UNIT 1: INTRODUCTION TO THE THEORY OF CHAOS

Contents

1.0 OBJECTIVES

This primary objective of this unit is to introduce the chaos theory by analysing it from the scientific and philosophical perspectives. In chaos theory you will find a perfect blending of, once considered irreconcilable extremes of linearity and non-linearity, determinism and indeterminism which were the characteristic features of Newtonian mechanics and quantum mechanics respectively. The developments in scientific fields do not remain aloof from the real life settings instead they trickle down to various fields, including philosophy leading to the formation and transformation of human thought pattern. This can very well be seen in mechanistic deterministic vision of the universe that assured future to be present before us like past on one hand and the indeterministic vision that led to submission to randomness and chance on the other. Chaos theory brings in an alternative to these extremes views in both scientific and philosophical realm. The essential scientific features of chaos theory are discussed without going into the complex equations. The philosophical analysis of chaos theory will showcase the paradigm shift that chaos theory has initiated.
Thus by the end of this Unit, you should be able to:

- have a basic understanding of the chaos theory and its concepts.
- analyse the chaos theory as an alternative to Newtonian and quantum mechanics.
- understand how chaos theory initiates a paradigm shift
- reflect on the relevance of chaos theory in the contemporary world.

1.1 INTRODUCTION

The word chaos in everyday life would mean a totally disorganized random state. The term chaos used in chaos theory must be taken as a term of art and does not go along with the ordinary connotations. To be more specific, the noun chaos and the adjective chaotic are used to describe the time and behaviour of a system when the behaviour of the system is aperiodic. The word ‘chaos’ first entered physics in the physicist James Clerk Maxwell’s phrase, ‘state of molecular chaos’ in the nineteenth century.

The sudden and dramatic changes in non-linear dynamic systems may give rise to complex chaotic behaviour. Underlying this aperiodic and apparent random behaviour, there is a determined order waiting to be revealed. The chaos that is being discussed here is deterministic chaos. Associating determinism with chaos may sound paradoxical but it is not the kind of determinism outlined by Newtonian laws but it depicts the uncertainty consistent with determinism. This is due to sensitive dependence on initial condition which results in the amplification of small scale uncertainties over a period of time resulting in unpredictability in long term behaviour even though the behaviour is predictable in the short term.

After Newtonian mechanics, relativity and quantum theory, the scientists have pinned their hopes on chaos theory as they believe in its potential to make significant contribution cutting across scientific disciplines. As chaos theory brought together thinkers from fields that had been widely separated, it is a science of the global nature of systems. The new alternative which chaos theory has opened incorporates both linearity in Newtonian mechanics and non-linearity in quantum mechanics. Chaos theory has not looked back since it made its first appearance in the scientific arena; the juggernaut still rolls on with lot of promises and surprises in store.

1.2 CHAOS IN HISTORY

Down the lanes of history, the concept of chaos can be looked at from both philosophical and scientific perspectives. Chaos was relatively a new entrant in the scientific field. Chaos began making appearance a century ago when scientists started bringing in the concepts of spontaneous change, irregularity and disorder, constructing a new epistemology which had the potential to call in to question the classical laws of physics. The philosophical roots of chaos are very deep with references dating back to 2500 BCE in the Asian, Egyptian, and Mayan cultures.

The focal point of human attempt during these times was to tame chaos and put it in an order to bring about harmony. Around the globe, people of various cultures and civilizations developed diverse techniques to master chaos and bring about an order. There were calendars to predict seasons, astronomical rules to judge the position of planets, markings in the river bank to note the rise and fall of water level in river Nile and the like. All these were done to infuse order to the chaotic world and were adorned with attractive myths. Beginning with myth and belief in magical powers, human beings moved forward into scientific thought process keeping in mind the intense desire to bring about order and harmony, or, in other words, to have a deterministic vision in order to have predictability. It was pure chaos that ruled in the age of early human history. Slowly, but steadily, the underlying rules in nature were brought in, the natural science as well as mathematics developed hand in hand.

In the Greek tradition, the concept of chaos made its first appearance in Hesiod's *Theogony*, dated back to 800 BCE. The mythical idea of chaos as immense and creative with an uneasy tension between chaos and order was injected upon with scientific attitude by the Greeks and also was subject to religious interpretations. With the arrival of Galileo, Kepler, Descartes and Newton on the scene, linearity and non-linearity or the order and chaos which once co-existed were separated. The reductionist science called the shots and sidelined the concept of chaos. Francis Bacon and Descartes were instrumental in reducing the four causes of Aristotle into two namely material cause and efficient cause. The formal cause and final cause were skipped to philosophy of religion. Thus Aristotelian holistic and organic vision of the universe was overthrown and was replaced by mechanical vision of universe. The laws and concepts of Newton gave a strong deterministic assurance to the whole world. Stating that the non-linear system as imperfect, only the linear systems were studied and the scientists even thought that non-linearity could be incorporated into linearity.

1.3 NEWTONIAN DETERMINISM AND QUANTUM INDETERMINISM

The scientific community and the world at large believed that on April 29, 1686, the day when Sir Issac Newton presented his research – *Principia Mathematica* to Royal Society of London, would mark the death of chaos and herald the birth of determinism and predictability. Newton for the first time provided a unified quantitative explanation for a wide range of physical phenomena with his laws of motion, law of universal gravitation, the concepts of absolute space and absolute time together with mathematical techniques of calculus. Thus he placed the stamp of approval on the rigorous deterministic philosophical vision of Descartes and Bacon. Determinism, predictability and reversibility were the characteristics of Newtonian mechanics.

In the Newtonian deterministic vision, the whole world was conceived to be a gigantic machine. When each part of the machine namely, mechanics, heat waves, sound, light, magnetism, electricity- were all brought under control, the wild excitement resulted in extreme deterministic views like Laplace Demon. It stated that there would be nothing in the world which would be uncertain and the future would be present before our eyes like past.

The Newtonian world view trickled down to various fields. Just like physicists reduce the property of gases to motion of their atoms or molecules, John Locke reduced the patterns observed in society to the behavior of individuals and stated that there were natural laws governing human societies as we had laws in the physical universe. He also stated that the function of government was not to impose laws but to discover and enforce the natural laws inherent to mankind which became the corner stone of the value systems of the enlightenment and influenced the development of modern economic and political thought. Science and Philosophy which were once wedded to each other were separated by the influence of Newtonian Physics. Man was considered to be the master of the gigantic machine called universe which was given to him to exploit and this led to the plundering of nature. Yet another consequence of Newtonian mechanics was that the present became a sum of the past events or a passage to determine future events resulting in the oblivion of the present. Chaotic or the non-linear phenomena were considered to be imperfections that could be appropriated to linearity and thus, linearity ruled the stage.

The Newtonian vision of a clock work universe with linearity, determinism and predictability remained at the helm of scientific affairs for years. Contrary to the expectation of the time, new theories came up. As Illya Prigogine says, "Classical science, the mythical science of a simply passive world, belongs to the past, was killed not by philosophical criticism or empirical resignation but by the internal development of science itself." As the time unfolded, relativity eliminated the Newtonian illusion of absolute space and time and Einstein said that everyone would have his or her own personal timings. Quantum theory eliminated the Newtonian dream of a controllable measurement process. The matrix and wave mechanics represented reality through mathematical symbols and manipulated them to get results. Three important philosophical principles associated with quantum mechanics were complimentality, uncertainty and probability. Complimentality suggests that particle and wave are complimentary while uncertainty explains that there is a certain amount of uncertainty when we are precisely measuring speed and position, time and energy. The probability determines the result. Thus uncertainty and probability together described nature as indeterministic.

