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CHAOS

THE STRANGE ASPECT OF NATURE

WORKSHOP ON HISTORY OF SCIENCE

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In Memoriam

Professor Shankar Sevak Baral, former head of the Department of Electronics & Telecommunication Engineering of Bengal Engineering College, Shibpur, passed away in the month of August this year. He left behind a rich legacy of single-minded devotion towards education and society.

Born in 1917, he did his schooling in Chandannagar, B. Sc. from Vidyasagar College, Calcutta, and M. Sc. in Physics from Calcutta University. He then worked under the guidance of the renowned scientist Prof. Sisir Kumar Mitra for his doctoral work. The quality of this work was so good that he was awarded the degree of D. Sc. in 1954.

He joined the Bengal Engineering College in 1956 and remained there till his retirement in 1979. In this era of rapid progress in the electronics science and its applications, he sensed the importance of this emerging discipline at the right hour and founded the Deparment of Electronics & Telecommunication Engineering at B. E. College in the year 1967. Till his retirement he was the head of the department.

For those who knew him, Prof. Baral was like a father-figure in the classes. His seriousness in teaching, his love for students and his unbending commitment towards the academy made him dear to all in the campus.

He strongly believed in the ethics of science that science & technology are meant for the welfare of the society and not merely for individual's career. *Breakthrough* found in him a patron of its science-ideals and had the privilege of having him in the Advisory Board from the inception of the journal.

Coming, as he did, from the academic arena into the field of engineering education, he strongly resented the neglect of study and researches in fundamental problem-areas of S & T. Moreover, he felt, that science and technology is and should for man's welfare, and must not be geared to destructive purposes.

Once, speaking at a seminar organized by *Breakthrough* in Calcutta against the installation of missile base in Baliapal, he unequivocally criticised the warlordish attitude of the Indian Government in building up formidable military might while the people remained unfed, unclad, and illiterate.

We, on behalf of *Breakthrough*, deeply mourn the demise of such an examplary academician and hope that his life will act as an example for the younger generation of scientists and technologists in our country.□

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CHAOS:
A Strange Aspect of Nature

Ranjan Mukherjee*

1. INTRODUCTION

A leaf floats down a stream in what seems to be a perfectly ordered fashion. Suddenly it gets trapped in a whirlpool that might exist in the stream. Its motion becomes complicated. Even an infinitesimal change in the position of the leaf as it enters the vortex would change the path or trajectory of the leaf. The motion is extremely sensitive even to very small perturbations. A slight difference in initial conditions would keep escalating at an exponential rate, and soon result in a totally different behaviour. All predictive power is lost. It is this sensitivity and unpredictability that is the hallmark of chaos.

Order and chaos are two aspects of the universe in which we live. Yet since, particularly physics, has always been preoccupied with order. Chaos was considered to be some sort of an anomaly, something not worth studying. Hence natural sciences have become associated with stability and order, the stability which is symbolized by the simple pendulum oscillating to and fro with clocklike precision. Nothing new or unexpected can occur in such stable systems.

Not all systems are stable. A pencil balanced on its tip is an example of an unstable system. A slight fluctuation in its position would make it fall. But this is an example of short-lived instability leading to another stable state. However, chaos is a persistant instability — instability not just at one instant, but instability which is present throughout the evolution of the system.

The study of chaos is a relatively recent enterprise. Simultaneous developments in abstract mathematics and the rise of the computer have made such studies possible. This, added to a realization that a large class of systems can exhibit chaotic behaviour, has generated a lot of interest in this subject. The study of chaos is compared to a river fed by different streams — the various branches of natural science, engineering, economics, mathematics and computer simulations.

2. UNIVERSALITY OF CHAOS

Chaos is universal. One can find chaos in the changing populations, in the electric signals of the brain, in the way a disease spreads. Chaos occurs in the motion of atoms and molecules in the complex systems. It is present in the turbulent flow of fluids and in chemical oscillations. Stars within a galaxy can exhibit chaos. Chaos is observed when trying to make weather predictions. Engineers find chaos interfering with their designs.

Even very simple systems can exhibit chaos. You might have observed a dripping tap. The water drops fall after regular inter-

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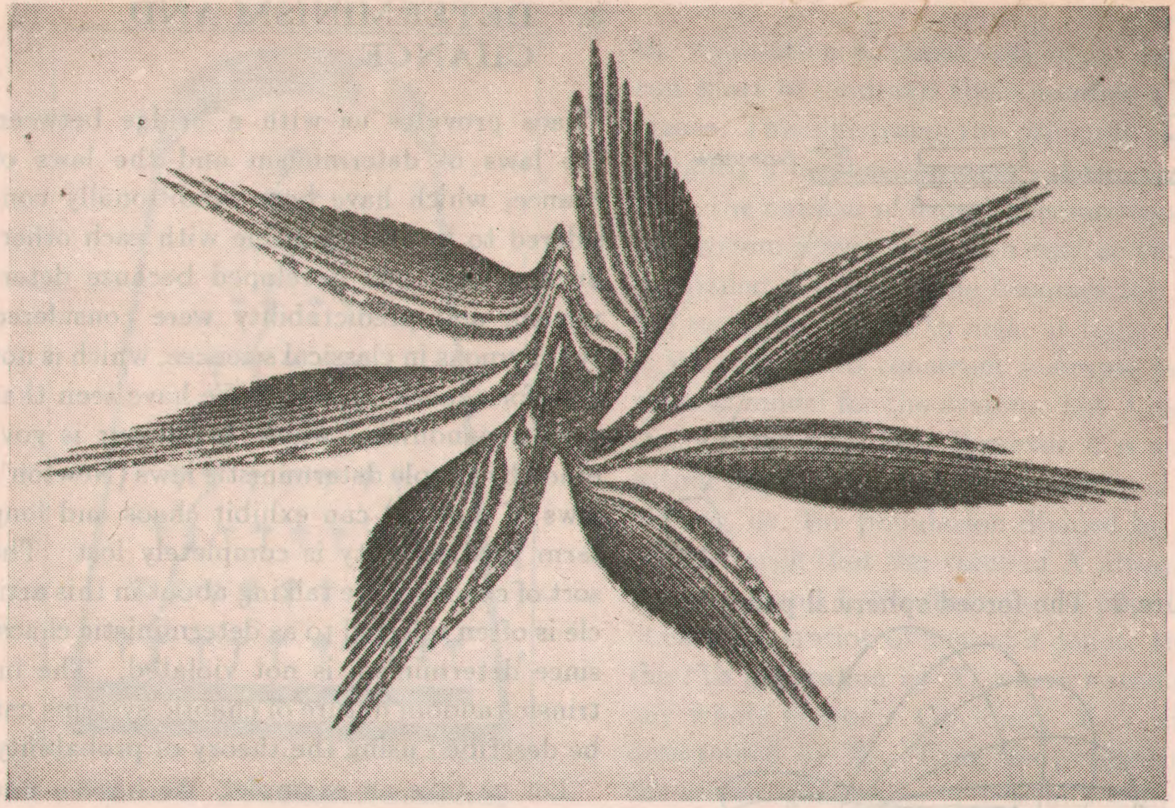


Figure 1: Chaos is beautiful. Points moving around chaotically according to a formula by I. Gumowski and C. Mira have generated this highly ordered structure. (From New Scientist, 21 Oct. 1989)

vals like the tickings of a clock. Let it drip faster—this regularity is lost—the rhythm has become irregular and chaotic.

Think of a pendulum with a bob that is attracted equally to two magnets below it. When the bob moves slowly close to a point midway between the two magnets, it is affected almost equally by the force from each magnet. Its future motion is extremely sensitive to small changes in its present position and velocity. Typically the error in measuring its position may increase ten times in one swing. To predict its position to within one centimeter after nine swings, we have to measure its initial position to within the size of an atom. No long term predictions are possible.

Take another very simple system, a simple pendulum suspended from a shaft which moves to and fro with a given frequency (fig. 2). This includes an oscillation of the pendulum with frequency of the shaft. We expect the pendulum to oscillate in the direction of motion of the shaft and this is usually what happens. But not always. Let us observe if the frequency of the shaft lies in a narrow range just below the natural frequency of the pendulum. (A freely oscillating pendulum oscillates with a fixed frequency independent of the amplitude of oscillation, provided the amplitude is small. This frequency is called the natural frequency). Here the oscillation of the pendulum in the direction of motion is an unstable motion, and

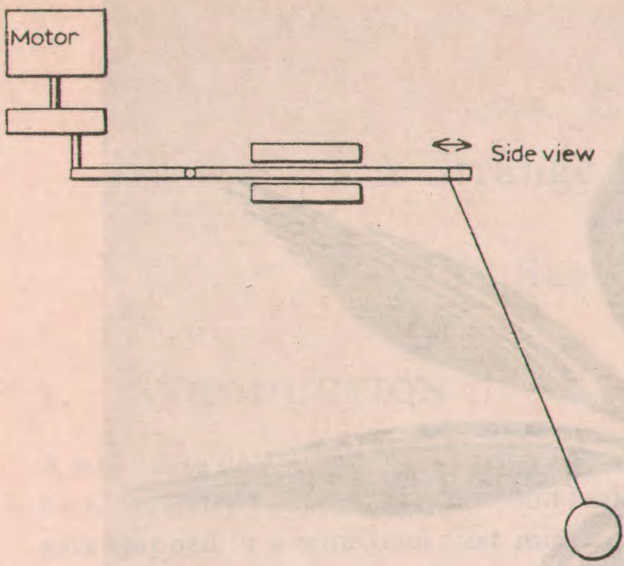


Figure 2: The forced spherical pendulum.

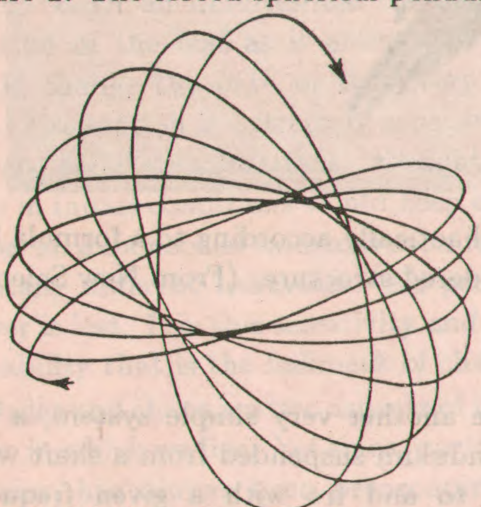


Figure 3: Motion of a pendulum bob. (From New Scientist, 24 July 1986)

the slightest fluctuations get amplified. The motion becomes extremely complex, and can be thought of as a sort of elliptical motion, but with the orientation and shape of the ellipse changing continuously (fig. 3). The pendulum keeps switching between clockwise and anticlockwise motion at random and it is not possible to discern any pattern in the behaviour. Everytime we try the experiment, we get a different motion. The behaviour is chaotic.

3. DETERMINISM AND CHANCE

Chaos provides us with a bridge between the laws of determinism and the laws of chance, which have been traditionally considered to be incompatible with each other. Such a view had developed because determinism and predictability were considered synonymous in classical sciences, which is not true for chaotic systems. We have seen that even a pendulum, whose behaviour is governed by simple deterministic laws (Newton's laws of motion) can exhibit chaos and long term predictability is completely lost. The sort of chaos we are talking about in this article is often referred to as deterministic chaos, since determinism is not violated. The intrinsic random nature of chaotic systems can be described using the theory of probability.

Let us take an example. We have a pinball game, where pins are placed in a regular arrangement on an inclined board (fig. 4). On top we have one pin, then two pins below it, then three pins and so on; a triangular arrangement with a horizontal base. If a small ball is released from just above the topmost pin, it will hit the top most pin and be deflected to the left (l) or to the right (r). It will hit one of the two pins of the second layer, and again be deflected to the left or right. Let's say the bottom-most layer consists of some twenty pins. It is impossible to predict which of the twenty pins the ball is going to hit. However, definite probabilities can be associated with the ball hitting any particular pin. The probability will be proportional to the number of paths the ball can follow whose final outcome will be hitting that particular pin.

