LIBRARY OF
Southern Methodist University
DALLAS, TEXAS

FIELD & LABORATORY

Volume XIII July, 1945 Number 2

Reciprocal Reinforcement, Its Limitations, and the Freedom of Man

John D. Boon

As a farmer boy, I often observed that when a litter of pigs was born, some of them were stronger than others, and these stronger pigs, because of their superior power, were able to get more milk from their mother than the weaker pigs. Of course this meant that the stronger pigs grew faster than the weaker; and the faster they grew, the more milk they were able to get, and the more milk they got, the faster they grew. It might seem that this cycle would be endless. It had, however, its limitation; for there is a limit to the amount of milk that even a strong pig can digest, and for various reasons, pigs never grow to be as large as elephants.

This homely example illustrates the principle of reciprocal reinforcement and its limitations. This great principle may be stated as follows: If two factors, B and M (in the illustration, B is brawn and M is milk) are so related that an increase in the value of B brings about an increase in the value of M; and in return, the increase in the value of M causes an increase in the value of B, so that the two build up to a maximum togther. This is Reciprocal Reinforcement. Many of the things which grow to large values do so by virtue of the operation of this principle: pigs and astronomical galaxies attain their maximum in this way.

The physicist often uses this principle to build large currents in electric dynamos. The strength of the current generated depends upon the rate at which the wires of the dynamo cut the lines of the magnetic field; and the strength of the magnetic field depends upon the current that produces it. In a dynamo, these two factors—the magnetic field and the current—"build up" together, each one aiding the other. There is, however, a limit to the current that may be drawn from any dynamo, because there is a limit to the strength of the magnet. Another illustration of the application of the principle of reciprocal reinforcement is found in the vacuum tubes that are used in radio broadcasting. The oscillations that characterize a broadcasting station are determined by the relation of two reciprocal factors known as capacity and inductance. The power of a radio station is limited by the carrying-capacity of the circuits used.

Chemical explosions owe their power to the operation of the principle of reciprocal reinforcement. The heat required to start these reactions is often supplied by impact; but once the reaction is started, the heat produced hastens the reaction; and the faster the reaction, the greater is the amount of heat available for producing the reaction, and so the two grow together with explosive violence.

As I write, I am sitting here where I can see clouds gathering overhead, and I am quite sure that it will rain before the day is over, because the ground is very wet. These "thunderheads" were formed largely by water that evaporated from the wet earth during the morning hours; and if it rains this afternoon, a large part of the water that falls will be the same moisture that evaporated this morning. If the surface of the earth were dry, I would not be sure that it would rain this afternoon, for the supply of moisture evaporating (and thus aiding in the formation of the clouds) would be very small; and the chance for precipitation would be greatly reduced. The more water there is in the earth, the more evaporation will take place; and the more evaporation, the more clouds will be formed and the more rain will fall. Thus we see that wet weather brings wet weather. The principle of reciprocal reinforcement operates not only during wet weather—it often brings dry weather. If the ground were very dry today, I fear it would not rain; there would be little moisture supplied from the earth below to aid in the formation of clouds above, and if it failed to rain today, the earth would be drier still tomorrow. And so dry weather brings dry weather. The weather may become extremely wet or dry, but there is always a limit to these extremes.

The rains which fall in the United States generally have their origin in cyclonic disturbances which begin in the north Pacific Ocean and move eastward across the continent.

These cyclones vary widely in size and in the amount of water which they contain; hence they may for a time bring in an abundance of moisture, but sooner or later the supply of water will be reduced and dry weather will follow wet weather, and *vice versa.*

A gigantic illustration of reciprocal reinforcement is found in tropical storms. Many of these storms have their origin in the Caribbean Sea, a body of water lying south of Cuba, with an extension from the twelfth to the eighteenth degrees of North Latitude. All summer, the sun pours out its heat upon this sea, warming its surface and saturating the air with a steaming vapor. This vast body of warm, moist air is very light, and hence tends to rise; but owing to the fact that the Caribbean Sea lies at the Doldrums—a belt where the air is calm—the up-currents of air are long delayed. Finally some small factor acting as a "trigger" upsets the equilibrium and an infant tropical storm is born. When the "trigger" is pulled and the body of light air begins to rise, air from all sides flows in to take its place. These inward-moving currents, because of the earth's rotation, fail to hit exactly "head-on," and so the ascending column is set in rotation. In the northern hemisphere the rotation is counter-clockwise; in the southern hemisphere, it is clockwise.

