SCIENCE AND FREEDOM

BY JAKOB KUNZ

THE fundamental assumption of the natural sciences is the determination of the phenomena of nature. All phenomena of heat, sound, light, electricity and magnetism are reduced to motion of small particles. Every motion is determined by previous conditions of material systems. This is the law of thinking, the guiding principle of science through the blossoming confusion of the phenomena. It applies in all physical sciences: physics, astronomy chemistry, mineralogy, geology. It is used as a hypothesis or guiding principle in the biological sciences and in psychology. The life phenomena of plants, animals and men are also determined by the given conditions; so are the physiological processes of the brain. Neurology claims to be as truly a science as physics is. If, in psychology, it is further assumed that our ideas are necessarily connected with material processes in the brain, then even all our thoughts, feelings, will powers, aspirations are determined by the motions of the atoms of the brain. Thus we arrive at the conception of the universal machine of nature. Nature, including human life without rest, is a machine or mechanism, in which every motion is necessarily determined by the previous conditions and by the surroundings. That in such a machine there is no room for freedom, is self evident, each part of the machine doing what it has to do.

But the question arises, how in such a machine the illusion of freedom could arise. Even if freedom in some form should not exist, the illusion of freedom would still have to be explained on the basis of a mechanistic conception of the universe.

We shall begin our thesis by considering the thinking process. I can think only if I am free to think. The brain does not think, but I think. I understand the expression; it thunders, but I do not

understand the expression; it thinks. This seems to be absurd, or nonsense. If the brain were thinking, then the thoughts would move topsy turvy through each other just like the processes in the brain, which are subject to diffusion. We would have a general chaos of ideas without distinction or definition, a wild dispersion and distraction; but it is a fact of fundamental importance that we are able to concentrate and direct our attention and create order and system in the thoughts which otherwise would move hither and thither in a haphazard stream of consciousness. We are free to control our thoughts. And we control them according to a very special ideal, the ideal of truth, which cannot have its origin in the mechanism of nature. Indeed there is not only no room for freedom in a mechanism; there is also no room for truth.

This statement requires a definition of truth, which I do not intend to give. I wish only to refuse any pragmatic definition of truth. Surely in some sense a machine, which runs without any deviation in accordance with the physical laws, is the expression of truth; some computing machines may ring a bell automatically when a mistake is made, an electric substation may automatically give a sign to another station, indicating that all transformers and other machines operate perfectly, electro-optical automatic signalling on railroads may control the perfect course of the trains, preventing collisions, eventually better than man. In mathematics, truth only means logical consistency; in the physical sciences we used to say a theory is true if it corresponds to the external physical reality. But as we do not know beforehand, what that physical reality consists of, this definition of correspondence is untenable. Yet I do not know of any other definition. And yet truth is the aim of all natural sciences, and truth at any cost, even with the sacrifice of the dearest impulses of the heart, even at the cost of all moral principles. The conviction of truth involves consciousness and possibly freedom. A machine has no consciousness and is often man's slave. A machine never errs.

Our thinking presupposes freedom to look at given phenomena and various problems in different ways. This is especially clear in mathematics and in all mathematical sciences like celestial mechanics and theoretical physics. The mathematician considers a problem from different points of view, and finds eventually by different methods exactly the same solution. A given machine however can

obtain a given result only in one way. If the brain were thinking itself, it would have to consider itself, its own mechanism in different ways, and find a solution of itself in mathematical form, which is absurd. And wherefrom should this mechanism, the brain, have its ideal of truth? Indeed, in the Darwinian theory of biology there is no ideal of truth. Ideas are only useful or harmful, in the struggle for existence of a given living being, but never true or false. This thought applies also to that strange continuation of Darwin's thoughts in philosophy, called pragmatism, which has no room for truth. In the struggle for existence a lie may be far more useful than truth. Lies and propaganda may win battles and decide the destinies of nations.