This relationship between determinism and chance is extremely important in statistical mechanics, which studies the relation-

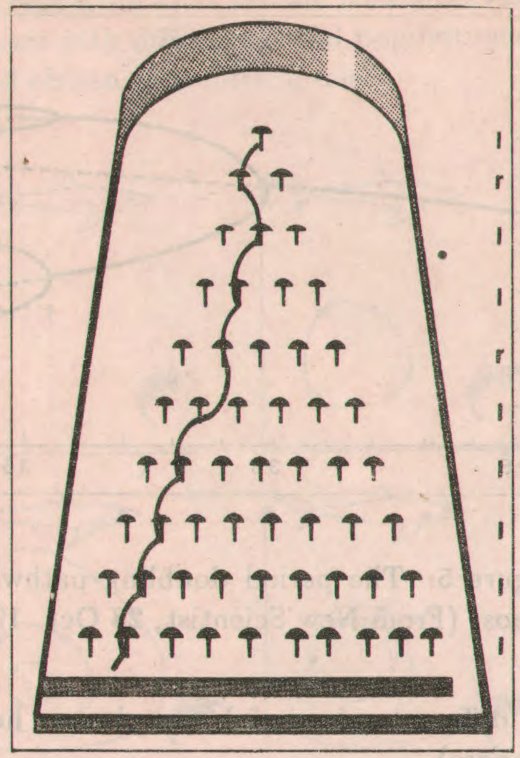


Figure 4: The pinball machine.

ship between the macroscopic properties of an object and the behaviour of microscopic particles constituting the object.

4. PATHWAYS TO CHAOS

What are the types of systems that can exhibit chaos? One of the primary requirements is that the system must be nonlinear, that is, the rate at which the variables (characterizeng the system) change does not depend linearly on the cause but is a more general function of it. The equation governing the way the system changes with time must be a nonlinear one.

Let us cite a simple system which is nonlinear. Consider the population of fish in an idealized lake, free from outside interference. There are no fishermen and no external pollution. If to start with, we have small number of fish, they will keep multiplying and the population keeps expanding. However if the population becomes very high, they will run short of food and their number will decrease. This illustrates the principle of what is called a feedback system—if the variable (e.g., the number of fishes) becomes too large the system moves in such a way as to make it smaller; if the variable becomes too small the tendency will be to make it large.

We can try to construct a simple mathematical model for the system. Let X denote the population of fish. However X is not the actual population, but the normalized population, i.e. the population divided by some number such that the value of X always lies between 0 and 1. We find out the population of each generation of fish, and denote that of the t'th generation by X_t where t stands for any whole number. Obviously X_{t+1} will be determined by X_t. Thus the population of the second generation is determined by that of the first, the population of the third by that of the second and so on. The relation between X_t and X_{t+1} can be expressed by an equation of the form

$$X_{t+1} = \lambda X_t(1 - X_t)$$

Where lambda is a constant which can have values between 0 and 4. Generally, if X_t is small, $(1 - X_t)$ will be large and hence X_{t+1} will be larger. Again, if X_t is large, X_{t+1} will be smaller. Thus the feedback principle has been incorporated in the equation. And, of course, the equation has a nonlinear form i.e., it can not be represented by a straight line.

If λ is less than 1, we find that X settles down to the value 0. Whatever be our initial population, the population tends to die down. This means that the conditions are not favourable for the fish to survive.

Take the value of λ to be 2. We find that after a few generations X tends to settle down to the stable value of 0.5. It is easy to verify that if $X_t = 0.5$, then $X_{t+1} = 0.5$. That the population should settle down to some stable value is what we would usually expect for this type of a feedback system. Everything is fine.

Now take λ around 3.2. We start with some initial value and observe how the population behaves after a few generations. Strangely X keeps oscillating between two values around 0.5 and 0.8 and does not settle down to one stable value. But this oscillation is stable, and does not die out. That means if the population of one generation is high, that of the next will be low, then again high and so on.

Keep increasing λ and we soon find X to be oscillating between four values. At still higher values of λ this becomes 8 and then 16, 32 ..... Thus at $\lambda = 2$, the same value of X was obtained after every step. Around $\lambda = 3.2$ this occurs after every two steps, then after every four steps and so on. This phenomenon is called period doubling. At $\lambda = 4$, the period has become infinity—the same value never repeats. No stable behaviour is exhibited at $\lambda = 4$ and we have chaos. We go from the order regime to the chaotic regime through a process of successive period doubling (fig. 5).

The above discussion may appear to be very idealistic—something of a pure mathematical pursuit. But many phenomena around us exhibiting chaotic behaviour actually go through similar pathways to reach the chaotic state. The period doubling route to chaos is quite universal. Universal mathematical properties characterize such systems, independent of the specific equation governing their evolution.

(Anyone who has access to a computer can actually try to feed in some value of X for different values of λ and observe how X changes).

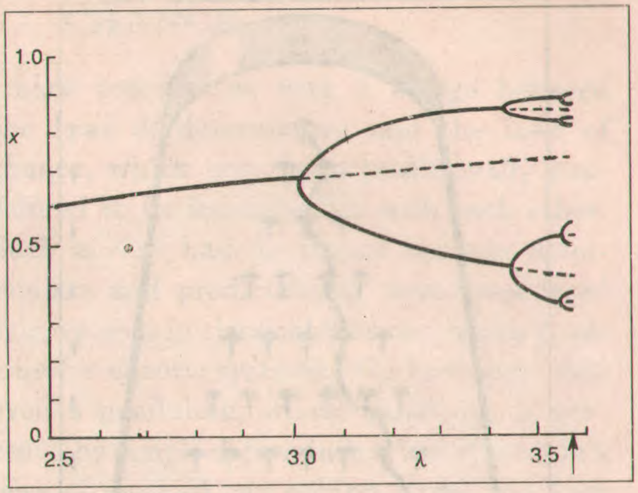


Figure 5: The period doubling pathway to chaos. (From New Scientist, 28 Oct. 1989)

5. PORTRAITS OF CHAOS

Think of a more complicated version of our earlier model. We have a sea of sharks and shrimps, with the sharks feeding on the shrimps. Initially there are a lot of shrimps and few sharks. The sharks keep gobbling up the shrimps and the number of shrimps goes on a rapid decline. But when the population of shrimps becomes small and the sharks have multiplied, the latter run out of food and their number starts decreasing, the population of shrimps increases. This system is characterised by two variables — the population of shrimps and the population of sharks. We can draw a graph of one of the variable versus the other (fig. 6). The system at any instant would be represented by a point on the graph; its evolution with time by a line. Volterra, who studied this system obtained that the populations would keep varying cyclically which would be represented by a circle on the graph. The populations would keep repeating after certain time interval. If we start with different initial populations we would obtain concentric circles.

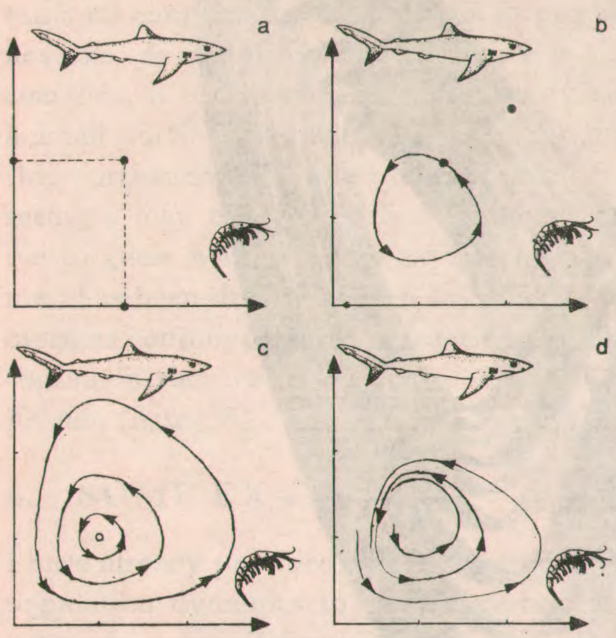


Figure 6: The graph of shark versus shrimp populations. (From New Scientist, 4 Nov. 1989)

However Volterra's model is not very good. In practice the shark- shrimp population would settle down into one stable cycle, represented by a particular circle on the graph. If the initial populations do not lie on this circle, they would spiral towards it. Such a cycle is said to be an "attractor" (we had earlier encountered another type of attractor— for fish in pond with $\lambda = 2$; the state $X = 0.5$ represented an attractor. It is a steady state attractor, because once this population is reached the system does not change with time).

To generalise these ideas I will introduce a few terms. Generally a system can be completely characterised by specifying the values of a set of variables; the minimum number of variables which need to be specified are said to represent the state of the system. If the state is specified at any instant of time, the future behaviour of the system is uniquely determined. For example, in the case of fish in a pond the state is specified by the value of population of fish. If there are sharks and shrimps, their populations are the two variables to be specified. In classical mechanics, the state of a particle is represented by six variables; three to designate its position and three its velocity.

Again mathematicians use the word 'space' in a much more general sense than we are accustomed to using. For a mathematician, space simply means a set of objects of a certain kind. He can talk of the space of polynomials for example. The concept of 'space'. that we are accustomed with is simply a set of three perpendicular lengths — the x, y and z coordinates. But that can be more generalized. Thus we can imagine a 6-dimensional space whose coordinates are the states of a particle, representing its position and momentum. The space of all states of any system is its state space or phase space. For a more geometrical description we focus on the variables that determine the state. Thus for the shark-shrimp system the phase space is the graph of the two populations that I have already referred to any point in this space represents a particular state. The way the system changes with time is represented by a line (the path or trajectory of the system) in the phase space. Thus I can draw different trajectories for different initial states which together constitute the "phase portrait" of the system. In this way we can give a geometrical character to its behaviour.

For a large class of systems we find that irrespective of the initial state, the system settles down into a particular state or cy-

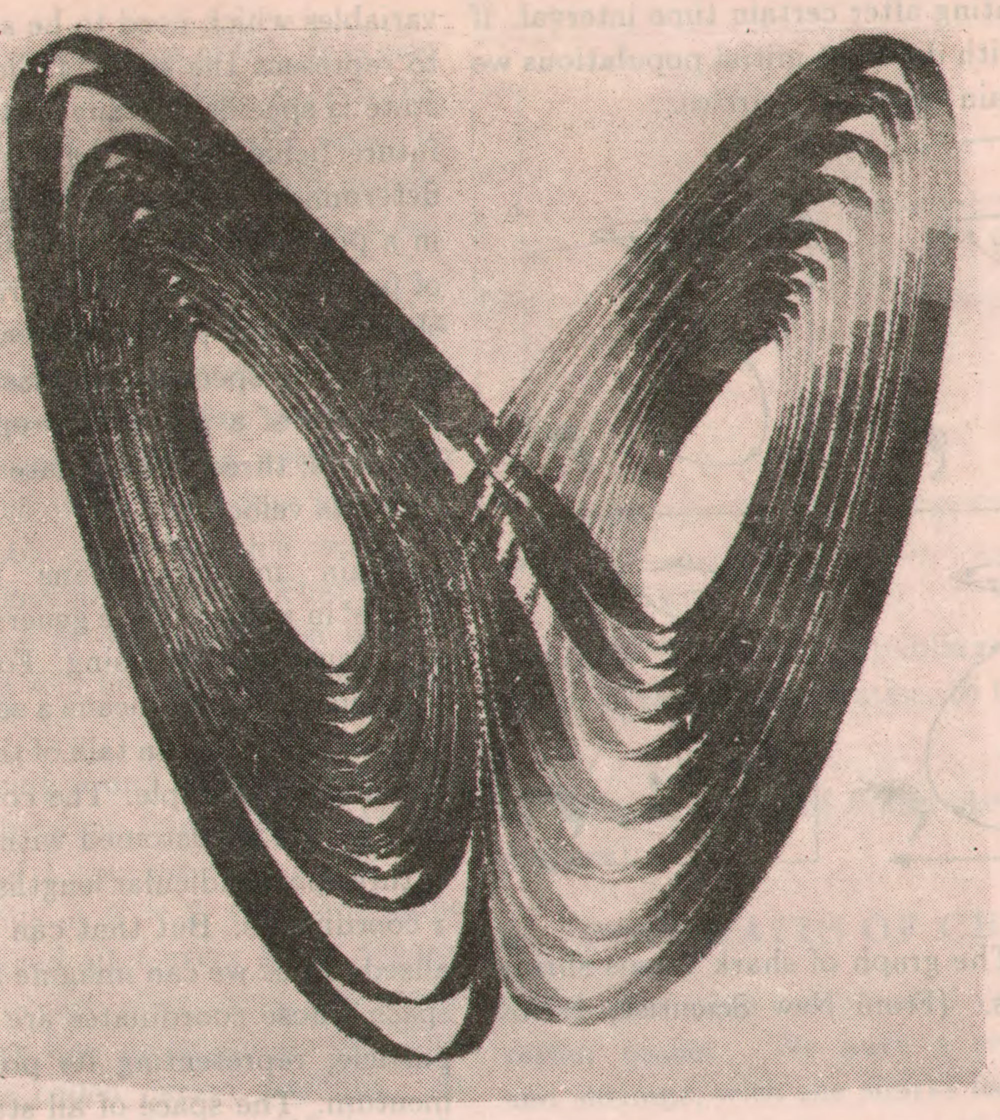


Figure 7: The Lorenz Attractor. (From New Scientist, 4 Nov. 1989)

cle. Such a cycle or state is said to be an attractor. Attractors can be steady-state or periodic or quasiperiodic. [1]

