight that opens up possibilities for new developments paralleling those of AB: infrared radiation X sensitizes lead sulfide and other chemicals Y as light waves A sensitize silver nitrate and other chemicals B, so suggesting the possibility of heat photography and infrared chemical analysis. Perhaps more often neither of the elements of a parallel exists and they must be constructed on the suggestion of their AB counterparts: the contests between married women X for the title of Mrs. America Y have doubtless been modeled on the Miss America contests AB with the appropriate distinctions embodied in the new title. In science particularly XY parallels frequently emerge from a discrimination between subcategories of A and B: whales A and fish X are different enough despite their resemblances to warrant their being placed in different classes B and Y; isotopes A and X are distinct enough to have radically different potentialities B and Y.

The balance between analogies and parallels is delicate, and what is an analogy to one person may be a parallel to another. At times this is intentional; XY is enough like AB to satisfy those who cannot have AB yet dissimilar enough to satisfy those who have some preclusive interest in it. Exclusive clubs and their imitations are good examples; so are the numerous dichotomous pleasures of the rich and the poor, the young and the old, the fit and the unfit. A practically universal category of parallels is the one founded on differential sex interests and prerogatives, among them entertainments, occupations, dress, and speech. Toy designers and ingenious parents exploit the potentials of parallel innovation by manufacturing diversions for the young that are enough like adult forms to satisfy youngsters but different enough to keep them out of mother's kitchen and father's tool box. Humorists have also discovered that the scientifically respectable device of discriminating subcategories of A and B can have a risible effect: Junior, when cautioned that he would have to improve his table manners if he were to be permitted to spend the weekend with his friend, scornfully replied, "You don't think I eat like this with <u>people</u> do you?"

If it is granted that the patterns of simple and double substitution prompted by conceptual similarities adequately characterizes and comprehends the range of phenomena here called innovation, we are led to consider several implications of this formulation of the innovative process. They can be discussed with reference to its multiplicative, its valued, and its adaptive aspects.

One of the most obvious characteristics of social, cultural, and technological change is its quantitative variation. The change is of two kinds: variability in the number of innovations at different times, and variability in the number of people who accept an innovation over a given period. The reasons for these differentials are beyond the scope of the present inquiry; but given the fact that an innovation has been made we can directly relate the process by which it came into existence to some of the ordinary features and consequences of its acceptance. More precisely, whatever the conditions and the motivations for them may be, the mechanics of innovation and the extensions of its use are the same. Hence trends, cycles, and pattern duplications are quantitative manifestations of the innovative process.

In a trend, either the number of people X accepting an innovation B increases or decreases; or the number of B's with which X is associated diminishes or increases; or the number of X's with which B is associated increases or decreases. Often these alternatives are simply different ways of saying the same thing. In any event, they all involve numerical variations in the equation and substitution of persons and things. If it can be said, for example, that there is at present a trend toward motorization, this means that gasoline or other engines B are being fitted to many X's, ranging from launches to lawnmowers (with perhaps baby carriages and wheelbarrows yet to come), all of which have something in common with, and can therefore be substituted for, older engined vehicles A. Sturtevant's invention of a suction fan B to remove dust from shoe factories A started a trend toward dust removal from homes and other places. And not only do such fans B now suck dust A but anything like dust, such as bulk grain X from boxcars. While it may seem inappropriate to speak of a trend in the latter instance, the impropriety derives from considerations that are irrelevant from the standpoint of the mechanism by which the extension of vacuum power has been accomplished. Similarly with fads, those short-lived waves of mass identifications of the self X with another person A which result in sudden rises and declines in the adoption rates of A's distinctive traits B. Fads are trends from the standpoint of process even though they may be different enough in other respects to deserve separate terms. Oddly enough, obsolescence is another quantitative manifestation of the innovative process. It is simply that aspect of it which occasions the displacement of old items A in favor of new ones X. Thus after 1880, as one person after another X equated himself with a user A of electric lights B--or as they equated electric lights B with gas lights Y--there was a progressive obsolescence of gas illumination. Another numerical change occurs when an equation of X with A results in an extension of their identity through X's assumption of not one but many of the B's previously associated with A. From the equation of women X with men A there have emerged over the past fifty years in the United States, female lawyers, railroaders, bartenders, bank tellers, and business executives--all formerly male prerogatives B--and the end is not yet in sight.