Check Your Progress I

Note: Use the space provided for your answers.s.

1) Trace the significant developments in the evolution of the concept of chaos till the time of Newton.

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2) What are the philosophical consequences of deterministic Newtonian mechanics?

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1.4 SCIENTIFIC ANALYSIS OF CHAOS THEORY

Torn up between the extremes of rigorous deterministic Newtonian mechanics and indeterministic quantum mechanics, Chaos theory shows the way out. Chaos theory has shown that chaos in non-linear dynamical systems is not random but it has got a hidden order that helps us in making short term predictions as well as long term trends. Thus, the alternative which Chaos theory opens up reconciling both determinism and indeterminism, yields meaningful and scientific output. The shift from mechanical worldview can be characterized by words like organic, holistic and ecological. Philosophically, the Aristotelian holistic vision of blending the abstract (mathematical), tangible (imaginative) and the metaphysical into a single whole is making a grand come back. Joseph Ford of Georgia Institute of Technology, terms chaos as, "Dynamics freed at last from the shackles of order and predictability … systems liberated to randomly explore their every dynamical possibility … exciting variety, richness of choice, of cornucopia of opportunity."

Henri Poincare had outlined the central features of deterministic Chaos Theory a century ago in his book *Science and Method*, "a very small cause which escapes our notice, determines a considerable effect that we cannot fail to see, and then we say the effect is due to chance." It was not well acknowledged during that time because of the emphasis on linearity and outright rejection on non-linearity. Edward Lorenz, a meteorologist at the Massachusetts Institute of Technology, presented a paper titled, "Predictability: Does the flap of a butterfly's wing in Brazil set off a Tornado in Texas?" and is credited with the renewed interest in Chaos theory. He coined the term Butterfly Effect. He came across this interesting concept while working on the problem of weather prediction in 1961. While trying to make weather prediction possible, Lorenz entered 0.506 instead of 0.506127 in his computer in order to save space, thinking that the shortened rounded off number which was once part in a thousand would make no effect. This very small difference made a great diversion in the outcome. This effect came to be known as the butterfly effect. Scientifically it is called sensitive dependence on initial condition.

Chaotic Systems are deterministic, non-linear, sensitive to initial conditions and bounded. Determinism in Chaos would mean that chaos does not arise from same lawless behaviour governed by chance but it is the stochastic behaviour occurring in deterministic systems or the lawless behaviour governed entirely by law. In linearity the output is directly or inversely proportional to the input but for a non-linear system, a small change in parameter can lead to sudden and dramatic changes in both qualitative and quantitative behaviour of the system. It will exhibit bifurcations and also have multiple basins of attractions. Boundedness in the chaotic dynamics would mean that even though chaotic systems have sensitive dependence to initial condition, the trajectories confine themselves to a bound region, which will have maximum and minimum parameter values beyond which they won't wander, unless perturbed.

Chaotic Systems are not random, or periodic. Random events have equal probability of being in any state they can be in, from one moment to the next, independent of the previous state. In the midst of the apparent random behaviour in a chaotic system, there is an underlying structure revealed in the phase space that sometimes allows us to make prediction about its long-term trend and very short term behaviour. Edward Lorenz called this 'orderly disorder' in normal space. The state space or phase space is the mathematical space where each point represents a possible state of the system and helps us to study the geometric properties of the trajectories of the target system without knowing the exact solutions to the dynamical equations. Chaotic systems usually possess strange attractors, often with fractal dimensions. They are called strange attractors because, unlike fixed point, limit cycle and torus attractor; they don't exhibit properties like seemingly random behaviour, sensitivity to initial conditions and mixing in finite time. Fractal image contain infinite detail when we zoom in. The advantage of fractal image is that the extraordinary detail present in fractal images can be generated by very simple recipes. The attractors not only provide the standard statistical observation but also the 'directional' information which show how the system tends to change from its current state. This helps us make predictions about long term trend and short term behaviour. The properties of attractors are key sign posts at the junction where Chaos theory matures past mere metaphor and offers opportunities for practical applications.

When chaotic, complex non linear system is perturbed, the system loses its stability. The farther the system moves from equilibrium the more unstable it gets. The system then makes changes so as to regain the lost equilibrium. These changes are linear, gradual, segmental, predictable, moderate and incremental. But when this doesn't work, the continued perturbation will result in bifurcation, the diverging point, where the possibilities are many. One fork is chosen where the bifurcation occurs at a certain point which leads to second order change, characterized as turbulent, chaotic, non-linear, sudden, dramatic, transformative and unpredictable.

The importance of bifurcation lies in its universality. The ratio of the successive spacing tends to a number $\delta = 4.6692$ as $n \rightarrow \infty$. What is again a pleasant surprise is that this number is universal for most single hump maps. There is yet another universal number associated with the pitchfork bifurcation. The spacing gets smaller and smaller and the ratio converges to a universal number $\alpha = 2.5029$, rather rapidly. Feigenbaum discovered that both δ and α are universal numbers for a period doubling cascades. Experiments conducted by scientists over the years confirmed Feigenbaum's discovery regarding the universality of bifurcation was not confined to turbulent fluids alone, but in all kinds of physical systems like electronic, optical and even biological.

Chaos was once considered unreliable, uncontrollable and therefore unusable, but scientists have turned the situation topsy-turvy by making chaos manageable, exploitable and even invaluable. Three basic methods of chaos control are- Ott Gregboi and Yorke (OGY) method, Pyrages method and Bradley's method. The Lyapunov exponent, discovered by the Russian mathematician Aleksandr M. Lyapunov, is useful for evaluating a model's sensitivity to perturbation which is indeed the root of unpredictability of chaos. Glenn E. James states the important consequences of chaos control in his book *Chaos Theory: The Essentials for Military Application*, "no model was needed, minimal computation was required, parameter adjustments were quite small, different periodic behaviours were stabilized for the same system and control was possible even with feedback based on imprecise measurements."

The ability to control chaos in the dynamical systems would mean that chaos theory can be put to work in a wide variety of fields. From laser technology to management leadership, chaos theory has proved to be of great value. Some of the applications of chaos theory in mechanical systems include laser, encryption, chaotic circuit, engine systems and also in space and satellite mission. In natural systems the applications can be seen in fisheries, ecology and in living systems it ranges from economy, management leadership and military systems. Thus chaos theory in action has set the ball rolling not only with an array of scientific discoveries from mechanical, living and complex systems, but also with far reaching philosophical implications.

Check Your Progress II

Note: Use the space provided for your answers.s.

1) Explain chaos theory as an alternative to Newtonian and quantum mechanics?

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2) What is the significance of strange attractor in chaotic dynamics?

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1.5 PHILOSOPHY OF CHAOS THEORY

Chaos theory has brought in a paradigm shift in the philosophical deliberations especially in philosophy of science where the benchmark had been the classical mechanistic paradigm. Differing methodologically and epistemologically from the classical science, chaos theory can be considered as an anti-establishment and holistic science.

Mark Stone analyses the term determinism and makes a fourfold division outlining the various senses in which the term determinism is used in order to understand better the determinism associated with chaos theory. The fourfold division are differential dynamics, unique evolution, value determinateness and total predictability. The determinism which is associated with chaos theory is differential dynamics. Differential dynamics would state that the system is deterministic if the way it changes in time can be specified by a set of differential equations. The complex behaviour in a dynamical system must arise not from the fact that system is an approximation of a huge number of complicated interacting subsystems but from the internal mathematical structure. The deterministic approach towards chaos theory takes to the study of apparently disorderedly behaviour is thus in contrast to a statistical approach which focuses on the evolution of average values at many places in the system, or averages over many systems.