Traditionally these were the only types of attractors considered. Recently, however, "strange attractors" have been discovered which are common but not well understood. They do not correspond to any such simple trajectory. One of the most well-known examples is the Lorenz attractor (fig. 7). It looks like a mask with two eyeholes. This type of an attractor is associated with chaos. How? There is an infinite amount of complexity between the two eyeholes, so that in general it will not be possible to predict whether the system will go around the left eyehole or the right. Two points close to each other will in the long run follow totally different trajectories.

This attractor has a complete structure on any scale of magnification; there are infinitely many layers. Such infinitely complex geometrical objects are termed as *fractals*. Our usual notion of an irregular curve is that

[1] The earth revolves round the sun and the moon revolves round the earth. Think of the moon's motion about the sun. This sort of motion, which may not itself be periodic but can be broken down into periodic motions is said to be quasiperiodic.

if it is enormously magnified, the irregularities smoothen out and a portion of the curve begins to look like a straight line. But a fractal is self similar—it looks the same and retains its complexities at all levels of magnification. A commonly given example is the coastline, it looks like a broken curve. Take a small portion of it and magnify it. Again this portion looks like a broken curve. By seeing a map of the coastline it is impossible to guess what is the scale at which the map has been drawn. we can say that irregularities contain further irregularities, which contain further irregularities and so on *ad infinitum* (figure 8).

6. SOME EXAMPLES

I have already provided some examples from population dynamics to explain certain aspects of chaos. However they are not very good practical examples because it is very difficult to obtain such isolated systems. There is a lot of debate about whether chaos is observed in changing populations and how to distinguish chaos from external disturbance.

The heart generally beats regularly, but sometimes there are alternate long and short gaps between the beats. In yet more extreme conditions, the rhythm becomes irregular. A small change in the timing of one beat makes a bigger change in the next. The beating becomes chaotic, and may threaten survival.

Chaos in heartbeats occurs due to the complex interplay between two frequencies—one of the external impulse which pumps the heart; and the natural frequency of heart cells which themselves keep "beating". And the rhythm changes from periodic to irregular—through the same period doubling cascade discussed earlier.

Researchers have found the presence of strange attractors in the way an epidemic spreads.

There has been a lot of debate about the accuracy with which weather predictions can be made. A meteorologist, Edward Lorenz, at the Massachusetts Institute of Technology, USA was studying general properties of weather systems. He found that they display chaotic behaviour. The atmosphere is heated more at the equator and is colder at the poles. If earth had been stationary, stable convection currents would have been set up between the poles and the equator. Because of the rotation of earth the currents however get deflected. We have a rotating fluid system heated at some areas and cooler at others. This system is unstable. Lorenz found the presence of a strange attractor in the behaviour which is the Lorenz attractor. So we can never predict exactly what the weather will be after some long period of time. There is an intrinsic probabilistic element in the long range weather predictions. We can however talk about global changes in weather pattern (such as the green house effect) where we are talking about how the shape of the attractor is going to change.

Chaos has applications in engineering as well. A ship moves in the sea, buffeted by waves. If the ship is tilted from vertical position it will tend to return to this position. This is something like a ball, put in a valley surrounded by hills. If the ball is displaced slightly from the valley, it will again settle down in the valley. However hills have a finite height, if the ball crosses the hills it will go over to the other side and will not return to the valley. Thus we have two attractors, one corresponding to the valley and the other at infinity. For the ship, the attractor at infinity correspond to disaster. There is certain domain of each attractor known as basin

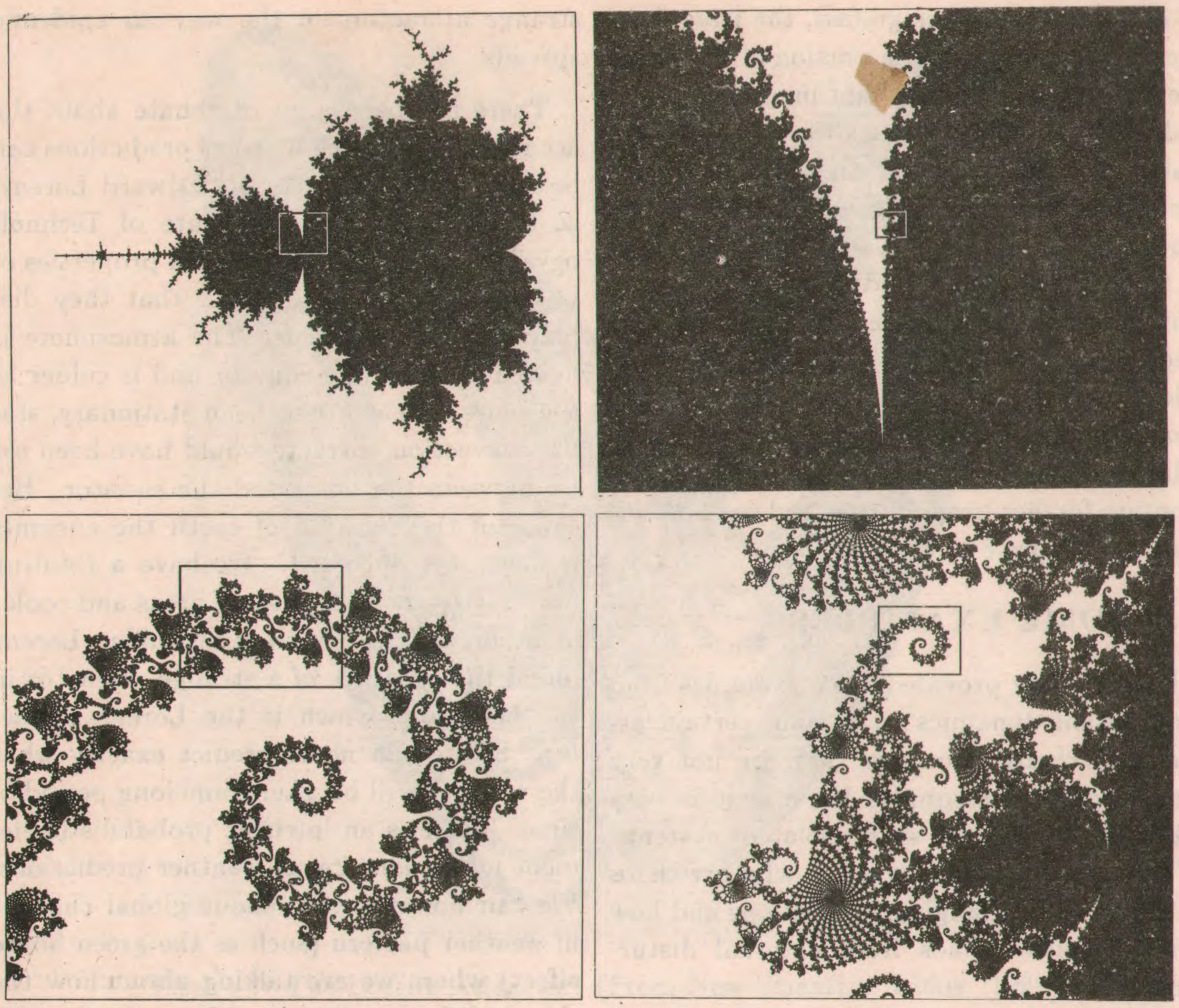


Figure 8: Successive magnifications in a fractal reveal more and more complexities. It is strange that the real world does indeed follow such beautiful patterns.

of the attractor; all points starting from the basin will go over to the corresponding attractor.

Now, the ship is hit by waves of some frequency. If we keep changing the frequency there is a certain range where period doubling is observed and the attractor (corresponding to the valley) becomes chaotic. Adjust the frequency further, the attractor disappears altogether, now no position of the ship is safe.

But this is not the only important point. What is also very important is the shape of the basins. The basin at infinity might keep making inroads into the basin of the "valley", the boundary between the two being fractals. And if the basin at infinity makes inroads into the valley, precariously close to the central attractor, the situation is dangerous.

Engineers need to have a feel for the stability of their structures under different conditions. It is in this respect that the theory of chaos and geometrical notions can be very useful for an engineer. ◇

MANGANESE NODULES: A RESOURCE FOR THE FUTURE

Subhasis Mitra

More than a century ago the Research-ship 'Challenger' of USA discovered and reported brown to black nodular objects scattered over a wide area of the deep ocean floors. Many subsequent research cruises confirm that these nodules wit ı the same range of size and shape as potatoes are densely concentrated in many ocean basins, at water depths of 4-5 km. Due to abundance of two common metals—Iron and Manganese in them, these nodules are commonly referred to as Ferro-manganese nodules or simply manganese nodules.

Recently there has been increasing attention and interest in many countries including ours directed towards mining of nodules from the ocean floor. It is not a technological luxury but a necessity, as we are really concerned about the long term availability of many metals from the existing land based resources which are first depleting. For example, the reserve of copper on land is perhaps just enough for anothei forty years only. We can appreciate this critical situation from atleast one simple fact that electrical industries are now replacing copper more and more by aluminium. This is exactly where the significance of ocean-floor nodules lie. Their importance is not because of the Fe and Mn content at all, but due to the content of other metals such as Copper, Nickel, Cobalt, Zinc in significant though small quantities. It is estimated that one dredge could supply the United States with half of its manganese demand, all of which is imported at the present time.

These manganese nodules formed from discarded wastes of bacteria are very abundant as a commercial ore. The Pacific Ocean is said to contain the richest known deposits of manganese nodules (also called polymetallic nodules). The Pacific nodules also contain larger amounts of valuable metals in comparison to what is found in other oceans. The average content of 4-metals in Pacific nodules is Mn=24.2%, Cu=0.53%, Ni=0.99%, and Co=0.35%. These percentages may as such appear unimportant but the total amount of metal available from pacific deposits would be tremendous. One estimate goes as follows: $Mn = 400 \times 10^9$ tonnes; $Cu = 8.8 \times 10^7$ tonnes; $Ni = 16 \times 10^7$ tonnes; $Co = 6 \times 10^7$ tonnes.