As in innovation itself, trends and pattern multiplications may be viewed as either simple or compound substitutions, depending upon our estimate of what constitutes similarity and difference between X and A and between Y and B. If we think that a Standard Oil Credit Card is no different from a Diners Credit Card, or that Divorcees Anonymous is no different from Alcoholics Anonymous, and that Smokers Anonymous (recently founded in England) is "just another copy" of the same idea, then we declare them to be instances of simple substitution.

But if we insist on their differences, as their innovators and adherents are likely to do, they are parallels.

Many studies of change deal with problems that emerge from a concentration upon a particular facet of the innovative process, the problems being chosen because of their social or psychological significance. They are evaluative approaches that seek to rate innovations among themselves or with reference to their consequences. It has been said, for example, that an invention is a "break with the past," and many attempts have been made to distinguish this kind of change from "trivial modifications" and so to establish a dichotomy, commonly called "basic" and "derived." Yet if innovation is the combined analytic-synthetic process here proposed, it follows that such distinctions are no more than reflections of points of view about what is fundamental. So, too, with attempts to weigh the elements of stability and upset in an innovation. Both elements, of course, are present in every innovation and their social or psychological impact depends upon the subjective assessment of their respective magnitudes. Discussions of change in terms of gains and losses are also evaluative approaches, as is evidenced by the frequent laments over the passing of displaced customs--including, we must not forget, the custom of manual labor. Beyond this a reckoning of debits and credits in change overlooks the fact that every innovation at one and the same time represents mutual gains and losses. As X gains B it loses Y and causes B to lose A in whatever degree XB comes to dominate or supercede XY and AB. The attempts that have been made to distinguish between inventions and discoveries are also essentially evaluative. Whether couched in terms of luck or insight, discovery usually connotes a lesser achievement than does invention. While it may be convenient to retain the two terms, it is impractical to distinguish the phenomena to which they supposedly relate because they are not distinct in origin. Both are innovations. No matter how random the search for some X, or how unexpectedly it looms, it must be equated to some A and so be related to some B before its potentialities can be appreciated. And even "blind" searches are never entirely random; they are conducted under the constraint of some hypothesis AB, however vaguely it may be formulated.

The innovative process is an adaptive mechanism. It is the means by which human beings adjust to changes of situation, whether the changes are initiated by events within themselves or external to them. It yields artifacts and artifices; that is, man-made things and behaviors. But there are good reasons for maintaining that it is not restricted to these manifestations, and that it is not an exclusively human function.

One of the primary conditions for the survival of any organism is its ability to generalize upon its experiences; that is, to treat two or more things as the same instead of each one as unique. This is another way of saying that classification is essential to survival; and this means, in human terms, that a present experience X must be recognized, that is, equated to a previous one A before it can evoke the response--any response--B which assigns it to the same category as A. Often we must infer that this equation-substitution process takes place on the assumption that equivalent stimuli evoke similar responses in order to provide a rationale for the repetition of responses. If we accept the inference we are led to the further conclusion that animals as well as men classify their experiences; and, presumptively at least, by the same process.

Furthermore, there is no point in the scale of organic life where we can draw a line which delimits this reaction to diversity in experience. Whether in all instances it is a cognitive process is arguable, but so is the nature of cognition itself. In any event, the process seems to manifest itself in an unbroken continuum, ranging from the reflexive reactions of the most elementary forms of life, through the limited but undeniably inventive adaptations of apes, to the prodigious array of artificial devices created by man.

All of this puts a new complexion on what are ordinarily called inventions. In this broader perspective they are those manifestations of the innovative process for which praise is reserved. They are, moreover, subjectively selected aspects, for it is notorious that one man's panacea may be a crackpot idea to another. Hence the difficulty of framing generally satisfactory definitions of invention. Perhaps an even more disturbing consequence of this perspective is that it humanizes inventive genius by robbing it of some of its glamour. For the truth is that every man is an inventor many times over. The problem is not to invent something, but to invent something that someone wants.

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