The unique evolution holds that the complete instantaneous description of a deterministic system fixes the past and future with no alternatives. As this forms the core of Laplacian vision of determinism, John Earman calls this the 'Laplacian determinism.' The third level of determinism namely value determinateness would mean that for deterministic systems the accuracy of a state description is infinitely refinable, even though any given state description will contain some error or in other words, physical quantities have exact values. Total predictability is the idea that the universe is predictable, in principle, by an all-powerful intelligence or computational scheme, given complete information of instantaneous conditions and the complete set of physical laws. Karl Popper calls this scientific determinism.

Determinism associated with chaos theory is used in the sense of differential dynamics and not in the sense of unique evolution, value determinateness or total predictability. The non-linearity in chaos theory, thwarts any attempt to fix the past and future, infinitely refine physical values and the dream of total predictability. The existence of chaotic systems leads us to the conclusion that the world is not totally predictable and any definition of determinism that includes total predictability in determinism is false.

The deterministic chaos theory with the presence of differential equation helps in the short term predictions. Even though long term predictions are ruled out in the non linear chaotic system, that doesn't mean it is completely indeterministic. The presence of strange attractor and the fractal nature of this strange attractor help in predicting the long term trend. Thus, chaos theory shows an alternative to the scientific world torn apart by rigorous determinism of the Newtonian mechanism and indeterminism of quantum mechanics.

While the popular literature hails chaos theory as a revolution, an analysis based on Thomas Kuhn's perspective in the philosophy of science gives a different picture. He states three characteristics of a revolution: "1) Rejection of once accepted scientific theory by the new one. 2) Shift in problems available for scientific scrutiny 3. Transformation of world within which scientific work is done." Apart from the first criteria, the second and third fits in with regard to chaos theory.

Focusing on the second criteria that call for interesting problems and successful solution to bestow the status of revolution, Katherine Hayles makes a convincing case. She brings before the study of physicist Bernardo Huberman that shows the chaotic model of eye moments in schizophrenics. Thus second characteristic fits the bill to classify chaos theory as a revolution. As chaos theory has brought about a change in scientific imagination, the third criteria too doesn't contradict chaos theory.

But chaos theory loses out in the first criteria which state the 'rejection of one time honoured scientific theory in favour of another incompatible with it.' Chaos theory so far has not displaced any theories. The chaotic behaviour occurs in Newtonian systems too. Chaos theory involves no fundamental theoretical change, while a Kuhnian revolution involves 'reconstruction of the field from new fundamentals, a reconstruction that changes some of the fields' most elementary theoretical generalizations.' So chaos theory cannot be called a revolution in the Kuhnian sense as it doesn't fit into the characteristic spelt out by Thomas Kuhn.

The focus of chaos theory is on qualitative understanding rather than quantitative information. Stephen H. Kellert defines chaos theory as "the qualitative study of unstable aperiodic behaviour in deterministic non linear dynamical systems." In qualitative understanding, rather than giving a fixed accurate solution, the emphasis is on giving general information and the great classification, which is obtained by dwelling to questions pertaining to periodicity and stability of orbits, the symmetric and asymptotic properties of behaviour, and the structure of the set of solutions. Thus chaos theory with its focus on qualitative understanding is a welcome change from the rigorous deterministic quantitative analysis of Newtonian mechanics. Thus, chaos theory initiates a paradigm shift.

Chaos theory can best suit Thomas Kuhn's analysis of scientific paradigms. According to Kuhn "a paradigm is not a theory as such, but a frame work of thought – a conceptual scheme – around which the data of experiment and observation are organized." The basic paradigm shift occurs from time to time in the history of ideas. So with this it's not only the scientific theories that change but also the scientist's conception of the world too undergoes a change. In the Kuhnian scientific understanding emphasis is not on the structure of the scientific theory but "theories are cohesive systematic bodies of knowledge defined mainly by the roles they play in normal science practice within a dominant paradigm."

The strict model-target approach too undergoes a change with the arrival of chaos theory. Following a strategy called piecemeal improvement there are two basic approaches to model a target system, invoking faithful model assumption in philosophical literature. In the first basic approach the model is kept fixed and initial data is successively refined so as to converge it to target systems behaviour. The second approach involves keeping the initial data fixed and making successive refinement in the model. As the principle of linear superposition no longer holds in non-linear models, the two approaches mentioned above are met with serious difficulties when applied to non-linear models. This is because a small change in the data quality of a small refinement in the model can result in huge divergence in system behaviour unlike linear systems. This non-linear approach from the perspective of chaos theory shows that in any non-linear system there can be mismatch between models and targets. Going behind the strict model oriented approaches that bank on rigorous deterministic predictability, without leaving space for creative response has all possibility to backfire.

1.6. RELEVANCE OF CHAOS THEORY

Chaos theory with its popular appeal, far reaching implications and wide range of applications has brought in a 'new paradigm' both in scientific and social arena. Chaos theory has neither created nor destroyed any laws it but it has brought to the forefront the once ignored disorder, instability, diversity, disequilibrium, non-linearity and temporality concepts which once suffered under the excessive emphasis of non-linearity, determinism, predictability and reversibility. Taking strong exception to the mechanistic vision that emphasis on fixed framework structures, chaos theory focus on a context which is in a state of becoming in an open environment that receives and exchanges data or information and are sensitive to the changes happening around.

Chaos theory as a metaphor has proved its usefulness in diverse fields. But irrational application of this metaphor will seriously question the credibility of the theory. Ian Stewart would point to the dangerous use of the metaphor of chaos in the wrong places with absolutely wrong interpretations. Chaos theory is fast getting misinterpreted as that which glorifies randomness and there is every possibility that it might end up in false conception like the popular interpretation of Einstein's theory of relativity, where relativity was taken by the popular interpreters as everything is relative, whereas Einstein meant relative to the speed of light. There are scientists argue that chaos is merely a subcomponent of non-linear dynamics which indeed is part of complex systems and so it can't be called a discipline in its own right.

The new generation in the globalized world is characterised by its reliance on randomness and chance and blind oppositions to dogmas of religions, structures, cultures, value systems and above all established systems. Chaos theory, by revealing the hidden order in the apparent disorder and by reconciling the extremes can turn out to be a powerful antidote in this regard.

Chaos theory also gives warning signals with the fact that the sensitive dependence on initial conditions which over the course of time result in bifurcations that can cause serious consequences. A recent example to such a phenomenon is the 2011 revolution in Egypt. It all began when a 26 year old woman wrote in the social networking site called facebook, 'People, I am going to Tahrir Square.' The message soon snowballed into a movement that ousted Egyptian president Hosni Mubarak. This would also mean that, even an uprising in a country or a war between two nations over the course of time may lead to a nuclear war between nations creating irrevocable harm to human beings.

Unveiling the mysteries of universe, sending out warning signals, providing breathing space in a world torn between extremes and seriously questioning the established theories, chaos theory has opened up innumerable possibilities of research. Chaos theory has heralded the dawn of a new era where the 'deterministic chaos' will have a greater say in the affairs of the world. Cutting across disciplines, chaos theory has the potential to permeate diverse streams and render intelligible the diverse phenomena, initiating a 'paradigm shift'.