Indian ocean nodules possibly rank next to the pacific ones. The metal contents in them are: Mn=16.26%; Cu=0.1-1.2%; Ni=0.6-1.2%; Co=0.1-0.4%. India has recently made enormous progress in the survey of polymetallic nodules from different prospective areas of Indian Ocean. A good mining site should have a nodule density of atleast 5 Kg/sqm with a total concentration of Cu, Co and Ni of 2.5%. India has already been able to locate a suitable area in central Indian Ocean where ocean floor mining is considered feasible. It is generally agreed that the future exploitation of nodules will depend heavily upon the development of ocean science, engineering and technology for working and living under the sea. However, to utilize these capabilities for the benefit of man would require solving the political, economic and legal impediments — some national and some international in scope — which have heretofore hindered a more rapid development. ◇

Elements	Avg.	Max.	Min.
Manganese	24.2	50.1	8.2
Iron	14.0	26.6	2.4
Silicon	9.4	20.1	1.3
Aluminium	2.9	6.9	0.8
Sodium	2.6	4.7	1.5
Calcium	1.9	4.4	0.8
Magnesium	1.7	2.4	1.0
Nickel	0.99	2.0	0.16
Potassium	0.8	3.1	0.3
Titanium	0.67	1.7	0.11
Copper	0.53	1.6	0.028
Cobalt	0.35	2.3	0.014
Barium	0.18	0.64	0.08
Lead	0.09	0.36	0.02
Strontium	0.081	0.16	0.024
Zirconium	0.063	0.12	0.009
Vanadium	0.054	0.11	0.021
Molybdenum	0.052	0.15	0.01
Zinc	0.047	0.08	0.004
Boron	0.029	0.06	0.007
Yttrium	0.016	0.045	0.033
Lantharium	0.016	0.024	0.009
Yttebrium	0.0031	0.0066	0.0013
Chromium	0.001	0.007	0.001
Gallium	0.001	0.003	0.002
Scandium	0.001	0.003	0.001
Silver	0.003	0.0006	

Pacific Manganese-nodules weight percentage (Dry weight basis). Statistics on 54 samples. *(From Congressional Research Service, Ocean Manganese nodules)* have to be acquired by a sort of special apprenticeship to the craft. To hear all these large words, you would think that the mind of a man of science must be constituted differently from that of his fellow men; but if you will not be frightened by terms, you will discover that you are quite wrong, and that all these terrible apparatus are being used by yourselves everyday and every hour of your lives.

There is a well-known incident in one of Moliere's plays (Le Bourgeois Gentilhomme), where the author makes the hero express unbounded delight on being told that he had been talking prose during the whole of his life. In the same way, I trust, that you will take comfort, and be delighted with yourselves, on the discovery that you have been acting on the principles of inductive and deductive philosophy during the same period. Probably there is not one here who has not in the course of the day had occasion to set in motion a complex train of reasoning, of the very same kind, though differing of course in degree, as that which a scientific man goes through in tracing the causes of natural phenomena.

A very trivial circumstance will serve to exemplify this. Suppose you go into a fruiterer's shop, wanting an apple – you take up one, and, on biting it, you find it is sour; you look at it, and see that it is hard and green. You take up another one, and that too is hard, green, and sour. The shopman offers you a third; but, before biting it, you examine it, and find that it is hard and green, and you immediately say that you will not have it, as it must be sour, like those that you have already tried.

Nothing can be more simple than that, you think; but if you will take the trouble to analyze and trace out into its logical elements what has been done by the mind, you will be greatly surprised. In the first place, you have performed the operation of induction. You found that, in two experiences, hardness and greenness in apples went together with sourness. It was so in the first case, and it was confirmed by the second. True, it is a very small basis, but still it is enough to make an induction from; you generalise the facts, and you expect to find sourness in apples where you get hardness and greenness. You found upon that a general law, that all hard and green apples are sour; and that, so far as it goes, is a perfect induction. Well, having got your natural law in this way, when you are offered another apple which you find is hard and green, you say, "All hard and green apples are sour; this apple is hard and green, therefore this apple is sour."

That train of reasoning is what logicians call a syllogism, and has all its various parts and terms – its major premise, its minor premise, and its conclusion, and, by the help of further reasoning, which, if drawn out, would have to be exhibited in two or three other syllogisms, you arrive at your final determination, "I will not have that apple." So that, you see, you have, in the first place, established a law by induction, and upon that you have founded a deduction, and reasoned out the special conclusion of the particular case. Well now, suppose, having got your law, that at some time afterwards, you are discussing the qualities of apples with a friend: you will say to him, "It is a very curious thing – but I find that all hard and green apples are sour!" Your friend says to you, "But how do you know that?" You at once reply, "Oh, because I have tried them over and over again, and have always found them to be so."

Well, if we were talking science instead of common sense, we should call that an experimental verification. And, if still opposed, you go further, and say, "I have heard from the people of Somersetshire and Devonshire, where a large number of apples are grown, that they have observed the same thing. It is also found to be the case in Normandy, and in North America. In short, I find it to be the universal experience of mankind wherever attention has been directed to the subject." Whereupon, your friend, unless he is a very unreasonable man, agrees with you, and is convinced that you are quite right in the conclusion you have drawn. He believes, although perhaps he does not know he believes it, that the more extensive verifications are – that the more frequently experiments have been made, and results of the same kind arrived at – that the more varied the conditions under which the same results are obtained the more certain is the ultimate conclusion, and he disputes the question no further. He sees that the experiment has been tried under all sorts of conditions, as to time, place, and people, with the same result; and he says with you, therefore, that the law you have laid down must be a good one, and he must believe it.

In science we do the same thing — the philosopher exercises precisely the same faculties, though in a much more delicate manner. In scientific inquiry it becomes a matter of duty to expose a supposed law to every possible kind of verification, and to take care, moreover, that this is done intentionally, and not left to a mere accident, as in the case of the apples. And in science, as in common life, our confidence in a law is in exact proportion to the absence of variation in the result of our experimental verifications. For instance, if you let go your grasp of an article you may have in your hand, it will immediately fall to the ground. That is a very common verification of one of the best established laws of nature — that of gravitation. The method by which men of science establish the existence of that law is exactly the same as that by which we have established that trivial proposition about the sourness of hard and green apples. But we believe it in such an extensive, thorough, and unhesitating manner because the universal experience of mankind verifies it, and we can verify it ourselves at any time; and that is the strongest possible foundation on which any natural law can rest.

So much, then, by way of proof that the method of establishing laws in science is exactly the same as that pursued in common life. Let us now turn to another matter (though really it is but another phase of the same question), and that it, the method by which, from the relations of certain phenomena, we prove that some stand in the position of causes towards the others.

I want to put the case clearly before you, and will therefore show you what I mean by another familiar example. I will suppose that one of you, on coming down in the morning to the parlor of your house, finds that a teapot and some spoons which had been left in the room on the previous evening are gone — the window is open, and observe the mark of a dirty hand on the window-frame, and perhaps, in addition to that, you notice the impress of a hobnailed shoe on the gravel outside. All these phenomena have struck your attention instantly, and before two seconds have passed you say, "Oh, somebody has broken open the window, entered the room, and run off with the spoons and the tea-pot!" That speech is out of your mouth in a moment. And you will probably add, "I know there has; I am quite sure of it!" You mean to say exactly what you know but in reality you are giving expression to what is, in all essential particulars, and hypothesis. You don't *know* it at all; it is nothing but an hypothesis rapidly framed in your own mind. And it is an hypothesis founded on a long train of inductions and deductions.

What are those inductions and deductions, and how have you got at this hypothesis? You have observed, in the first place, that the window is open; but by a train of reasoning involving many inductions and deductions, you have probably arrived long before at the general law — and a very good one it is — that windows do not open of themselves; and you therefore conclude that something has opened the window. A second general law that you have arrived at in the same way is, that tea-pots and spoons do not go out of a window spontaneously, and you are satisfied that as there not now where you left them, they have been removed. In the third place you look at the marks on the windowsill, and the shoe-marks outside, and you say that in all previous experience the former kind of mark had never been produced by anything else but the hand of a human being; and the same experience shows that no other animal but man at present wears shoes with hobnails in them such as would produced the marks in the gravel. I do not know, even if we could discover any of those "missing links" that are talked about, that they would help us to any other conclusion! At any rate the law which states our present experience is strong enough for my present purpose.

You next reach the conclusion that, as these kinds of marks have not been left by any other animal than man, or are liable to be formed in any other way than by a man's hand and shoe, the marks in question have been formed by a man in that way. You have, further, a general law, founded on observation and experience, and that, too, is, I am sorry to say, a very universal and unimpeachable one — that some men are thieves; and you assume at ones from all these premises — and that is what constitutes your hypothesis — that the man who made the marks outside and on the window-sill, opened the window, got into the room, and stole your tea-pot and spoons. You have now arrived at the *vera causa* — you have assumed a cause which, it is plain, is competent to produced all the phenomena you have observed. You can explain all these phenomena only by the hypothesis of a thief. But that is an hypothetical conclusion, of the justice of which you have no absolute proof at all; it is only rendered highly probable by a series of inductive and deductive reasonings.

I suppose your first action, assuming that you are a man of ordinary common sense, and that you have established this hypothesis to your own satisfaction, will very likely be to go off for the police, and set them on the track of the burglar, with the view to the recovery of your property. But just as you are starting with this object, some person comes in and on learning what you are about, says, "My good friend, you are going on a great deal too fast. How do you know that the man who really made the marks took the spoons? It might have been a monkey that took them, and the man may have merely looked in afterwards." You would probably reply, "Well, that is all very well, but you see it is contrary to all experience of the way teapots and spoons are abstracted; so that, at any rate, your hypothesis is less probable than mine."

While you are talking the thing over in this way, another friend arrives, one of the good kind of people that I was talking of a little while ago. And he might say, "Oh, my dear sir, you are certainly going on great deal too fast. You are most presumptuous. You admit that all these occurrences took place when you were fast asleep, at a time when you could not possibly have known anything about what was taking place. How do you know that the laws of Nature are not suspended during the night ? It may be that there has been some kind of supernatural interference in this case." In point of fact, he declares that your hypothesis is one of which you can not at all demonstrate the truth, and that you are by no means sure that the laws of Nature are the same when you are asleep as when you are awake.

Well, now, you can not at the moment answer that kind of reasoning. You feel that your worthy friend has you somewhat at a disadvantage. You will feel perfectly convinced in your own mind, however, that you are quite right, and you say to him, "My good friend, I can only be guided by the natural probabilities of the case, and if you will be kind enough to stand aside and permit me to pass, I will go and fetch the police." Well, we will suppose that your journey is successful, and that by good luck you meet with a policeman; that eventually the burglar is found with your property on his person, and the marks correspond to his hand and to his boots. Probably any jury would consider those facts a very good experimental verification of your hypothesis, touching the cause of the abnormal phenomena observed in your parlor, and would act accordingly.

Now , in this supposititious case, I have taken phenomena of very common kind, in order that you might see what are the different steps in an ordinary process of reasoning, if you will only take the trouble to analyze it carefully. All the operations I have described, you will see, are involved in the mind of any man of sense in leading him to a conclusion as to the course he should take in order to make good a robbery and punish the offender. I say that you are led, in that case, to your conclusion by exactly the same trend of reasoning as that which a man of science pursues when he is endeavoring to discover the origin and the laws of the most occult phenomena. The process is, and always must be, the same; and precisely the same mode of reasoning was employed by Newton and Laplace in their endeavors to discover and define the causes of the movement of the heavenly bodies, as you, with your own common sense, would employ to detect a burglar. The only difference is, that the nature of the inquiry being more abstruse, every step has to be most carefully watched, so that there may not be a single crack or flaw in your hypothesis. A flaw or crack in many of the hypotheses of daily life may be of little or no moment as affecting the general correctness of the conclusions at which we may arrive; but, in a scientific enquiry, a fallacy, great or small, is always of importance, and is sure to be in long run constantly productive of mischievous, if not fatal results.

Do not allow yourselves to be misled by the common notion that an hypothesis is untrustworthy simply because it is an hypothesis. It is often urged, in respect some scientific conclusion that, after all, it is only an hypothesis. But what more have we to guide us in nine-tenths of the most important affairs of daily life than hypotheses, and often very ill-based ones? So that is science, where the evidence of an hypothesis is subjected to the most rigid examination, we may rightly pursue the same course. You may have hypotheses and hypotheses.