In these storms there are a number of related events, and and if we are to understand the whole process, each of these must be properly related to that which precedes and that which follows. These events and their relations may be exemplified as follows: The pressure on the rising column of air diminishes as it moves upwards; the decrease in pressure causes this air to expand; the expansion reduces its temperature; reduction of temperature causes water-vapor to condense; condensation results in gain of heat, which tends to counteract the cooling-effect due to expansion; reduction in the rate of cooling makes it possible for the column to rise to a great height before it falls to the temperature of the surrounding air and thus loses its power to rise. It is not easy to see why these causes and effects do not block each other, but if we remember that cause always precedes effect, it will not be so hard to understand.

In a dry whirlwind, the ascending column of air is soon cooled to the temperature of the surrounding air because there is no condensation of water-vapor to give up heat, and thus retard the cooling process. For this reason, dry whirlwinds never rise to great heights nor become so powerful as hurricanes. On the other hand, in a tropical storm, or hurricane, the situation is quite different. There, the heat set free by the condensation of vapor is very great (amounting, at the temperature of storms, to about 570 calories per gram), hence the cooling effect of expansion is greatly reduced. There is a second set of reciprocal factors that cooperate in hurricanes. Here again the exact order of these related events must be followed: The rotation of the central column of air brings into play centrifugal force; the centrifugal force tends to hurl the air outward; the outward movement of the air reduces the density at the center of the column; this reduction of density increases the unbalanced force that is pushing the column of air upward; the increase in the unbalanced upward force increases the speed upwards; the increase in upward speed increases the centrifugal force, and so the cycle of reciprocal action goes on and on. During all of these changes, water-vapor is being condensed; and it is the heat given up by its condensation that supplies the energy to "run" the storm—a supply that, while very great, is limited: therefore, the power of the storm is limited.

Jupiter has the greatest mass of all the planets in the solar system, and (since gravitational attraction is proportional to mass) it is probable that it is growing faster than any of the other planets. The gravitational power of this planet is well illustrated in the fact that Jupiter has a large family of comets under its control—comets that it may swallow in time, if the sun does not get them first. Every time Jupiter swallows another body of matter, its power of attraction grows greater, and so the principle of reciprocal reinforcement acts to build up this planet, that is already the greatest of all. There is, however, a limit to the growth of Jupiter, for some day the supply of available matter will be exhausted, and it is possible that even before this time comes, the sun (being greater than Jupiter) will swallow Jupiter itself.

When the mass of a celestial body becomes very great, as is the case with our sun and the other stars, the gravitational power becomes exceedingly great. This may make us wonder why some giant sun has not drawn into itself all of the matter in the universe. Unquestionably we have here the operation of the principle of reciprocal reinforcement on a grand scale; but for some reason it has not been possible for stars to build their mass beyond certain fixed limits. The matter which makes up the mass of a star is drawn inward by its gravitational force; it is held expanded by two forces—one, the expansive force of heat, and the other, the expansive force of light-pressure. It is a fact well known that when light falls upon a body, it exerts a pressure tending to drive the body away from the source of the light. At ordinary temperatures, this force is so small that it is difficult to measure. However, the radiant energy, or light, given out by a hot body is proportional to the fourth power of its absolute temperature. This means that at the center of giant stars (where the temperature may be as high as twenty million degrees Centigrade), the outward forces of heat- and of light-pressure may become as great as, or even exceed the force of gravity. When this condition prevails, a star cannot grow larger—in fact, it may be in danger of exploding.

It has been suggested that the Novae (or new stars) that are at times seen to flare up suddenly out in space, are stars that grew so massive and hot that they are blown to fragments by the forces of heat- and light-pressure. It should be stated, however, that this is hypothetical; no one knows the secrets of the Novae. Stars are often many times greater in *volume* than our sun, but these bodies are very highly expanded gases, and their *mass* does not greatly exceed that of the sun.

The last great unit of the stellar universe is found in the Spiral Nebulae. Our galaxy, the "Milky Way," is such a spiral nebula. Millions of these strange, symmetrical star-clouds are scattered throughout space. Eddington[1] has calculated that there are no less than one hundred thousand million of these star-clouds in the stellar universe. They are

[1]Sir Arthur Eddington, *The Expanding Universe*, 1933, p. 6.

found in every stage of evolution; and while they differ in many respects, they are all very nearly the same size, and as a rule show a more or less spiral form. Some astronomers believe that our galaxy is much larger than the others, but recent studies have indicated that this is not true. It would, indeed, be strange if we happened to live in the largest spiral nebula. Far out in the southern celestial hemisphere there are two star clouds, known as the Magellanic Clouds, that are rapidly moving away from us. It is possible that they were once a part of the Milky Way. If this be true, our galaxy may be too large for stable equilibrium, and may be now in process of partial disintegration. No one knows how the spiral nebulae were formed, nor what stage of evolution they represent; but the fact that they are nearly uniform in size indicates some force that puts a limit to the mass they are able to control.