Check Your Progress III

Note: Use the space provided for your answers.s.

1) According to Mark Stone, what kind of determinism is associated with chaos theory?

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2) What is the relevance of chaos theory in the contemporary world?

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1.7 LET US SUM UP

In this unit we have tried to give a general introduction to the dynamics of deterministic chaos theory. Beginning with the evolution of the concept of chaos in world history revealing the diverse way in which chaos and order was perceived. The scientific and philosophical implications of the extremes of Newtonian mechanics and quantum theory are discussed followed by chaos theory, which is presented as an alternative that brings together the opposing poles without making any rejection or addition of laws. Finally we conclude the unit by showing the significance of chaos theory as having the potential to initiate a paradigm shift in the state of affairs of the contemporary world.

1.8 KEY WORDS

Attractor and Strange Attractor: Attractors are the set of points in the dynamical system that attracts the orbits and to which the system settles down after its transient dynamics die out. Strange Attractor is complicated, bounded orbits of trajectories of a chaotic system, exhibiting fractal nature, allowing us to make short term predictions and long term trends.

Linearity and Non-linearity: In linearity the output is directly or inversely proportional to input. Non-linearity means that the output of a system is not directly or inversely proportional to its input. A small change in parameter can lead to sudden and dramatic changes in qualitative and quantitative behaviour of the system and give rise to complex behaviour called chaos.

Bifurcation: The tendency of a non-linear system exhibiting the drastic appearance of a qualitatively different solution when one controlling parameter is varied.

Fractals: A fractal is a rough geometric shape that can be split into parts, each of which is exactly, approximately or statistically a reduced-size copy of the whole, a property called self-similarity.

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UNIT 2 FRACTALS AND ROUGHNESS OF REALITY

Contents

2.0 OBJECTIVES

This unit is conceived to give a general introduction to the concept of fractals that can represent and analyse the roughness of reality. Rather than going into the scientific intricacies, the philosophical and scientific significance associated with fractals are emphasized. In comparison with Euclidean geometry, which remained unchallenged for centuries, we shall see how fractal geometry comes in as a worthy alternative. We shall also analyse how Benoit Mandelbrot, the father of fractal geometry, successfully represented the irregular and rough texture of nature with fractal dimensions while the Euclidean geometry unsuccessfully tried to fit in the complexities of nature into predefined shapes. A discussion on fractals like Koch curve, Mandelbrot set and others will give a basic understanding on some of the famous fractals. The significance of fractals can be seen in their practical application in myriad fields initiating a tectonic shift in scientific and philosophical outlook. Thus by the end of this Unit you should be able to:

- have a basic understanding of fractals
- contrast Euclidean geometry and Fractal Geometry
- understand how fractals represents the roughness of reality
- analyse the practical applications of fractals
- creatively ponder on the philosophical implications of fractals

2.1 INTRODUCTION

The fractal Geometry better represents the complexity of nature which was once bracketed off by the Euclidean Geometry and also reveals the micro-macro relationship. Rather than singularly approaching and analysing nature from the perspective of Platonic perfection, the introduction of fractals has initiated a paradigm shift that very well incorporates and analyses the irregularity and roughness of the nature.

Benoit Mandelbrot was the man behind the discovery of fractal dimension. The fractal dimension was initially called the Hausdorff-Besicovitch dimensions after the mathematicians Felix

Hausdorff and A.S. Besicovitch who invented and developed it. The concept of fractal dimension was considered by mathematicians to be an abstract mathematical idea. They used to go behind the fractal dimensions purely for their own entertainment. So the fractal dimension which was once ignored by most mathematicians was given a fresh lease of life by Mandelbrot. Thus today, these fractal dimensions finds application in real life as it helps in analyzing the complexity of fractal shapes, describing a wide range of natural phenomena.

Mandelbrot wrote in his book, *The Fractal Geometry of Nature*, "clouds are not spheres, mountains are not cones; coastlines are not circles, and bark is not smooth, nor does lightning travel in straight line." He moved beyond the Euclidean geometry where space has three dimension, a plane has two, a line has one and a point has zero dimension to the fractional dimensions. Mandelbrot evolved a new type of mathematics, capable of describing and analyzing the structured irregularity of the natural world, and coined a new name for the geometric forms involved: fractals. Fractional dimension became a way of measuring qualities that otherwise have no clear definition: the degree of roughness or brokenness or irregularities of the object. Fractals are ubiquitous in nature; they are seen in clouds and coastlines, ferns and trees. The human circulatory system is a series of self similar fractal from 'aorta to capillary.'

Mandelbrot made a claim which the world stood up and listened. The claim was that the degree of irregularity remains constant over different scales. Surprisingly, often, the claim turns out to be true. Over and over again, the world displays a regular irregularity. Rather than applying Euclidean geometry which bypassed the irregular structures, the fractal geometry made sure that the irregularities of the nature were incorporated. Above all it finds order in the apparent disorder which is seen in the nature. It is a movement inspired from nature rather than dominating nature with our own set of rules.

2.2 FROM EUCLIDEAN TO FRACTAL GEOMETRY

Euclid collected, studied the works of his predecessors on geometry and systematically presented in his book *Elements* which contains treatises on maths and geometry. Until the arrival Non-Euclidean Geometry in the second half of nineteenth century, Euclidean Geometry stood unchallenged. Geometric statements in Greece were derived by logic alone from self evident geometric assumptions called axioms. Euclid chose five axioms and from them he formed the body of theorems known as Euclidean geometry. The Euclidean postulates can be given in modern terms as: 1. A line joining two points is a straight line. 2. This line can be extended indefinitely. 3. Given any straight line, a circle can be drawn having the segment as radius and one point as the centre. 4. All right angles are congruent. 5. If two lines are drawn which intersect a third in such a way that the sum of the inner angles on one side is less than two right angles then two lines inevitably must intersect each other on that side if extended far enough. As the fifth postulate stands as basis for the uniqueness of parallel lines, it is called the parallel postulate.

The classical Euclidean geometry is predominantly influenced by the Platonic philosophy. The Platonic philosophy gave utmost importance to the world of forms or ideas which were considered as eternal and absolute. The temporal and changing world which we live in was considered only to be the shadow of the unperceived real world that is permanent and unchanging. As a necessary after effect of Platonic philosophy, irregularities or complexity of nature was not taken up into Euclidean geometry. Thus we have the shapes of classical geometry restricted to lines and planes, circles and spheres, triangles and cones. Whatever be the irregular features that were present in the reality, they were all powerfully abstracted into these perfect shapes.

The absoluteness of Euclidean geometry was challenged by mathematicians like Janos Bolayi, Nikolai Lobachevski, and Karl Friedrich Gauss in the nineteenth century. The Non Euclidean geometry came up with the realization that the Euclid's parallel postulate was independent of the other four axioms and could never be derived from them. They also understood that a consistent system of geometry can be built if one add the negation of the parallel postulate to other axioms. The two main types of non Euclidean geometry are hyperbolic geometry and elliptical geometry, having negative and positive curvature respectively. The properties of the Non-Euclidean geometry such as curvature were far beyond the every day human experience which Einstein could apply to his theory of relativity.

The strong influence which Euclidean geometry wielded can be well understood from Immanuel Kant who claimed that people could think about space only in Euclidean terms. The arrival of non Euclidean geometry showed that there are other conceivable descriptions of space. Non Euclidean geometry was the first step forward from the rigid notion of viewing the reality from a linear outlook with excessive emphasis on perfection and leaving out imperfect and irregular feature. The arrival of fractal geometry brought in the once ignored realm of complexity found in nature.