A man may say, if he likes, that the moon is made of green cheese: that is an hypothesis. But another man, who has devoted a great deal of time and attention to the subject and availed himself of the powerful telescopes and the results of the observations of others, declares that in his opinion it is probably composed of materials very similar to those of which our own earth is made up: and that is also only an hypothesis. But I need not tell you that there is an enormous difference in the value of the two hypotheses. That one which is based on sound scientific knowledge is sure to have a corresponding value; and that which is a mere hasty random guess is likely to have but little value. Every great step in our progress in discovering causes has been made in exactly the same way as that which I have detailed to you. A person observing the occurrence of certain facts and phenomena asks, naturally enough, what process, what kind of operation known to occur in nature, apply to the particular case, will unravel and explain the mystery? Hence you have the scientific hypothesis; and its value will be proportionate to the care and completeness with which its basis has been tested and verified. It is in these matters as in the commonest affairs of practical life: the guess of the fool will be folly, while the guess of the wise man will contain wisdom. In all cases, you see that the value of the result depends on the patience and faithfulness with which the investigator applies to his hypothesis every possible kind of verification.

Wherever there are complex masses of phenomena to be inquired into, whether they be phenomena of the affairs of daily life, or whether they belong to the more abstruse and difficult problems laid before the philosopher, our course of proceeding in unraveling that complex chain of phenomena with a view to get at its cause, is always the same; in all cases we must invent an hypothesis; we must place before ourselves some more or less likely supposition respecting that cause; and then, having assumed an hypothesis, having supposed a cause for the phenomena in question, we must endeavor, on the one hand, to demonstrate our hypothesis, or, on the other, to upset and reject it altogether, by testing it in three ways. We must, in the first place, be prepared to prove that the supposed causes of phenomena exist in nature; that they are what the logicians call *verae causae* — true causes; in the next place, we should be prepared to show that the assumed causes of the phenomena are competent to produce such as those we wish to explain by them; and in the last place, we ought to be able to show that no other known causes are competent to produce these phenomena. If we can succeed in satisfying these three conditions, we shall have demonstrated our hypothesis; or rather I ought to say, we shall have proved it as far as certainty is possible for us; for, after all, there is no one of our surest convictions which may not be upset, or at any rate modified by a further accession of knowledge. It was because it satisfied these conditions that we accepted the hypothesis as to the disappearance of the tea-pot and spoons in the case I supposed; we found that our hypothesis on that subject was tenable and valid, because the supposed cause existed in nature, because it was competent to account for the phenomena, and because no other known cause was competent to account for them; and it is upon similar grounds that any hypothesis you choose to name is accepted in science as tenable and valid.◇

HISTORY OF SCIENCE

Proceedings of the All Bengal Workshop

"One cannot claim to have knowledge of science without knowledge of its history. From the first idea that engendered it to the present time — what ceaseless effort, what groping in the dark! We light-heartedly use our predecessors' works without stopping to consider the tremendous amount of physical labour put into them to clear the roads for us. How many of them ruined their health, spent their fortunes, and spurned honours and pleasure in the name of their passion for knowledge! How many of them died martyrs, upholding the eternal truth to their last breath!"

This was how an important lesson was conveyed to us by Albert Poisson, the famous scientist and mathematician. But the average student in our country and even many practicing scientists do not have any idea about this aspect as it is given no weightage in the education system.

Feeling the necessity to cultivate the history of science, an essential ingredient in the formation of scientific mentality, BREAKTHROUGH organized an All Bengal Workshop on the subject at Presidency College, Calcutta, on 2-3 November 1991. An overwhelming response was received as 473 interested participants from various districts of West Bengal actively involved themselves in this workshop.

An exhibition entitled "Evolution through ages" was also displayed at the workshop venue. It showed, in the form of posters, charts and diagrams, the various stages of material evolution — the origin of the universe, evolution of stars, origin of the solar system, evolution of the Earth, origin of life, evolution of life, and finally culminating in the origin of the human race. An exhibition of quotations of famous scientists on various issues were also displayed. There were a few video shows on scientific topics in between the sessions.

Professor Samarendranath Sen, the famous historian of science and the author of the first Bengali book on the subject, inaugurated the programme. Professor Sushil Kumar Mukherjee, chairman of the advisory board of our magazine and the former Vice Chancellor of Calcutta University presided over the inaugural session.

During the two days, many eminent scientists discussed the various periods in the history of science. Dr. Saroj Ghosh, Director-General of the National Council of Science Museums spoke on the Renaissance period and the industrial revolution in Europe. There was a study circle conducted by Prof. D. Mukhopadhyay, Editor-in-chief of this magazine and Professor of Geology, Calcutta University. Prof. Subir Basuroy, Professor of Chemistry, Ashutosh College discussed the history of the modern physical sciences. Prof. J. J. Ghosh, Professor of Biochemistry, Calcutta University spoke on the history of biology. Professor M. Bhattacharya of the Department of Mechanical Engineering, Jadavpur University and Professor Anandadev Mukherjee of the Department of Geology, Jadavpur University presided over the two sessions. The last session was dedicated to the discussion on the future course of science movement and the activities of the science clubs.

Brief proceedings of the two days discussions follows.

Speaker: Prof. Samarendra Nath Sen (Inaugural Speech)

Professor Sen in his inaugural lecture pointed out that though the renewed thrust towards the study of history of science started only after the second world war, attempts were made by many people in the antiquity to look at science from a historical perspective. He gave the examples of Hippocrates and Galen, who in between the 5th and 2nd centuries B.C., wrote the history of science of that time, Eudimus wrote a book on the history of mathematics and philosophy, and Aristotle wrote "Metaphysica".

It was Arabs who continued the study of the history of science when the West sunk into the darkness of the middle ages. People like Al-Beruni and Abu-Al-Rashid wrote books on ancient, especially on the history of scientific activity in India.

With the emergence of Renaissance in Europe, the outlook towards science, philosophy and their history changed. So far the books written on science did not have any reference to the relationship between science and society. The approach to view these two as related aspects was initiated by Roger Bacon and was carried on by Rene Descartes and his successors. Professor Sen mentioned the influence of Bacon's "New Atlantis", Descartes' "Decour de Relementa" and John Hershley's "Preliminary Principles of Inductive Science" on shaping the contemporary thinking.

In his forty-five minute speech, Prof. Sen also touched upon the history of science in India. The evidences of the ancient Indus valley civilization prove the existence of a scientifically and technologically developed culture in this region. The Vedas were not only a religious text, but contain a significant amount of biology, astronomy and mathematics. The ancient Indian science also inherited ideas from other countries. But in spite of such a glorious tradition, the culture of scientific study was lost due to increasing dominance of religious bigotries and superstitious beliefs. For example, dissection of human body was prohibited by Manu, and that sealed the fate of medical science. It was only in 1935 that Madhusudan Gupta and others performed a dissection on a corpse but that news also had to be suppressed from the public for ten years.

Prof. Sen stressed the contribution of the pioneers of Indian renaissance like Vidyasagar and Rammohan Roy in breaking the age-old mental roadblock. The British did spread education, but that for producing the clerks to run the administration. They did not foster a scientific education. P. C. Roy, J. C. Bose, Mahendralal Sircar and Ashutosh Mukherjee paved the path for true cultivation of science in our country.

He concluded by requesting the younger generation to study the history of science in details and to contribute actively in the progress of scientific mentality.

Speaker: Prof. S. K. Mukherjee (Presidential address)

In his ten minute deliberation Prof. Mukherjee stressed upon the inspiration behind the scientists in colonial India, like J. C. Bose,

> "....A hundred times everyday I remind myself that my inner and outer life depends on the labours of other man, living and dead, and that I must exert myself in order to give in the same measure as I have received and am still receiving....We eat food that others have grown, wear clothes that others have made, live in houses that others have built. The greater part of our knowledge and beliefs has been communicated to us by other people through the medium of language which others have created."
>
> -- Einstein

P. C. Roy, C. V. Raman, Meghnad Saha, S. N. Bose and others. They fought against all odds to place India in a prestigious position in the field of science. Today in spite of the country being independent and so much facilities being available, we are not being able to produce scientists of such calibre. He asked the participants to ponder over the problem.

While pointing out the necessity of studying the history of science, Prof. Mukherjee narrated his own experience of studying under Acharya P. C. Roy. Acharya Roy used to highlight the historical background before entering into the subject in every class. His "History of Hindu Chemistry", was a monumental work on the subject.

Professor Mukherjee cautioned the audience about the overemphasis on the technological aspects of science which undermines the importance of the conceptual aspects that are fundamental to scientific thinking.

Speaker: Dr. Saroj Ghosh. Topic: Industrial revolution and its impacts on science

At the very outset Dr. Ghosh defined the word "Revolution" — a change that has nothing to do with violence, but is a rapid and irreversible change. He cited the example of the agricultural revolution in the neolithic age, which changed the very mode of existence of human society irreversibly.

The Industrial Revolution was such a change. It is known that the progress of science was blocked in the middle age due to emphasis on faith rather than on enquiry. It was broken in the philosophical and conceptual levels during the renaissance. Industrial revolution became possible only after the peoples' minds were freed of the feudal fetters. What followed is an outburst of human endeavour.

During renaissance the Europeans flourished in every field, especially in establishing industries with the help of the new-born scientific ideas. With this technological progress the mainstream of life was bifurcated and city-centred lifestyle began to grow. Having powerful machines in their command, people realized their potential which gave them dignity and self esteem.

Dr. Ghosh pointed out that there are two theories on the basis of discoveries — the social deterministic theory and the Heroic theory — the latter believed on the scientific genius of the discoverer whereas the former interpreted it only as the need of the time. Dr. Ghosh opined that the remarkable incidences of parallel discoveries in various fields where the discoverers had no idea of the other's work, support the social deterministic viewpoint.

He resented that the modern trend in science is almost detached from the mass. He requested the audience to resist the devotion of human intellect to the invention of the weapons of mass destruction, the neglect of basic sciences, and the increasing tendency of using science and technology only as powerful tools for the powerful people.

The study circle

In the study circle, questions were invited from amongst the participants on the period of history covered. Out of the large number of questions that were tabled, the following four were simulated for discussion:

1. What was the necessity of the workshop on History of Science?
2. What were the mutual relations between science and society?
3. Why is renaissance underscored in history of science as the beginning of modern science?

The Exhibition

4. Why had science faced conflicts with religion?

Many participants from different science organizations of different districts took the floor and gave their opinions in the form of answers to those questions. On behalf of BREAKTHROUGH Mr. Ashoke Mukherjee addressed the house to discuss the questions elaborately.

Since the necessity of the topic was discussed to some extent by earlier speakers, Mr. Mukherjee started from the second question. He pointed out that science is more or less co-historic with man. That is to say, since the time modern man embarked on his existence on this planet, he also started creative activities that are synthetically called science. That is how the use of fire, wheel, raft etc. were discovered and invented by ancient men. But it is only from renaissance that what we call modern science took birth. Till then science was basically of empirical nature, scientists gathering informations, facts and observations on various aspects of nature. Theories were there, but most of them were speculative, metaphysical and subjective, not amenable to verification, and therefore neither capable of future projection.

However, science of the renaissance period and thereafter took up different turn. It not only gathered facts and informations but tried to correlate individual observations into their essence, called laws. theories, principles, etc. That is, it generalized similar things and phenomena, then similar set of both and so on. And thereby it became possible to project a future result or extrapolate something from the past. Both of these projections can be verified in experience or by experiment. That is why it has been called the theoretical science. Another fact was the birth of modern scientific outlook. Modern science not only lent itself to be verifiable but simultaneously posed a methodological question — how to find truth. Earlier people believed only what were apparently obvious to them and what were taught as true by theology. Both these attitudes were challenged.