Just as in mathematics, so freedom of thinking is necessary in the physical sciences. The genius who creates a new theory of a certain field of phenomena is independent of the processes of the brain, which is only determined by the previous conditions, but the previous conditions in this case lead only to the old theory and a mechanism can never produce anything new. It may change a pattern, but it can not give rise to something new which fills us with surprise and admiration. That thinker must even be free of all traditions in his science; old knowledge for him is prejudice; he looks at nature in a new way, as nobody did before; and so he discovers new laws of nature.

Mathematics is not based on facts of observation or experiments, but on assumptions, in the choice of which we are free to a large extent. But when the assumptions are chosen, then by mere logical deduction one conclusion is drawn after another until a whole structure of theorems is built up of unshakable firmness and marvelous consistency. So mathematics is a free creation of the human spirit; and it serves as model for all other sciences. For the fundamental theoretical progress in the physical sciences, mathematics has to be developed first. First mathematics, then physics. The Greeks developed the geometry of conic sections, which was applied by Kepler to the motion of the planets. Lobatchevski, Riemann and others developed the non-Euclidean geometry which was applied by Einstein in the new theory of gravitation. Physics does not determine mathematics but mathematics is the lamp for the progress of physics. There is no "natural history" of mathematics, but there is a mathe-

matical theory of natural phenomena. It is not a material system of the brain which thinks, but something non-material, which we will call mind or spirit. Then we can express the facts in the following way: The human mind creates by free thinking systems of mathematics which are the most important tool for the physical sciences.

In thinking, I feel directly, intuitively, a creative activity of my own being, which I call mind, soul, or spirit, a reality different from the material realities. My soul is filled with sensations, feelings, will impulses, imaginations, memories of the past, ideals of the future, daily and religious experiences. The spirit of man is consciously or semi-consciously creative, his life is a creative evolution; science, ethics, art, philosophy and religion are the free creations of man's spirit. Culture in the highest sense is the birthright of the free genius of man, Soul is the realm of freedom, material nature the realm of necessity.

The contrast between spirit and matter appears deeper and deeper with progressing physical sciences. The redness of the rose in my consciousness enters nowhere into the mechanism of nature, neither out there in the rose nor in the nerves of the brain. Nor can culture be deduced from the mechanism of nature.

Naturalistic and materialistic philosophies maintain: *"nihil quod in intellectu quod non in sensu,* nothing is in our mind or intellect except that which entered through the doors of the senses." But the existence of mathematics proves this statement to be wrong. It is more nearly true to say: mathematics begins where our sensations cease. A function for instance which is continuous in every point, would be expected to have a derivative, according to our sense experience, even to our intuition. But this is not so. The mathematical thinking power of the spirit is far more powerful than sense perception and even intuition. Mathematics uses, for instance, conceptions like convergence to which there corresponds no sensation, and for which there exists not even a symbol. Finally, all the complicated operations of mathematics cannot be learned from nature, as can for instance, the plant species in Linne's system.

If the naturalistic philosophy were true, we might hope to learn mathematics by investigating the physico-chemical processes of the brain, but conversely, we can only study these material processes by means of mathematical tools. That a system of theorems like that of mathematics built over a period of two thousand years can

exist, that sciences like astronomy and physics may live and grow from generation to generation in spite of the continuous changes of the human brain, with all its instabilities, in spite of the instability of the scientific, social and political institutions of the human race, this invariable rock in the stream of the phenomena is due to the human spirit, its free creative power, and its invariable laws of thinking. As the waves of the ocean cross and interfere with each other, so the ideas in the tempest of excitement, in the tumult of the revolutions may cross each other in a wild dance, giving rise apparently to endless confusion; yet man can make use of his sovereign power in controlling that storm of ideas, and correct his mistakes. A machine, however, makes no mistakes and can never examine itself with respect to truth or falsehood. Mathematics is not based on sense experience, Nevertheless physical phenomena may make suggestions for new mathematical problems; but the solution of these problems also is not found by observation, but by thinking. As a matter of observation one and one is not always two.