I have a friend who is a mental pickpocket; every time I talk to him he filches something from my mind, and (like all good pickpockets) he does this without letting me know it. Strange to say, he claims that *I* am a pickpocket—that I steal *his* thoughts. The truth about these claims is that, because of our common interests, we stimulate each other very greatly. If I express the simplest idea he is apt to take it up and to go much deeper than my first thoughts, and in turn my new thoughts lead him into still deeper thinking. Thus the process of mental reciprocal reinforcement goes on. No man can attain his highest intellectual development without the stimulating action and reaction of mind upon mind. Universities worthy of the name are great centers of mental reciprocal action; and their laboratories are obstetrical-wards where new thoughts are born continually. In recent times, large industrial concerns have built laboratories where groups of men of like thoughts and training are in constant, vigorous mental contact, trying to discover some of the basic laws of the physical world.

Not all parts of our country have participated to the fullest extent in these reciprocal intellectual developments. Some regions, like the stronger pigs of my homely illustration, had initial advantages which made it possible for them to get the greater part of the (intellectual) food supply—

an advantage that has accelerated reciprocally. In the intellectual world, as in the physical world, however, great centers of thought reach stages where reciprocal action is retarded, and new centers begin to appear. It is possible that this shifting of intellectual centers is going on at the present time. This does not necessarily mean that the old centers are declining: it merely means that the new centers have the advantage of youth—a priceless possession. It is hard to block the run of time from youth to old age. Perhaps the most significant characteristic of this age is the realization of the importance of purposeful intellectual reciprocal reinforcement.

One of the corollaries of the theory of relativity is that matter and energy are identical—that matter is one form of energy, and may be changed into other forms. This theory is so well established that astronomers now generally believe that the heat of the sun is maintained by the destruction of its mass. According to reliable calculations, this would require the destruction of 4.5 million tons of mass per second of time. This is a large amount of matter, but the mass of the sun is so great that it would have little effect even in a million years. When a lump of coal is burned, a large amount of heat-energy is liberated. Could this lump of coal be *completely* changed to energy, many-million times as much heat would be produced.[2] It is almost impossible to comprehend the amount of energy set free when the mass of any substance is changed to heat.

The element Uranium is composed of a number of isotopes that differ in weight or mass. The most common Uranium atom has a weight of 238; another atom, found in small quantities, has a weight of 235. When a neutron (one of the small uncharged particles found in atoms) is shot into Uranium 235, that atom is split into two parts with a violent explosion, and a change of mass. In other words, *a portion of the mass has been changed into energy.* Atoms other than Uranium 235 may be used to produce fission (the breaking of an atom into two atoms), with a loss of mass and the liberation of a vast amount of heat. When an Uranium 235 atom is divided with explosive violence into

[2] H. A. Perkins, *College Physics*, rev. ed., 1943, p. 760.

two atoms, this fission is accompanied by the liberation of more neutrons which, in turn, bring about the fission and explosion of adjacent Uranium 235 atoms. Thus, the explosion and production of new atoms bring about a new supply of neutrons to continue the chain- or reciprocal reinforcement process. All of these changes take place with extreme rapidity, and the liberation of inconceivable amounts of energy.

Will atomic energy be a practical source of energy for the everyday uses of civilized man? No one knows the answer to this question. We only know that at the present it comes from elements that are not abundant, and that its production is very expensive. Will Atomic Bombs be used to destroy Civilization? The answer to this question is that moral forces are developing that will control its use. The most cynical man will admit that nations are trying now, as never before, to learn peaceful ways of settling their disagreements. Back of every peace-making movement on the part of the nations, two forces are at work: one "*We ought,*" the other, "*We must.*" Both in the long run are irresistible.

In this paper, no effort has been made to mention all of the diverse applications of the principle of reciprocal reinforcement. Unquestionably, men grow wealthy, cities grow large, and nations expand by virtue of this principle. There is "wisdom" in a universe that puts a premium on growth, yet sets a limit, so that no pig can get all of the milk; no wet or dry season can last forever; no hurricane can destroy the earth; no star can gather to itself all the matter in the universe; no man can gain the wealth of the whole world; no nation can make slaves of all of the other nations—a world where the Atomic Bomb did not come until the conscience of the nations was sufficiently developed to limit its use. Running through the world of mind and matter, there is a principle that, by analogy, might be called one of "democracy"—*the Democracy of the Universe.* The freedom of man is confined within the framework of these limitations.