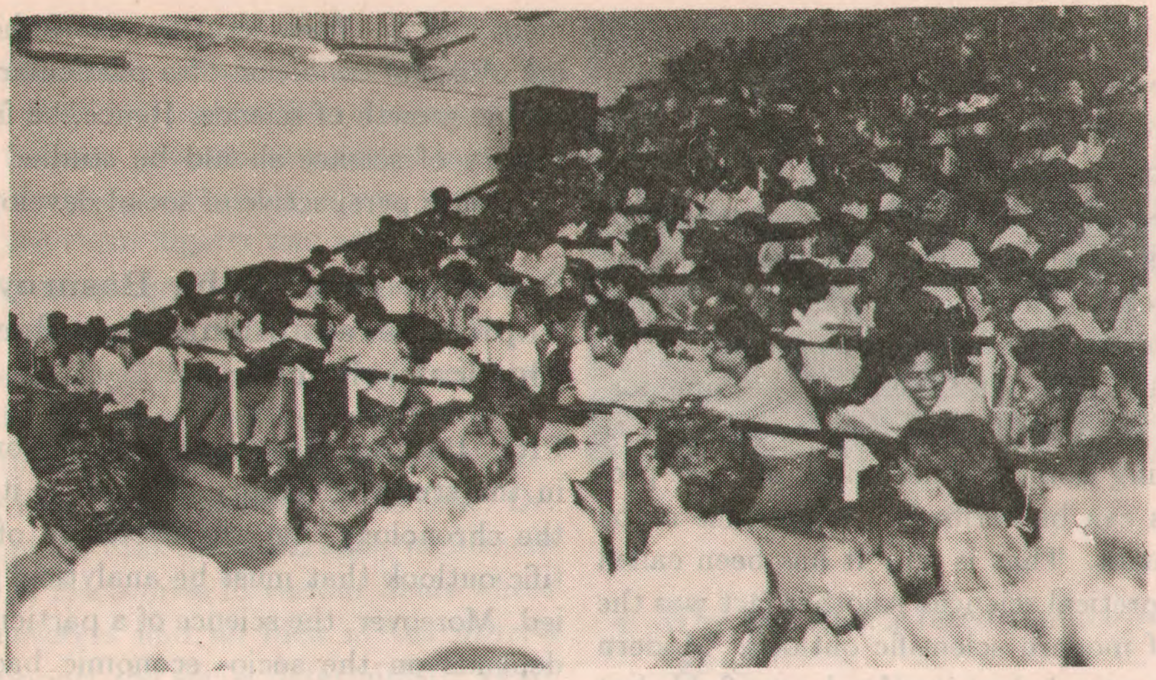
Citing many examples from history, Mr. Mukherjee showed that modern science posed the method of experiment, observation and verification as a general method to arrive at truth in any branch of knowledge. This is where science came into conflict with religious outlook. All the established religions in all corners of the globe placed certain dogmas and certain sacred books as the criteria and authority to decide upon truth. Whenever and wherever science challenged those dogmas or infallibility of those books, religious and social authorities tried to suppress science and persecute the scientists. But ultimately the scientific outlook prevailed.

On the question of interrelation of science and society, he observed that impact of science on society was already well known. But the converse fact has been very little studied. The history of science and the history of social evolution not only elicit parallel development, but on closer scrutiny reveal the bearing of social condition of a particular epoch on the growth of science. Hence, he felt, the history of science should be studied in the long term perspective of social development.

Speaker: Prof. Subir Basuroy.
Topic: Development of modern physical sciences

Prof. Basuroy started by pointing out that in the study of history of science, it is not the chronology, but the evolution of scientific outlook that must be analytically studied. Moreover, the science of a particular era depends on the socio- economic backdrop. There is a continuity in the course of development. That is why an Einstein was not possible before a Newton. Social necessity has in all ages been the basis of scientific advancement. It is because of the social urge to know the truth that science emerged during the renaissance as a congregation of systematic correlated knowledge, based on verifiable laws.

He touched upon the conceptual evolution in physics during the Newtonian and post-Newtonian periods that led to the spectacular developments at the beginning of this century. Before Newton, the existing belief was that things move only as long as someone makes it move. As we see many things happening around us, this concept strengthened the idea of a supernatural Master who is at the cause of all events. Newton's theory, on the contrary, said that things, once set into motion, will move by itself unless someone acts to change the motion. Everything is in relative motion and external action can only change the direction and speed. Naturally the necessity of the hand of God behind every event was no longer there. This gave the vigorous impetus for the study of nature and



The audience

natural laws, because people felt they don't depend on somebody's will and are knowable. The tremendous success of Newtonian mechanics influenced almost all branches of scientific inquiry and the two hundred years following Newton can rightly be called the Newtonian age.

But the magnificent Newtonian concept also had its own weakness. Though not requiring a supernatural entity behind everything, it did require something to set it into motion initially. This led to the idea of a *prime mover* who gave the *first impulse.* Moreover, the Newtonians tended to look at the Nature as a machine, and tried to reduce every phenomenon to a machine principle giving birth to mechanical outlook. This, Prof. Basuroy pointed out, hampered the understanding of new facts and phenomena posed before science in the post-Newtonian period, which were too complicated to be viewed mechanically.

Later developments of science, namely quantum mechanics, particle physics, relativity theory etc. broke this mechanical outlook or to be more precise their real imports were fully understood only when the older outlook was overcome. Prof. Basuroy pointed out that one of the major achievement of this new scientific development was the realization that there is no absolute truth in nature. The concept of space and time, causality, probability etc. had to be redefined in the light of the new discoveries. But he further commented that these developments only helped to improve the scientific outlook, and not to reject it.

He then discussed in details the modern concepts in physics like Maxwell's electromagnetic theory, Plank's quantum theory, de Broglie's wave particle duality, Dirac's electron-positron theory and Heisenberg's uncertainty principle in a lucid manner.

Speaker: Prof. J. J. Ghosh, Topic: Development of modern biology

In his speech Prof. Ghosh laid emphasis on the correct outlook in the development of biological sciences. For example, he said that for a long time biologists declined to correlate biology with other branches, and resisted attempts by physicists and chemists to apply physical laws in the field of biology. This slackened the progress of biology for a long time.

He also cited the example of the vitalistic theory, which believed in the existence of a special "vital force" in living matter which made them fundamentally different from other forms of matter. The predominance of this belief prevented scientists for a long time from trying to obtain organic chemicals from inorganic ones. In this context he also cited the experiment of fermentation done by Louis Pasteur and the controversy over the cause of fermentation — whether it is chemical or biological.

He said that the main difference between the old-school of biology and that of the modern times is that the former tried to study life in its diversity, whereas the latter tried to find the unity -- to identify the minimum common factor present in all life forms. Thus developed the science of organic chemistry.

He identified the discovery of Gene theory as the starting point in modern biology and mentioned the discovery of the double helix structure of the DNA molecule as important an event as Darwin's theory.

He touched upon the plethora of possibilities that genetic engineering has opened and hoped that it will be used in the welfare of mankind and not in its destruction. ◇

MOLECULAR BIOLOGY AND BIOTECHNOLOGY IN HUMAN WELFARE

N. P. Bhattacharya*

The last half of the twentieth century has observed rapidly growing scientific arenas in molecular biology and biotechnology which have lasting effects on modern society. Advances in both the branches are having a major impact on a variety of industries including chemical, agricultural, food processing, pharmaceuticals, animal husbandry etc.(see table-1). Among the various fields which have been enriched by the development, I shall concentrate the impact on the pharmaceuticals and DNA diagnostics (identification of human diseases and their cure).

1. Biotechnology and Molecular Biology

Biotechnology can be broadly defined as the utilization of living systems to produce or modify organic products and includes the traditional processes and techniques of fermentation, plant cross-fertilization, animal husbandry etc. Although these techniques have been used for centuries, advances in the understanding of biology in the molecular level helped in the exponential growth of biotechnology since the mid 1970s. Based on the recent technological advances, biotechnology can be more precisely defined as the process of in vitro alternation of genetic material for the purpose of creating new gene combinations or modifications. This definition implies that biotechnology is a technique that uses living organisms (or parts of organisms) to make or modify products, to improve plants or animals or to develop micro organisms for specific uses.

2. A few facts about life

It is now established that the building blocks of all living bodies are cells. Cells are tiny expandable factories that can simultaneously synthesize several thousand different molecules which are of different sizes. Among all the molecules, deoxyribonucleic acid (DNA) is supposed to be the master molecule. Except for a very few viruses for which ribonucleic acid (RNA) is the genetic material, for all the cases DNA is the genetic material and contains all the genetic information. In general, the flow of information is from DNA to RNA and RNA to protein.

$$DNA \longrightarrow RNA \longrightarrow protein$$

DNA is a very long thread-like macromolecule made up of a large number of deoxyribonucleotides, is composed of a base (adenine: A, guanine: G, thymidine: T and cytocin: C), a sugar and a phosphate group. The bases of DNA molecules carry the genetic information, whereas their sugar and phosphate groups perform a structural role. Any changes in the linear array of the bases

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in general would eventually change the structure of the protein and inheritably change the function of the cells. It, thus, appears that the malfunctioning of a cell is generally due to the defects in the DNA structure, although the interaction among the hundreds of other molecules also play a major role in the cell's function.

In the late sixties it was observed that three bases in the DNA contain codes for a particular amino acid, the building block of proteins. So the arrangement of the nucleotides in the DNA primarily determines the sequence of the amino acids in the protein and thus determines the function of the protein. There are thousands of proteins each of which is coded by a particular segment of the DNA, known as "gene". For example, the human genome contains about 100,000 genes encoded roughly by 3 to 5 percent of the total 3×10^9 base pairs. This huge DNA sequence is distributed on 22 autosomes and one sex chromosome, X or Y from each parent. Thus each autosomal gene is present in two copies.

The recent explosion of growth in the development and application of biotechnology may be traced to a number of successive discrete milestone discoveries and events.

1. Discovery of DNA in the sperm of trout from Rhine River in 1871.

2. In 1943, DNA was identified as the genetic material capable of altering the heredity of bacteria.

3. A complementary double helical structure was proposed on the basis of X-ray diffraction data in 1953.

4. DNA polymerase, an enzyme that makes DNA in test tube was isolated in 1958.

5. In 1960, RNA polymerase, another enzyme, which can synthesize RNA molecule on DNA template was discovered.

6. The complete genetic code was established in 1966. Thus it was possible to identify the "triplet" base pairs which code for specific aminoacid.

7. Another enzyme, ligase, which can join DNA chains together, was discovered in 1967.

8. After three years the first restriction enzyme, an enzyme that cuts DNA molecules at specific sites, was isolated. Since then over 100 restriction enzyme that cuts specific sequences of DNA (some recognize specific groups of four bases, other recognize groups of six) have been isolated.

Thus at the early part of the last decade, the stage was set for cutting DNA at a specific sequence and joining them at a different place to modify the function of the gene, creating prokaryotic and eukaryotic cells with unique genotypes and phenotypes producing large-scale production of genes and gene products (proteins). The technology was further strengthened by the discovery of fishing out a specific gene among the large number of genes ("cloning the gene"), and sequencing the DNA (that is identifying the array of nucleotides in a segment of DNA).

The fruit of these advancements was coming out early in the last decade. The first micro-organism (bacteria) capable of degrading oil contaminant, was made using the recombinant technology and the U.S. Supreme court rules that these new "man made" micro organisms are patentable (General Electric "superbug", 1980). In 1982, human in-

Table 1:

Industry	Benefits
Agricultural	Higher yielding and heartier plant varieties.
Chemical	Synthetic applications for bulk and specific chemicals.
Pollution control	Waste treatment and detoxification.
Food processing	Desirable supplements and additives.
Pharmaceutical peptide products	Increased quantity, purity and specificity.
Diagnostics	Monoclonal antibody, genetic probes.
Husbandry	Gain weight, less backfat etc.
Transgenic mammals	Change in the milk composition containing proteins of therapeutic value, animal mimicking human genetic diseases.
Creating new industries	Genetically engineered molecular functional groups organized into a 3-dimensional network may be the basis of a "bio-chip" for use in future generation of ultrasmall computers, organic computers.

sulin was produced using the technology and got approval in U.S.A. Similarly, in 1988, genetically engineered mammal (transgenic mouse) was created. In the following section, I shall concentrate on the use of these techniques in the last decade for identification and cure of human diseases.

3. DNA Diagnostics

Advances in molecular biology and biotechnology are creating exciting possibilities for DNA diagnostics. These developments will profoundly alter many aspects of modern medicine, including the pre or post natal analysis of the genetic diseases, the identification of individuals predisposed to conditions such as diabetes, coronary heart diseases, the analysis of infectious diseases ranging from common cold to AIDS, the diagnosis and classification of cancer.

Fundamental to DNA diagnostics is (a) the identification of the nucleic acid sequences that are informative in the disease and (b) the development of techniques that permit monitoring these sequences in individual patients. Both of these tasks are complicated not only by the huge number of genes ($\approx 10^5$) coded by only a fraction ($\approx 3\%$ to 5%) of the total DNA sequence, but also their spatial distribution in the different chromosomes.