Thinking is a free act of our mind, yet thinking is not arbitrary; it follows definite rules of logic. It looks as if the thinking spirit itself were determined by its own laws. But in thinking I feel no tyranny of logic; while, in hunger, I feel the tyranny of the body. I use logic; logic does not use me. I obey the principles of logic freely. Free obedience is an act of my own choice. Finally, though there is logic with its principles, yet there is no logical theory of thinking in the sense that if a new question or problem arises, I might go to an expert of logic who would tell me how to think in order to solve the given problem. A mathematician who has a problem to solve does not seek help from a pure logician. Each problem requires its own specific thinking, which in each case is an act of freedom, yet requires determination.

In my consciousness I find apparently two conflicting categories: *thinking* which demands necessity, determination, and *the moral voice,* which demands freedom of choice. Character, personality, ethical independence, presuppose freedom. A projectile fired from a gun follows its course determined by inexorable law. There is no moral virtue or crime in it. Its course is completely determined and expressed by differential equations in physics. On the other hand, we blame and punish the gunman who fires the shot at another man, because we feel that some element of choice or free will was in-

volved in his conduct. But do we not praise a patriotic soldier in war who shoots an enemy? This question we will consider in a further study. We are convinced that ethics is possible if there are numerous points of experience, in which a genuine choice is possible. That a person in many ways is subject to natural law, is not inconsistent with the development of character. That our body is subject to the law of gravity, does not interfere with ethical character, nor does the fact that light is refracted in our eyes according to the principles of geometric optics. Indeed law and order in the body and its environment is necessary for the stability and reliability of character. But it is equally necessary that man shall not be subject to a complete determination. There must be room for real choice. We seem to have arrived at contradictory conclusions: Science and logic demand necessity, the law of nature; ethics, on the other hand, freedom of choice. And my conscience and consciousness do not allow me to sacrifice one at the cost of the other. I seem to be forced by myself and against myself to live in this world of duality. A duality, resisting all efforts at unification seems to run throughout all nature. Positive and negative electricity, which play such an assymmetrical role in the heart of the atoms, acids and bases in chemistry, male and female individuals in the living world, mind and matter, rationalism and irrationalism in philosophy, are examples of this dualism.

Dualism may be unsurmountable, but in the dilemna of freedom and necessity, modern science itself, the fortress of necessity opens the doors of freedom.

Science requires the existence of comprehensive natural laws and ethics demands a significant measure of freedom of choice for the development of character. Both requirements may be met, without interference of the other, if a certain range of phenomena is determined by inexorable law, the laws of nature, while under other significant circumstances natural phenomena are amendable to direction by the mind, so that the course of events is not subject throughout to a mechanistic determination. The existence of science and moral character in our world shows indeed that the phenomena of the world are in some way consistent with both necessity and freedom.

The laws of nature appear mostly in the form of differential equations, the solutions of which are not determined by the differen-

tial equations alone. We have to add to these equations certain information about the state of phenomena at a certain instance or about the states at a certain succession of instances. Now if the initial condition of the system is given and we follow up the successive states of the system, then two sorts of events are logically and physically possible; either the successive states are uniquely determined by means of the equations and the initial conditions, or we reach a certain state of indetermination where the previous states leave the next states undetermined. Here the laws of mechanics alone are insufficient to determine the following course of events. Some directive agency, the will or the mind, seems to be necessary to give rise to further activity, and the next course of events is determined by this directive agency.

As a first argument in favor of freedom we consider the case of unstable equilibirum, which occurs over and over again in the physical sciences. A mathematical or physical pendulum is allowed to carry out oscillations in a vertical plane under the influence of the gravity of the earth alone. Let us suppose that it has received sufficient kinetic energy to enable it to reach the highest point so that the center of gravity is exactly vertically above the axis of rotation. It will arrive in the highest point with zero velocity. There it will stand still. An immeasurably small impulse will make it fall toward one side or the other. The necessary impulse is so small that it can not be detected or measured by physical instruments. And the differential equation of motion tells us nothing of what will happen after this unstable equilibrium is reached. Symbolically we may represent the known evolution of the earth by an arc of the pendulum motion. If, then, we know the laws of the phenomena in this limited region, we can draw no conclusion as to the future history of the earth. A famous mathematician said: "Give me the differential equations and the initial conditions of the world, and I will tell you the future history from moment to moment." This claim is not justified by modern science. Whenever an unstable equilibrium is reached, the differential equations cease to describe the future course of events. Moreover, we can never know the initial conditions of the world by the empirical methods of natural sciences. Therefore, the statement of the French mathematician, Laplace, is meaningless. Again, a complete description of the phenomena of the world require a very large if not an infinite