2.3 FRACTAL GEOMETRY AND THE THEORY OF ROUGHNESS

Euclid was preoccupied by the vision of unrealistically ordered universe, and could not provide a geometry that could picture the roughness and irregularity of the world Galileo stated that the Great book of Nature is written in the language of mathematics with characters being circles, triangles, and other such shapes.. With Fractal geometry, Mandelbrot was knitting together a theory of roughness. This changed the notion that pure mathematics was incompatible in representing the irregularity of the substances in the world through the fractal geometry of nature.

Emphasizing the roughness of the universe, Mandelbrot states that everything in the world is rough except for the circles. Geometry and physics have ignored the roughness of reality as they were too complicated. Beyond the regular geometrical structures like circle, cone, sphere, straight line and the like, Mandelbrot wanted to show that the odd shapes that is found in the nature carry meaning. He heralded the arrival of a new geometry which provided a language to describe the nature with its imperfections and irregularities.

The fractal geometry measures the degree of roughness or brokenness or irregularity of an object. The term fractal was coined by Mandelbrot in 1975 from the Latin term *fractus* which describes a broken stone – broken up and irregular. According to Mandelbrot, "Fractals are geometrical shapes that, contrary to those of Euclid, are not regular at all. First, they are irregular all over. Secondly, they have the same degree of irregularity on all scales. A fractal object looks the same when examined from far away or nearby – it is self similar." Fractal geometry is called the geometry of nature because unlike the classical or Euclidean geometry it helps us model things that we see in every day life.

Self similarity, a hall mark of fractals, means the object is similar to a part of itself exactly or in an approximate way. Many examples of fractals can be seen in nature like ferns, cauliflower and many other plants where the branch and twig are very like the whole. There are three types of self similarity namely exact self similarity, quasi self similarity and statistical self similarity. Objects displaying the exact self similarity appear identical at different scales. In quasi self similarity, the fractal would be approximately self similar across scales. Statistical self similarity means a numerical or statistical measure of the fractal is preserved across scales.

Yet another feature of fractal geometry is the fractional or non integer dimension. In 1967, Mandelbrot wrote a seminal paper titled, "How long is the coast of Britain? Statistical self-similarity and fractional dimensionality," in *Science* magazine. Though it seemed to be simple question, the answer would depend on the way we measure the coastline. If we measure it with a meter stick, the answer will be approximate as it would be overlooking the little nooks and crannies. If measured with a smaller scale then we would get a greater length for the coastline as it would go into smaller spaces of the coastline and count them. Thus the length of the coastline would depend on the one's choice of measuring stick. This problem according to Mandelbrot can be solved only by moving away from the ordinary three dimensions to fractal dimensions.

Going beyond the classical Euclidean geometry that works with objects existing in integer dimension, Mandelbrot moved to the non integer dimension. Non integer dimension helps in measuring the qualities of an object which exhibits roughness or brokenness or irregularity. He specified the ways of calculating the fractal dimension of real objects and stated that irregularity remains constant over different scales. The fractal used to model coastlines have the dimension between 1 and 2, while those used to model mountain surfaces have dimension between 2 and 3. The fractal dimension of earth's surface as indicated by NASA photos is 2.1 while that of Mars is 2.4.

Even though the term fractal has been coined recently by Mandelbrot; mathematicians knew well about the complex fractal structures for a century or more. For pure mathematicians these fractal sets that they derived from complex numbers were a means of entertainment. During those times geometry was considered inferior to pure mathematics. Mathematicians remained aloof from the real world confining themselves to the world of numbers. With the arrival of Mandelbrot, mathematics again combined hands with reality. Thus, fractal sets which were once the object of bizarre fancies of mathematicians were found to be useful for describing diverse natural phenomena.

Check Your Progress I

Note: Use the space provided for your answers.

1) Why was Euclidean geometry unable to represent the roughness of reality?
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2) Explain the fractional dimension and self similarity associated with fractal geometry.
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2.4 SOME FAMOUS FRACTALS

In order to model the fractal shapes found in nature, geometric figures that exhibit precise self-similarity are constructed. Iteration is the method by which mathematical fractals are constructed. It means continuously repeating a certain mathematical operation. There are three types of iterations namely generator iteration, Iterated Function System (IFS) Iteration and Formula Iteration. In generator iteration, certain geometric shapes are repeatedly substituted by other shapes to create a fractal. Iterated Function System iteration applies geometric transformation repeatedly in order to create a fractal. In the formula iteration a certain mathematical formula or several formulas are repeated to create a fractal.

Koch Curve

Koch curve or the Snow flake curve is one of the simplest fractal shapes generated by iteration. It was discovered by Swedish Mathematician Helge von Koch in 1906. The process starts with a line segment. It is divided into three equal parts and the central section is replaced by two sides of an equilateral triangle. This process is repeated for the four segments repeated after the first iteration and the process is repeated to get the Koch curve.

The Cantor Set

Cantor set is named after the nineteenth-century mathematician George Cantor. The generation of this set involves iteration of a single operation on a line of unit length. The middle third from each line segment of the previous set is removed with each iteration. With the increasing iterations the number of separate line segments tends to infinity while the length of each segment approaches zero. Magnification reveals self similarity as the structure is essentially distinguishable from the whole.

The Sierpinski Triangle

Named after the polish mathematician Waclaw Sierpinski, Sierpiniski triangle is made by making infinite removals. Each triangle is divided into four smaller, upside down triangles. Then we remove the centre of the four triangles. Iterating this process, an infinite number of times the total area of the set tends to infinity as the size of each new triangle goes to zero. Upon zooming into the completed Sierpinski triangle to any depth would reveal the exact replica of the entire Sierpinski triangle. It provides one of the basic examples of a self similar set.

The Mandelbrot Set

The Mandelbrot set, one of the famous fractals in existence, is the modern development of a theory developed independently in 1918 by Gaston Julia and Plerru Fatou. This set is named after Benoit Mandelbrot. It is born out of the quadratic equation $z = z^2+c$, where z and c are complex umbers. Mandelbrot set is the set of all complex c such that iterating $z = z^2+c$ does not diverge. One of the interesting features of Mandelbrot set is that it retains its highly complicated structure even while zooming at higher levels of magnification.

The Julia Set

The Julia set was discovered by Gaston Julia and Pierre Fatou. The Julia shares a very close relation with Mandelbrot set. It is the difference in function iteration that separates Julia set and Mandelbrot set. The Mandelbrot set iterates $z = z^2+c$ with z always starting at 0 and varying the c value. The Julia set iterates $z = z^2+c$ c for a fixed c value and varying z values. While the Julia set is in the dynamical space or the z plane, the Mandelbrot set is in the parameter space, or c plane.

Check Your Progress II

Note: Use the space provided for your answers.

1) What is iteration used for and what are its different types?

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2) How is a Mandelbrot set created?

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2.5 PRACTICAL APPLICATIONS OF FRACTALS

The fractal concept and the fractal objects find immense use in diverse fields. From image compression to finance, artists and scientists are experiencing the value of fractals. Fractal Geometry is used to describe many complex phenomena. From physics to astrophysics, biology to chemistry and even in market fluctuations fractals have found various applications.