The identification and characterization of DNA sequences responsible for a particular disease proceeds at a very rapid rate. The defective gene product has been at least tentatively identified for 400 human diseases. DNA sequences associated with such diseases differ from corresponding normal sequence in single base pair, gross changes such as deletions, insertions, duplications, rearrangements etc.

For identifying a change in the particular gene which is responsible for a particular disease, the segment of the DNA has to be identified first using the techniques of molecular biology. Once it is identified, that particular segment of DNA is fished out of the entire genome (cloning the gene) and sequenced, that is nucleotides are arranged. The cloned gene can then be compared with the same gene from the normal individuals to find the changes. Similarly, individuals predisposed to the disease can be screened. Using this approach in the last decade genes responsible for Haemophilia A, muscular dystrophy, cystic fibrosis have been identified.

For DNA sequence analysis one needs relatively large quantity of DNA. This was rather a limiting factor for sometime. However, the recent discovery of an enzyme which is stable at high temperature ($\approx 95^oC$) helped in the development of a technique (polymerase chain reaction: PCR) by which a single gene copy can be amplified 10^6 fold within hours. The amplified gene can then be analyzed for the required purpose. This technique has wide application in almost all the branches of molecular biology and biotechnology. This is now also used in the forensic science for detecting criminals.

4. Molecular Biology of Cancer

Cancer is one of the major killers in the world. Advances in the molecular biology have fostered major progress in understanding the cause of cancer and ultimately may promote the discovery of rationally derived methods for diagnosis and treatments. Molecular-oriented techniques have led to the identification of a discrete set of genes (proto-oncogene) in normal individuals which after activation may give rise to a wide variety of human cancers. Proto-oncogenes are highly conserved throughout evolution and strictly regulated in normal cells, and hypothesized to be essential for certain aspects of normal cellular function. The identification of the genetic changes which led the "normal functioning genes" to the "cancer causing genes" represents a major diagnostic challenge in cancer.

At present time there are about forty oncogenes which act dominantly. These genes can induce cancer in vitro when introduced into the cell or animal in a structurally altered form or when improperly expressed. There are also oncogenes which have lost both the copies in tumor cells and are known as "anti oncogene" or "recessive oncogene". Retinoblastoma, tumours arising in the retina of young children serves as a classical example of anti oncogene. The introduction of an 'intact' gene into such tumor cells would correct the phenotype. The dominant acting oncogenes may be activated in a variety of mechanisms: like substitution of a "single base pair" modifying the corresponding amino acid in the proteins, translocating a gene to another place, where its expression is deregulated, amplifying the number of genes with concomitant increase in the amount of the protein products.

Understanding the mechanism of oncogene activation at least for certain specific cancers, led to the rapid and sensitive detection methods. For example, early detection of breast cancer reduced the number of deaths caused by the disease. Using the technique in the molecular biology and recombinant technology, works in several laboratories are going on for targeting the oncogenes for cancer treatment.

Table 2: Calendar of the events in the last decade

1981	The first approval for the diagnostic kit using monoclonal antibody technology was offered by United States.
1982	Human insulin produced in bacteria by recombinant DNA technology is marketed under the trade name "Humulin".
1983	Expression of a foreign gene in plants. First time a human gene was able to express and function in animal.
1984	First patient for Auto Immune Deficiency Syndrome (AIDS) was reported. Consequently a virus was identified as the causative agent for the disease.
1985	First papers describing the methods of polymerase chain reaction (PCR) were published. Since that time PCR has grown into an increasingly powerful, versatile and useful technique by which millions of copies of any sequences of DNA can be made within a very short time. Thus it offers molecular biologists a precise technique for detecting just one gene in a cell. Researchers have only begun to explore its potential in areas such as forensic science and medicine. In 1989, SCIENCE, selected PCR as the "Molecule of the Year".
1987	Even though, the molecular nature of the virus causing AIDS was known, the production of vaccine was in vain due to the typical nature of the virus. However a drug, azidothymidine, which stops the growth of the virus was used clinically for treatment of the patients and raises some hope.
1988	First transgenic mice got patented in U.S.A. and served as the human model of diseases.
1989	Cystic fibrosis is a disease of malfunctioning of lung, pancreas and sweat glands. Affected individuals usually die within 30 years. Cloning and characterization of the gene will help in screening for carriers of the gene, prenatal diagnosis and developing therapies. First genetically engineered bacterial gene has been introduced into the humans for understanding the types of T-cells that best fight cancer. Techniques for targeting a specific gene (either for correcting or disrupting the function of the gene), together with technology of producing mice with foreign gene, raised hope for making a model of human disease with animals. Genetically engineered kidney hormone which stimulates the production of red blood cells, was approved by U.S. Food and Drug Administration. This drug will help patients with kidney failure, AIDS and certain types of cancer.

5. Therapeutics

Production of naturally occurring peptides, hormones, enzymes in sufficient quantities can be achieved using the methods of molecular biology and recombinant technology.

One such example is making human insulin gene into the bacteria so that large amount of purified insulin is available for diabetic patients. Similarly the production of blood- clotting factor in large amount in bacteria helped in treating the haemophiliacs. Production of human growth hormone promised the treatment for dwarfism. The most exciting and important one is the production of tissue plasminogen activator (tPA), an enzyme, which can be used as an effective therapeutic agent in clotting disorder. Mammalian cells carrying the tPA gene have been selected for high expression. This is often cited as a successful application of modern techniques in biology. The cells are grown in fermenters large enough to satisfy an ever- increasing demand for the protein.

It has been pointed out in the earlier section that activation of proto-oncogenes is through quantitative and qualitative changes in the normally functioning genes. Understanding the mechanism of activation will help in targeting the activated oncogenes with genetically engineered proteins or genes. Thus identification and isolation of putative dominant acting *ras* suppresser genes and gene products, use of antisence *mye* RNA, identification of regulatory element for *mye* gene expression will have substantive value in near future for cancer treatment.

6. Prospects for the future

The ongoing efforts to use the modern technology in human welfare and health would make it possible to understand the function of the cells in depth. Advances in DNA and protein sequences and synthesis technologies, site specific integration of a known DNA sequence, alterations of genomic DNA, gene therapy, production of mice with desired altered gene, will emerge in the future decades. The sequencing of the human genome would help the identification and cure of several thousands of human diseases which are now inaccessible. Continued evolution of biotechnological processes coupled with public and corporate enthusiasm and commitment is expected to fuel this expansive growth into the next century.

Benefits to science as well as the human welfare of the various achievements discussed above are tremendous. However, there are also some potential risks from the new technologies. For example, release of genetically altered micro-organisms for detoxifying chemical spills and environmental contaminants, may disturb the normal ecology of the environment. With the advancement of the diagnosis of several genetic diseases, the susceptible group may be discriminated in case of insurance, jobs etc. Deliberate correction and modification of genes of germ cells in mice gives opportunity of "gene therapy" or transgenic animals as "models for human genetic diseases". However, there are ethical uncertainties in the use of the same techniques in human beings. We must be vigilant about the ethical concerns. The immoralities of commission is avoidable in principle. However, the "immorality of omission" — the failure to apply a great new technology to aid the poor, the infirm and the underprivileged will remain a great concern. ◇

Further Readings:

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2. The molecular genetics of cancer (1987); J. M. Bishop, Science, 235, pp 305-310.

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4. Progress towards humane gene therapy (1989); T. Friedmann, Science, 244, pp 1275-1280.

5. Genetic-Engineering of Livestock (1989); Science, 244, pp 1281-1288.

6. Cut, paste and save: new approaches to altering specific genes in mice (1989); M. A. Frohman and G. R. Martin, Cell, 56, pp 145-147.

7. Genes unlimited (1990); J.Cherfas, New Scientist, 14 April, 1990.

Nature's "Manifesto for British Science"

The prestigious science journal "Nature" has recently published a "Manifesto of British science" (Nature, 12th September, 1991) to put before the public the scientific issues that must be settled politically. The declared objective of the article is to throw the problem of science education and research into political debate in the forthcoming British general election, so that the political parties are forced to take definite positions regarding the issues raised in the article.

Such a move is quite unheard of in the scientific community — which traditionally distances itself from political affairs blissfully closing eyes to the fact that the state policies which determine the fate of science are decided politically. But such ivory tower approach could no longer be continued, as the Nature essay points out, due to political mismanagement of science in the form of severe budget cuts, wrong education policy and interference with the scientists' freedom in academic pursuits. Nature urges the scientific community to stand as a people to force its opinion on the political decision making. There is a lesson to be learnt from the endeavour of the British scientists.

Rules for Code for Conduct evoke storm in U.S.

Recently the U.S. government has enacted a new set of rules to be applicable to scientists in employment of the government. The so called "code of conduct" has created widespread resentment in the scientific circles and mainly among the scientific societies which fear that the new rules in the name of ethics would undermine their very existence and independence.

Most of the rules are controversial. The rules would prohibit government scientists from doing almost any society work or social service on Government time. The scientific societies argue that these rules would make Government researchers '2nd class citizens' among the scientific community.

Ozone loss worse than expected

The protective ozone layer in Earth's atmosphere is disappearing much faster than previously thought, according to a study done by researchers at the National Aeronautics and Space Administration (NASA),USA. The study suggests that depletion of 4-5% has occurred since 1978 over the USA—past studies had shown about half that amount.

The ozone depletion is widely believed to be caused by the release into the atmosphere of chlorofluorocarbons (CFCs) — man made gases used for refrigeration, the manufacture of insulating foams and as cleaning solvents in making computer chips. Besides the larger-than-expected drop, ozone depletion has been found further south than previously observed. And more importantly, ozone depletion has been detected well into the spring months (previous belief was winter). Because people are more likely to be outside and exposed to the sun in warmer months, and because of 1% depletion of ozone layer an extra 2% of sun's UV radiation reaches the earth, the springtime loss will increase the skin cancer. In the next 50 years the rate of skin cancer will be almost double, causing as many as 2,00,000 extra deaths in U.S.A. alone. [From *Nature*,vol.350;No.6318, 1991.]

A star is born

For the first time the astronomers in Hawaii have managed to see the birth of a star. The object was first noticed in Nebula *MGC 1333-a* 1100 light years from earth—in 1983 when the infrared astronomy satellite made its sky survey. The protostar — the first stage in a star's life after the gravitational collapse — is now in sharp focus, thanks to the Maxwell telescope in Hawaii islands (to learn how a star is born, the reader may refer to the last issue of this magazine).

Promising to be several times larger than the sun, the protostar is still enveloped in a dust cloud. This forced the astronomers to measure the source at wavelengths between 0.35 mm and 2 mm. This observation is of far-reaching significance; till now scientists had only been able to focus on fully-fledged stars generating energy from nuclear fusion. Only now they will have a brief peek at the origin of stellar activity.

U.S. universities facing massive budget cuts

The glorious days of university research in the United States, when the government paid Universities to build hundreds of laboratories and keep them running may be at end. Budget pressure and congressional legislation last year forced both National Science Foundation and the US Department of Agriculture to reduce payments of indirect costs (which may include everything from new construction to heating and upkeep). NIH (National Institute of Health), the largest single source of funds for university based research and one of the few science agencies still paying indirect costs may have to cut back its budget as signaled by the White House. The White House Office of Management and Budgets (OMB) last year (December 1990) sanctioned less than full reimbursement of indirect costs in NIH-funded university research. NIH extramural research director John Diggs described the OMB plan as shocking. Doghes Kelly of the American Association of Medical Colleges is worried about "a coming confrontation between faculty and administration". (Nature, vol. 349, No 6308 1991)

Most universities are having to manage by reducing administrative and support stuff, postponing construction and equipment purchases, raising tuition and student fees, delaying salary increases, offering early retirement to tenured faculty and even eliminating some departments and courses.

The universities in the California State face $402 million cut from its 1992 request, 20% increase in student fees, layoffs of 864 staffs, 420 faculties face early retirement. Similarly, the universities in the state of Massachusetts have faced $115 million cut, elimination of 1000 faculties and one third increase in tuition fees. The state had to abolish the community health education programme to make both ends meet.