number of differential equations, which could not be solved. Finally, if we consider the universe as finite, then it is in its totality not determined by external conditions; all its phenomena are only determined by internal conditions or it is the expression of free action. If the material universe is infinite in space and time, then the question of its determination becomes meaningless. Instabilities occur everywhere. In the problem of three bodies, there are positions of unstable equilibrium for one body; and, with increasing number of particles, the number of unstable positions increases. There are unstable rotations also. If a particle moves in a channel which branches into two or more arms, its motion at the branch point may become indeterminate. If a sphere falls along the axis of a cylinder filled with water, the motion is indeterminate; the sphere may in any point leave the axis and move toward the wall of the cylinder. Very small particles even in air do not fall in a straight line, but along a zig zag path. In all cases of unstable equilibrium the differential equations of motion cease to determine the next course of events, the principle of conservation of energy is satisfied, even if an immaterial agency, the will or the mind, gives direction to the future course of events.

The second argument in favor of freedom is given by the theory of heat. All phenomena connected with changes of temperature take place in a certain direction. Just as water under the influence of gravity alone flows always downward, so heat by itself sinks from a higher to a lower temperature. At the same time, a certain quantity, the entropy, increases; and the theory shows that this quantity is proportional to the probability of the state of the heat system. All heat phenomena are, except for limiting theoretical cases, irreversible and the phenomena of the known material universe take place only in the direction of increasing probability. Now let us, with Maxwell, consider a vessel filled with a gas of a given temperature and having a partition with two doors, one opening into the first chamber, the other into the second chamber. If a demon opens one door when a fast moving molecule arrives and if another demon opens the other door when a slowly moving molecule arrives, then by and by all the fast molecules will be in one chamber, the slowly moving molecules in the other. Then the temperature, which in the beginning was the same in both chambers, will be higher in one chamber and lower in the other. This process contradicts the funda-

mental law of thermodynamics, or the second law of heat phenomena. If the doors are in neutral equilibrium no work will be required for the demons to open and close the doors. In other words, microscopic agencies doing no work, are able to reverse the general course of those natural phenomena, which are not necessarily determined, but only probable.

From time to time, unexpected and unexplained explosions occur in stores of high explosives. The theory of probability as well as the Brownian movement show that in rare instants molecular movements of an amplitude may occur, so large that a local chemical reaction of unstable compounds takes place. Once started in ever so small a region, the reaction will spread rapidly and the whole powder magazine explodes without any assignable external cause. Such spontaneous reactions resemble the submicroscopic events in the living cell which, though of immeasurable size, are able to control microscopic and macroscopic events. And, just as stores of explosives explode every now and then without an external cause, so the living powder magazines, the armies and navies of the world, explode from time to time without any external cause and with any internal excuse. Then a couple of men, in strategic positions, may lead millions of men to death and whole countries to ruin. But here the voice of freedom of mankind demands the abolition of the powder magazines living and non-living.

Necessity excludes freedom, probability leaves room for freedom. And probability enters not only in the molecular phenomena of heat and chemistry, but also in the atom itself,—for instance, in the spontaneous radioactive transformations. It is even thinkable that all laws of nature can finally be reduced to probability. The smaller and more numerous the bricks of the material universe become, the wider the reign of probability and the greater the chance for freedom. The creator has perhaps given to matter such a fine structure that the living creatures, especially man, may enjoy a high degree of freedom.