Yet another important application of fractals is in the non linear dynamics, especially with regard to chaos theory. Both chaos theory and fractals appeared unrelated in the nineteen seventies during their infancy even though they are mathematical cousins. The predictability in a chaotic system is ruled out due to sensitive dependence on initial condition and makes one wonder about the scope of finding any order in the system. Here fractal structure of the strange attractor comes to the rescue. Fractals help us decode the language of chaos and present us with a meaningful picture. The strange attractors of chaotic systems are often fractal. This does not mean that all fractals are examples of chaos. Chaos naturally produces fractals. As nearby trajectories expand they must eventually fold over close to one another for the motion to remain finite. This is repeated again and again, generating folds within folds, up to infinity. The beautiful microscopic structure of chaotic attractors results from this process. The advantage of fractal image is that the extraordinary detail present in fractal images can be generated by very simple recipes. The fractal intricacy of an attractor gives the best solution to the modelling problems that involves a structure with infinite intricacy and having the characteristic of chaos.

Mandelbrot was involved in the study of financial prices during the early and toward the end of his career. He stated that the price fluctuations, as assumed by economists are not smooth but often discontinuous and irregular and the most important ones are concentrated in time in such a way that the wealth acquired in stock markets is confined to a very small number of favourable periods. Great attention is received for Mandelbrot's notions of fractals and multi-fractal forms of economic concentration. His study of the financial markets in 1963 resulted in a paper titled, "The Variation of Certain Speculative Prices." and in 2004 he co-authored a book with journalist Richard Hudson titled *The (Mis) Behaviour of Markets: A Fractal View of Risk, Ruin, and Reward*.

Fractals aid in modelling self similar natural forms. It helps in mimicking the large scale real world objects. Fractals comes in handy for an environmentalist who want to estimate the effect of a disaster like a large scale oil spill or the doctor who needs to calculate the surface area covered by bronchial tubes within a human lung. In both the cases fractals are used to an approximate the structure of a real object for the better understanding and implementation.

Fractals create amazing visual effects which has been successfully tried and tested in many films like Star Wars and Star Trek. They not only have the aesthetic value but also trick the mind. The Fractal images are aesthetically and economically far better alternative to the outdoor costly and elaborate shooting sets.

Fractals are used in architecture. According to Mandelbrot, "some cultures have a very strong fractal aspect; Persian, Indian and Mughal architecture often show the contours of small domes within large ones." Identifying the fractal structure of a building helps one to adjust the structure so as to improve the strength and integrity.

Fractals also find use in psychology and counselling. Theoretical biologists have began finding fractal organization that control structures all through the body a decade after Mandelbrot published his physiological speculations. Geologists have found that the distribution of earth quakes fitted into a mathematical pattern which is fractal. The fractal patters also helps in making weather predictions.

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2.6 SIGNIFICANCE OF FRACTALS

Fractals have stimulated new and deeper investigations in diverse fields. It unravels a new regime of nature which is subjected to mathematical modelling. The formless and irregular patterns receive a new meaning with fractals. Fractals convincingly explain and explore the innumerable complex natural phenomena which were conveniently bypassed for the want of scientific explanation.

Fractal geometry was successful in representing the reality with its irregularities and imperfections which classical and Euclidean geometry could not do. The idea of fractal dimension was a worthy replacement for the Euclidean measurements that failed to capture the essence of irregular shapes. Thus, rather than bracketing out the roughness of the reality as an imperfection, fractals helps in incorporating them with others thus resulting in a holistic understanding of the reality.

It is impossible to quantitatively measure the individual details of a fractal. We have a shift from quantity to quality. The fractal dimension gives the numerical measure of the degree of roughness of a fractal. The understanding of fractals displaces the general notion that the 'complexity of structure is a result of complicated interwoven processes.' This would mean acknowledging the greater significance of simple process, which could result in complex patterns. The fractal patterns arising out of the iteration of simple equations underline this fact.

The fractal dimension has reignited the interest in mathematics by creating a renewed interest both for teaching and studying. Fractals are extremely useful in teaching mathematics in combination with physics and some aspects of art. Mandelbrot finds the tremendous interest seen in fractal geometry outside the mathematics community as a healthy development. This would impart mathematical literacy to the otherwise highly educated people. As Ian Stewart states, "So today, fractals appear in science in two different ways. They may occur as the primary object, a descriptive tool for studying irregular process and forms. Or they may be a mathematical deduction from an underlying chaotic dynamic."

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Check Your Progress III

Note: Use the space provided for your answers.

1) How is chaos theory and fractals related?

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2) Explain how fractals have stimulated new and deeper investigations in diverse fields.

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2.7 LET US SUM UP

In this unit we have initiated a discussion on the concept of fractals. In comparison to Euclidean geometry that strived for Platonic perfection and lost out in representing the roughness of reality, fractal geometry is presented as means to picture the roughness of reality in the best possible way. We have seen how Benoit Mandelbrot related the fractals, which once remained an exclusive property of mathematicians in successfully explaining the complexity of nature. Some of the famous fractals and the way in which they were modelled also have been discussed in brief. After the discussion on the practical application of fractals, we conclude by outlining the far reaching significance fractals have in store for mankind.

2.8 KEY WORDS

Benoit B. Mandelbrot: The mathematician who coined the term Fractal. It was Mandelbrot that the fractal sets which were once the object of bizarre fancies of mathematicians were found to be useful for describing diverse natural phenomena.

Fractals: A fractal is a rough geometric shape that can be split into parts, each of which is exactly, approximately or statistically a reduced-size copy of the whole, a property called self-similarity.

Fractal Dimension: Fractal dimension is the fractional or non integer dimension which helps in measuring the qualities of an object which exhibits roughness, brokenness or irregularity in a better way.

2.9 FURTHER READINGS AND REFERENCES

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UNIT 3 NANOTECHNOLOGY: BASIC IDEAS AND APPLICATIONS

Contents

3.1 OBJECTIVES

Nano technology is an innovative development in science and technology. It has a convergence with many disciplines. It has revolutionary implications for society. It has even a potential to challenge the existing notions of reality. This unit provides the basic ideas and applications of nano technology. Further it explores the social ethical implications of this kind of technological developments in contemporary world situation.

3.2 INTRODUCTION

Nanotechnology involves working with matter at the atomic or molecular scale. Nano technology is a technology of rearranging and processing of atoms and molecules to fabricate materials to nano specifications such as a nanometre. Materials and devices designed and made at the molecular level would be quite different from those of daily use today. It is argued that the new products would be far superior in terms of strength, toughness, speed and efficiency. The products are considered cleaner, stronger, lighter and more precise. Nano technology is set to bring about a fundamental change in several areas- materials science, electronics, biology, medicine- and is expected to profoundly change the pattern and standard of life of people. The goal of research in nanotechnology is to discover and understand these unique properties and ultimately find a way to put these characteristics to use.

Nano science is a convergence of physics, chemistry, materials science and biology, which deals with the manipulation and characterization of matter on length scales between the molecular and the micron size. Nanotechnology is an emerging engineering discipline that applies methods from nano science to create products. Nanotechnology is an emerging range of technologies in which medicine and engineering meet physics and chemistry. Nanotechnology involves ‘research and technology development at the atomic, molecular, or macromolecular levels, in the length scale of approximately 1 to 100 nm range, to provide a fundamental understanding of phenomena and materials at the nanoscale and to create and use structures, devices, and systems that have novel properties and functions because of their small and/or intermediate size'. Materials of molecular and macromolecular scales have new and often unexpected properties. Nano technology poses a challenge to manipulate atoms individually and place them precisely where they are needed with predefined features.