Melbourne Skull may hold clues to the origin of man

Australian Scientists have isolated DNA from a 15000 year-old- skull found at Kow-Swamp, north of Melbourne. This is now the oldest known human DNA.

"The finding raises the exciting possibility that we can test some of the ideas that have been developed over the years to explain the origin of the Australians,"— says Alan Thorne of the prehistory dept. at the Australian National University in Canberra.

Some scientists argue that Australia was settled by a single group of immigrants who arrived from Indonesia between 40,000 and 50,000 years ago. Other, including Thorne, believe modern Aborigines are descended from people who came from China as well as South-east Asia, either in two waves or regularly over a long period.

Thorne also believes that with such easy DNA it might be possible to resolve the debate about whether modern human originated in Africa or if they evolved simultaneously in Africa, Asia and Europe.

The team used techniques pioneered by Loy to extract minute amounts of mitochondrial DNA from the ancient skull and then amplified the DNA with the polymerase chain reaction.

The next step, says Throne, is to sequence the DNA and compare what has been reserved of the genome with DNA from more recent bones. Throne also hopes to compare the DNA with modern sample. Aboriginal people inhabiting Kow-Swamp site have expressed an interest in learning how their genetic material compares with that of their early ancestors. [New Scientist, 27th July, 1991]

Germany cuts aid by 25% citing "excessive armamentation"

While the Narasimha Rao government called upon the people to practice austerity due to the "severe economic crisis", the nation was stunned to learn that Germany has decided to reduce the developmental aid to India by 25% for "excessive armamentation". In the milieu it was revealed that for many years the Indian government has been diverting the developmental aid given by advanced nations to purchase modern war machineries instead of using the money for peoples welfare.

This practice has resulted in accumulation of such war-power in the hands of India that most neighbouring countries and even some western countries are now worried. This action by the German government is only a reflection of the global concern.

It is indeed condemnable when a government of a country passes the burden of a crisis ridden economy on the people, keeping the people half-fed, half-clad and homeless while carrying forward an arms build-up, outrageous in extent even in world standards.

North Bengal People Share Global Concern Over Pollution From Hazardous Industry

Pollution from the chemical industries is now really a threat to mankind as well as to the environment in the world. There is very little difference between the developed and developing countries in relation to the safety measures of chemical industries. 20 percent of Europe's big industrial groups have already been sentenced for infringing environmental laws, 50 percent still have no strategy in this area, according to a survey carried out by an international environment auditing and consultancy agency, BDA, Deloitte and Touche (New Scientist, 20th July,1991).

Similarly, thousands of industries in our country do not bother for pollution . As for example Sarada Fertilizers Ltd., Bankura district, W.B. producing fertilizer and acid pollutate a vast zone of cultivated land and environment; Mridula Chemical factory, Calcutta, created a severe health hazard among school students; Union Carbide, Bhopal, M.P. has caused the worst industrial disaster in the world.

The modern science and technology now can provide every help in this respect. But what we see in reality? Practically, no safety measure operates in most of the cases. People naturally question whether it is due to lack of knowledge or lack of honest effort of authority or something else?

Naturally, people are very much afraid of and much more concerned about installation of industries producing hazardous chemicals and are building up mass movements in many parts of the country.

This type of movement has been observed in recent times when the Sundarban Fertilizer Ltd. installed a fertilizer plant in Rajganj, Jalpaiguri district, W.Bengal. It is planned to produce 66,000 tons of single superphosphate and 33,000 tons of sulfuric acid per year. Initially, it was supposed to be placed in south 24-parganas district of W.Bengal but the plant location had to be changed due to strong public resistance.

Actually, this type of industries create hazards like acid mist, sulfur dioxide, phosphate rock dust, hydrogen fluoride and liquid effluent for disposal. All these hazards have long term dangerous effects on human beings, animal and plant kingdom and on the soil. So, all out safety measures inside and outside the plant as well as for the surrounding environment are absolutely essential. But in the case of Sundarban Fertilizer Ltd., the company management has not acquainted the public about the safety measures. We observe that there is dense population within 1 km, six villages, one H.S. school, one primary school within half km., a fifty bedded rural hospital within three km. of the aforesaid plant and highly fertile cultivated land area in the vicinity of the plant. So, the factory owners have violated the factory act 41A of provisions relating to hazardous processes concerning the constitution of site appraisal committee. But still the W.B. pollution control board has given the permission without visiting the site. The people of North Bengal, therefore, rightly raised a firm protest against the establishment of the factory.

All Bengal Science Meet Planned

At the All Bengal workshop on History of Science held on 2-3rd November, a decision has been taken to launch an All Bengal Science Movement. A booklet in Bengali entitled "Ajker Bigyan Andolan", giving the aims and objectives of the movement has been published. A preparatory committee comprising of representatives from all districts has been formed. It has been announced to organize an 'All Bengal Science Conference' in the month of May 1992. In this context the committee sketched out the lines of activities to be carried out as follows:

Academic Work: To organize study classes, seminars, workshops on history of science, life and struggles of different scientists, and to publish local magazines, wall magazines on such topics. The objective should be to build up the faculty of inquisitiveness, the urge for social activities, and the habit of self-study among the people who come in contact with us.

Science Programmes: To construct models, charts, posters for exhibitions to expose superstitions, unhygienic habits; to organize protest movements against polluting industries; to arrange excursions to different educational institutes, Nature study, slide shows and sky watching programmes.

Organizational Work: To open new science clubs in localities, schools, colleges and universities, and to initiate science branches in existing cultural organizations.

Movement Against Corrupted MBBS Educational System

Medical students of West Bengal, under the banner of "Medical Students Action Forum" started protesting against the malpractices, irregularities and favouritism in first professional MBBS examination 1991 held by the university of Calcutta. It is an open secret nowadays that the common malpractices which are regularly occurring may be named as simply corruption. This type of practices of the teachers in this noble profession are nothing but condemnable. Only a strong and united movement of the students, professors with the support of the people from all levels can eliminate the problem from the root—the movement organizers feel.

Programme Panorama

In accordance with our declared objectives, we organize regular group discussions, popular talks, lectures and seminars on scientific topics. The following were the programmes organized in the past few months:

The Main Working Group, Calcutta

"Science and Religion" — Mr. Ashoke Mukherjee, a science activist, 7th July, 1991

"Chaos" — Mr. Ranjan Mukhopadhyay, Research Scholar, Dept. of Physics, California Institute of Technology, USA., 4th August,1991.

"Future of Science and Technology in India under the New Industrial Policy" — Mr. Biplab Chakraborty, Columnist, 19th August, 1991.

"Let there be Light!" — Mr. Subhasis Maity, Research Scholar, Saha Institute of Nuclear Physics, 22nd Sept.,1991

"Causality and Quantum Mechanics" — Mr. Subhasis Maity, Research Scholar, Saha Institute of Nuclear Physics, 6th Oct., 1991.

"Science, Ethics and Society" by Mr. Debashis Roy, Member, Editorial Board, Breakthrough, 1st December 1991.

Seminar on "The Feedback Mechanism and the Continuity of Life"

The Kalyani Chapter of our journal (founded by the professors, research scholars and the students of Kalyani University and the Bidhan Chandra Krishi Viswavidyalaya in 1990) organized a timely seminar on "The Feedback Mechanism and the Continuity of Life" on 14.9.91 at the Dept. of Zoology. Prof. S. P. Sen of the Dept. of Botany was the speaker. With his much appreciated mode of exposition, Prof Sen delivered a very lucid and illuminating lecture. He also drew the attention of the scientific community to the grave problem of ecological imbalance, misuse and abuse of natural resources etc. He convinced the audience with facts and figures that the disturbances in the feedback mechanisms in nature, created by the irresponsible actions of the developed nations, would imperil the very existence of even the human race on earth. If it would come true, The very mechanisms and pathways which once brought forth the origin and evolution of life cannot be repeated—he opined.

Programmes by "Society for Young Scientists", Calcutta

A slide show was organised by the "society for young scientists" at the St. Paul's school on 24 th August, 1991. Mr. Subhasis Maity, member of the Editorial Board, Breakthrough discussed on the passage of the Voyager-II through the members of the solar family and What new informations we have got from it.

The birth anniversary celebration of Acharya J. C. Bose was held on 30th November 1991. Prof. T. K. Naskar, the publisher of our journal, discussed the life and works of Acharya Bose on this occasion.

Jogamaya Devi College, Calcutta

On 10th August 1991, the students of Jogamaya Devi College, organized a discussion on "Origin of Universe". Dr. Soumitro Banerjee of I.I.T Kharagpur delivered the lecture.

Nibadhoi High School, Dattapukur, North 24-Parganas

"Origin of Life on Earth" — Mr. Parimal Mishra, Research Scholar, Indian Institute of Chemical Biology, 30th November, 1991.

Students' Cultural Forum, South Calcutta

The birth anniversary of Acharya J. C. Bose was observed on 30th November by the Students' Cultural Forum in South Calcutta. On behalf of BREAKTHROUGH, Mr. Subhasis Maity, Research Scholar, Saha Institute of Nuclear Physics spoke on the occasion.

Acharya J. C. Bose College, Calcutta

Students of this college organised a deliberation entitled "What is Time" on 5th October 1991 . Dr. Soumitro Banerjee, Assistant Professor, Electrical Engg. Dept., I.I.T. Kharagpur presented an attractive speech before a large audience.

Prof. S. S. Baral memorial lecture at B. E. College, Howrah

Under the joint auspices of the dept. of Electronics and Telecommunications, B. E. College and the Editorial Board of 'Breakthrough', the Prof. S. S. Boral Memorial Lecture was organized to commemorate the much beloved and outstanding teacher who breathed his last in August 1991. On 20th Nov. 1991, the first memorial lecture was held at lecture hall of E&TC Department at 2p.m. and it was delivered by Prof. G. P. Rao of the Dept. of Electrical Engg., I.I.T, Kharagpur on the topic "Origin and Development of the Mathematical Concepts in Systems, Control and Signal Processing". Over 150 students and professors from different departments enjoyed the talk. Prof. B. Sen, Principal, B.E.College and a member of the advisory board of Breakthrough, Prof. P. K. Sinharoy, Head, Dept. of E&TC and Prof. B. R. Nag, Dept. of Radiophysics and Electronics, Calcutta University discussed on the life and works of Prof. Boral. They also expressed their concern over the fact that the teacher like prof. Boral are becoming rare day by day whose memory will remain fresh in our mind not only for his outstanding teaching ability but also for his amicable personality and love for his pupils.

Jadavpur University Chapter

"Origin and Evolution of stars" — Miss Nivedita Pramanik, M. Sc. student, Jadavpur University, Calcutta, 11th January, 1991.

"Artificial Intelligence" — Mr. Asta Daskhan, Post MCA student, Jadavpur University, 25th January, 1991

"Energy and Society" — Dr. Soumitro Banerjee, Asst. Professor, Dept. of Electrical Engg., 27th April, 1991

"Action Anthropology-Its development in the Indian Perspective" — Mr. Sudipta Barman, M. Lib. student, Jadavpur University, 25th September, 1991

"Calcutta Libraries Network (CALIBNET)" — Mr. Sabyasachi Sen, 9th October, 1991.

"What does happen under the sea" — Mr. Subrata Gouri, PG Student, Dept. of Geology, Jadavpur University.

Programmes in North Bengal

Science Age, a science organization in Alipurduar held a discussion on "Science, Ethics and Society" on 14 Nov., 1991. Mr. Debashis Roy, member of the Editorial Board of BREAKTHROUGH discussed the topic. The programme was presided over by Dr. Bishnupada Chakraborty of Alipurduar College.

A discussion on the same topic was also held in Siliguri town on 16th November 1991 by the science organization *Science Era*.

Murshidabad District

A preparatory committee to establish a science organization has been formed in Baharampur, during a meeting on the occasion of Vidyasagar Death Centenary on 2.10.91. Prof Dipak Bhattacharya of Krishnanath College was elected the president of the committee and Kashinath Basak the secretary of the committee.

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