The next argument I take again from mechanics and the quantum theory. In our human life we act for the realization of certain purposes. We try to realize certain ideals, we work and live "subspecie eternitatis," we try to bring about a better human society, we try to abolish old traditions, and create new and better conditions of life. We are not slaves of the past, but dreamers and

workers for a better future. We act, not only driven by causes of the past, but also driving toward the realization of purposes which lie in the future. Our will power becomes a cause itself. This action into the future is called teleology. It points in the direction opposite to that of causality. Teleology appeals to our free will. In spite of the causes of the past, in spite of tradition and environment we are about to realize a different and better future. Now it is very interesting to find that even the laws of nature, especially Newtons laws of mechanics, can be expressed in teleological form. Indeed, the principle of least action seems to reach as far as all reversible phenomena of mechanics, electricity and heat. Every motion takes place with a minimum expenditure of work. The material particles themselves seem to move under the influence of the future. In the principle of least action it is shown that the motion of a particle in a given moment is governed by the past as well as by the future, and whether the past or the future has more weight depends entirely on the time limits, which we can choose arbitrarily. Either the past or the future may have the dominating influence.

In the quantum theory of the atomic structure, this teleological viewpoint has been expressed even stronger. An electron, jumping from one orbit to another, must know beforehand where it is going to land, in order to emit the amount of light required by the theory. But this theory is so fragmentary, temptative and changing, that we will not further insist on it.

To this last argument we shall add a general remark on causality which, if not a new argument in favor of freedom, shows at least that we are not slaves of causality. We have seen that we can look at the laws of nature from the point of view of the past as well as of the future. The law of causality is of our own making. In the history of physics we see clearly two different aspects of causality. From Newton down to the time of Faraday, the natural scientists considered the energies of material and electrical systems as residing in the particles themselves, which were acting at a distance, being imbedded in empty space. But Faraday and Maxwell, being repelled by the incomprehensible idea of action at a distance, considered the ether between the particles as the seat of the energies of the electric and magnetic systems. Matter, i. e., electric charges and magnets were only sources and sinks of lines of forces, or else empty spaces

in the universal ocean of the ether. The causes of the electromagnetic action have been transferred from the material bodies in the ether, or the space between the bodies. Moreover, this field action has been transformed into a pure space action in the modern theory of relativity of Einstein. Here again the idea of physical causality has been changed, as well as the idea of physical reality itself, which seems to become meaningless without an observer. If thirty years ago scientists would have asserted that masses change in motion itself, they would have looked for the change in chemical or heat processes. But now we declare that a mass changes for some observer only because the velocity of light is constant and because we can detect and measure only the relative velocity. Again, in general relativity the idea of force has disappeared, and dynamics becomes mere kinematics, in which merely the uniqueness of temperal succession of phenomena is the expression of physical causality. So we see that the idea of physical causality changes in the course of time, with our changing theories; but the idea of physical determination we maintain as the law of thinking.

Action at a distance is incomprehensible. But just as incomprehensible and nonintuitive is the field action. Indeed, how does a particle change the space-time of its neighborhood? One riddle is replaced by another one. The mathematical forms of the laws of nature are merely rules of calculation, which give no insight whatever into the mechanism between the particles. Necessity in nature remains a mystery or a riddle. If in my free will I move the finger and the pen, wishing to express freedom, the action of my will on my body is not more or less a mystery than the effect of gravitation.

No matter how far the natural sciences have succeeded in demonstrating in some realm of phenomena the rule of necessity, we could always imagine a determination to exist which is stronger than that really observed. For instance, let us suppose that the sun sends out shafts or darts of light at random in all directions of space; then most of the energy radiated would be lost, while only a small part strikes the earth and the other planets, where it may be absorbed or reflected. Now suppose that the atoms of the sun know beforehand all the particles of the planets and that they send out the light particles, at such moments and in such direction that an atom of a planet can just catch them. In this case we would have a

physical predetermination which is stronger than the physical determination so far used in our theories. Thinking is of a finer order than observation, and mathematics begins about where sense observation ceases.

The arguments here advanced in favor of freedom do not prove absolute freedom; but I hope they show that even science, especially theoretical physics and chemistry, the old fortresses of necessity, leave the door open to freedom.