3.3 NANO TECHNOLOGY: DEFINITION

There is no common agreement on the definition of nanotechnology. Many scholars and research agencies defined it differently. The current dictionary definition of Nanotechnology is 'the design, characterization, production and application of materials, devices and systems by controlling shape and size at nanoscale.' (E.Abad. et al., *Nano Dictionary*. Basel: Collegium Basilea, 2005) The Royal Society (2004) defines *Nanoscience* as the study of phenomena and manipulation of materials at atomic, molecular and macromolecular scales, where properties differ significantly from those at a larger scale. *Nanotechnologies* are design, characterization, production and application of structures, devices and systems by controlling shape and size at nanometer scale. US National Nanotechnology Initiative (NNI), one of the largest founders of nanotechnology research in the world uses the definition: nanotechnology is the understanding and control of matter at the dimensions between approximately 1 and 100 nanometers, where unique phenomena enable novel applications. Encompassing nanoscale science, engineering, and technology, nanotechnology involves imaging, measuring, modeling, and manipulating matter at this length scale. (NNI, 2008). US Foresight Institute came with a definition, "nanotechnology is a group of emerging technologies in which the structure of matter is controlled at the nanometer scale to produce novel materials and devices that have useful and unique properties."

3.4 HISTORICAL DEVELOPMENT OF NANO TECHNOLOGY

Though the term Nanotechnology was coined in 1974 by a Japanese scientist Norio Taniguchi, it has nothing to do with the present day usage. The prefix of nanotechnology derives from the unit of length, the nanometer, and in their broadest definitions these terms refer to the science and technology that derives from being able to assemble, manipulate, observe and control matter on length scales from one nanometer up to 100 nanometers or so. One nanometer is a billionth of a meter or one thousandth of a micrometer, sometimes called a micron, which in turn is one thousandth of a millimeter. It is abbreviated to 1 nm. Molecules, viruses and atoms are objects that range from less than 1nm to about 100 nm. For instance, a human hair is roughly 20,000 nm in diameter. A bacterial cell might be up to a few thousand nanometers in size. They are too small to see with the eye, or even with the microscopes that use visible light. New technologies are facilitating to visualize even these small particles. The technologies like the scanning tunneling microscope and the atomic force microscope are not only for seeing but also manipulating things at this small scale.

Prior to invention of scanning tunneling microscope, the atomic structure of matter was quantitatively revealed by x-ray diffraction. The information they contain are not direct real space representation of matter. With them you cannot pinpoint the position in space of a given atom, molecule or cluster. With the development of Scanning Tunnelling microscope, not only could the individual atoms and molecules be imaged; they could also be individually manipulated. Through the inventions of scanning tunneling microscopy (STM), scanning force microscopy (SFM) in second half of twentieth century, images are obtained not by gathering reflected or refracted waves from a sample, as happens in conventional microscopies such as light or electron microscopy. Instead, a very fine tip is scanned across the surface of the sample, interacting with it in one of a number of possible ways. The picture is built up electronically by recording the changing interaction with the surface as the tip is scanned across it. New techniques – including scanning force microscopy – are capable of interrogating the properties of single molecules. It is the information about the properties of a single molecule provided by these techniques will be essential in the design of nano scale devices.

Today, nano technology has emerged as an important interdisciplinary subject with internalizing the recent developments in various fields. The nano technology has wider applications and products produced by nano technology have serious implications too for contemporary world- economically, ethically and politically. The world of nano technology is broadly divided into two major application areas- wet and dry areas. The wet area includes the biological domain, where nano structures may function within biological cells. The dry area includes hydrophobic architectures and strategies that govern improvement of materials including computer chips. Dry nano technology applications have preceded the biological use. Initially, biology and electronics are likely to be the major areas of application. Nano technology is also expected to provide a new tool to read the genetic code. The discoveries that have been made so far in the science of nano scale, offer new possibilities for a multitude of industries.

3.5 NANO TECHNOLOGY: NEW TECHNOLOGICAL REVOLUTION

Nanotechnology is being heralded as a new technological revolution. It is so profound that it will touch all aspects of economy and society. Through the developments in nano technology, energy will be clean and abundant, the environment will have been repaired to a pristine state, and any kind of material artefact can be made for almost no cost. Space travel will be cheap and easy, disease will be a thing of the past, and we can all expect to live for more years.

Current applications for nanotechnology are dominated by tools for scientists, and by new materials that are structured on the nanoscale. Such materials are used in cosmetics, health and medicine and in a variety of manufactured goods. The electronics and information technology industries are also a prominent driver for these new technologies. Carbon nanotubes have potential applications in electronics, improved materials, and drug delivery. Today we have already been witnessing a few commercial applications of nanotechnology such as improved hard-disks for computers, sunscreens, and improvements to telecommunications. Much of the potential for the translation of nanoscience into useful and viable products is likely to be realised within the next decade or two. As the knowledge and tools improve, it is likely that at least some of the possible applications will become commonplace in our everyday lives. For instance, new lithographic techniques to make nanoscale components for computers are highly likely to replace current methods and materials. Levels of public expectation that nanotechnology may bring about significant improvements in the length and the quality of life are high. In the field of bio technology and medicine, the public expectation on this new technology is high. The biggest economic driving force for nanotechnology now comes from information technology. Nanotechnology has the potential for smaller and faster computers with larger memories than current processes of making transistors and other components permit. In the long term, entirely new applications may emerge.

Technological optimists look forward to a world transformed for the better by nanotechnology. For them it will cheapen the production of all goods and services, permit the development of new products and self-assembly modes of production, and allow the further miniaturisation of control systems. At the same, there is strong criticism on the implication of nano technology in our society on different accounts. However, it is too early to predict its implications.

3.6. APPLICATIONS OF NANO TECHNOLOGY

Nanotechnology applications in development can be broadly divided into several thematic areas: the development of the tools that enable the research and ultimately the technology; applications relating to new or improved materials; applications within the sphere of electronics and IT; advances in health and medicine; improvements in cosmetic products and advances in food technology; developments in products for military and security use, and space exploration; and products and processes to improve the environment. Nano technology has tremendous development in the fields of material science, electronics, biomedical science, biotechnology, military and the environment. The computing and electro communications industries are driving large investments with the aim of maintaining the relentless technological advances that the structure of those industries seems to demand. In Biomedical science, the driving force for innovation is as much political as economic, as spending on medical research seems to be one of the most popular and widely supported forms of public spending in western economies.

Material science

The science of metals, ceramics, colloids and polymers, has always concerned itself with controlling the structure of materials on the nanoscale. Here, nanoscale science and technology will largely facilitate incremental advances on existing materials and technologies. The improved control over nanoscale structure, and better understanding of relationships between structure and properties, will continue the long-run trend towards materials that are stronger and tougher for their weight. Some specific areas in which Nano science technology is contributing to materials science now include: new forms of carbon; nanocomposites; quantum dots and wires; and nanostructured materials produced by self-assembly. The cosmetics and paints industries are perhaps perceived as being the most developed in incorporating nanoparticles into their products, for example, the shampoos, skin creams, and sunscreens already being used by consumers.

Medical

The medical area of nanoscience application is projected as one of the most potentially valuable, with many projected benefits to humanity. With the advent of new materials, and the synergy of nanotechnologies and biotechnologies, it could be possible to create artificial organs and implants that are more akin to the original, through cell growth on artificial scaffolds or biosynthetic coatings that increase biocompatibility and reduce rejection. These could include retinal, cochlear and neural implants, repair of damaged nerve cells, and replacements of damaged skin, tissue or bone. The diagnostics and drug delivery is likely to benefit from the development of nanotechnology. With nanoparticles it is possible that drugs may be given better solubility, leading to better absorption.

Cosmetics
Cosmetics and personal products companies have been extremely active in using nanotechnology to improve their existing products and to develop new ones. Cosmetics companies were among the first to get products that were labelled as being nano-enhanced to market. Shampoos and skin creams, containing nanoparticles with the ability to deliver the desired ingredient to where it is needed.

Military
In the field of military, improved materials, lighter but with tough, heat resistant properties, are being used in the design and construction of spacecraft and satellites, and this process will gain from nanotechnology. There is also the possibility of nanotechnology facilitating improvements in civilian security equipment. The Institute of Nanotechnology suggests fingerprinting will become cheaper, quicker and more effective using DNA techniques involving nanotechnology, and there is also the possibility that nano-based sensors could be used as electronic detectors ('sniffer dogs') for improved airport security. Quantum dots, fluorescent nanoparticles which glow when exposed to ultraviolet light, may be used as tags and labels to prevent theft and counterfeiting, and to trace the course of drugs within the body.

Biotechnology
In the field of biotechnology researchers are looking to nanotechnology as the basis of new implants that will replace lost hearing or vision, as new ways of delivering 'smart drugs' to parts of the human body, and as ways of carrying 'body repair' cells to areas where tissue has been damaged. As researchers master this new field, revolutionary concepts such as replacement arteries, nanofibre bone reinforcements, powerful microscopes the size of a pen, and new diagnostic technologies are becoming more and more probable.

Green Technology
Nanotechnology can be used to prevent, monitor and alleviate a wide range of environmental problems, while significantly reducing cost and improving performance. Current and future applications of nanotechnology will allow us to:

- Develop new "green" processing technologies that minimize the amount of undesired by-products;
- Detect and remove the finest contaminants from air, water, and soil, which would enhance the ability of governments to respond to terrorist threats and ensure the safety of water supplies;
- Attain sustainable development by reducing the use of raw materials;
- Design cars that are lighter and more resistant to denting and scratching, resulting in fuel savings and increased longer-lasting vehicles;
- Extend the shelf life of food and beverages by creating barriers against water vapor and oxygen;
- Save energy through "smart" insulation and construction materials

Hi-Tech

Nanotechnology provides unprecedented control of light and power. Light emission and/or absorption are crucial for optical communications, display technologies, information storage, solar energy collection, genome sequencing, and even targeted drug delivery. The integration of organic/inorganic/mechanical properties can result in self-intelligent systems and self-correcting systems with internal control. Miniaturization is a critical concern for microelectronics, computing and telecommunications industries. Optical routers, large-scale displays, and ultra-dense molecular memory are only some of the short-term applications. A cool flat-panel screen will replace your bulky television set at an affordable price, thanks to carbon nanotechnology. This technology will produce better displays at a lower cost, for home theatres, office equipment, portable computing tools, and many other applications. Based on a fusion of biology and photonics, there are also potential applications in non-invasive cancer therapies, laser tissue welding, drug delivery, and diagnostics.

Check Your Progress I

Note: Use the space provided for your answers.

1) Define nanotechnology?

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2) Discuss the applications of nanotechnology?

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3.7 DISCOURSE ON NANO TECHNOLOGY

The debate on nanotechnology is founded on a range of conceptions of what this emerging technology encompasses, and judgments on what it may mean for society. The scientific community too divided on the potential and future of nano technology. Some of them attributed radical departure from science and technology and visualized revolutionary implications of nano technology. Some of the scientists are skeptical about the potential of nano technology and even critical about the ongoing research and propaganda about nano technology.

The term nano technology was popularized by a book written by K. Eric Drexler, nanotechnology visionary in a book of 'future history' called *Engines of Creation*. Drexler used the word to describe his vision of a world where molecular manufacturing would allow people to manufacture *anything* they might need – from automobiles to pieces of beef – simply by feeding waste material into a box that would use nano scale assemblers to re-configure it into the necessary form. Jamie Dinkelacker, in his paper *Transitions to Tomorrow* (2002), Nanotechnology heralds a new industrial era, a 'Molecular Epoch' that involves major social changes. The advances in science have been achieving near total control over the structure of matter. He viewed that the era of nano technology promises "novel materials and capabilities, leading to novel living patterns, new ways of socializing, and yielding fresh approaches to cooperation and competition. He speculates that nanotechnology offers the potential for global material abundance, and it is the loss of scarcity that has the "potential for dramatic social change. Especially, the molecular nano technology has the ability to “programme matter with molecular precision”. In *‘Why the Future Doesn’t Need Us’*(2000), Bill Joy, chief scientist of Sun Microsystems, also adopts the radical conception of nanotechnology, where the “replicating and evolving processes that have been confined to the natural world are about to become realms of human endeavor”. Joy accepts that nanotechnology, coupled with advances in genetics and robotics, is highly revolutionary and transformative.

George M Whitesides, an experimental surface chemist and pioneer of new nanotechnology techniques, in his article *The Once and Future Nanomachine* (2001), is much more skeptical about the radical view of nano technology. He contends that nanotechnology could learn much from biology. Rather projecting the magnitude of nano technology and the nano machines, he appraises the developments in biology and chemistry, on which nano technology is based. Whitesides seems reluctant to believe that new forms of sophisticated nanoscale machines are feasible, particularly not from scaling down macro-machines. Instead, “biology and chemistry, not a mechanical engineering textbook” may hold solutions for nanotechnology. Whitesides is skeptical that the Drexlerian vision of molecular manufacturing is possible, though he does not explicitly rule it out.

Richard E Smalley, chemist and the Nobel Prize winner for the discovery of fullerenes in 1996, in *Of Chemistry, Love and Nanobots* (2001) too is skeptical as Whitesides. For Smalley, chemistry is the most effective method of molecular manipulation, as atoms perform a “complex dance involving motion in multiple dimensions” in chemical reactions. He argues that nanobots or assemblers “are simply not possible in our world”, due to constraints imposed by the limitations of the scale. In his view, the need to control all the atoms surrounding the reaction site would require so many manipulators that there would not be room, while the atoms forming the nanobot would themselves bond with the atoms to be manipulated. Whitesides, and Smalley represent the scientific argument against the radical viewpoint; they are particularly skeptical that the Drexlerian vision of molecular manufacturing is feasible. These highly respected scientists argue that this conception of nanotechnology does not fit within the laws of physics and chemistry as they operate on the nanoscale, or is redundant due to the superior power of biological processes.

Drexler’s vision for nanotechnology is one of the atomic precision and perfect and complete control over molecular reactions. It is essentially an engineer’s vision. Smalley’s vision in turn, insists on production of detectable and controllable phenomena, and takes a crucial part of scientific activity the manipulation and stabilization of the phenomena. This is essentially a chemist’s vision. The writing on nanotechnology has been discussed in terms of two dimensions: its conception of nanotechnology and its perception of the possible social and economic effects. There is an emerging concern that the needs of society to be considered as part of the development process and that nanotechnologists not be left alone to dictate what materialises. This implies that any assessment of possible social and economic effects be incorporated into this process as early as possible, and hence that social science, as a major provider of such understanding, can help shape the future of nanotechnology.

3.8 SOCIAL AND ETHICAL IMPLICATIONS OF NANO TECHNOLOGY

Many of the applications arising from nanotechnology may be the result of the convergence of several technologies. The technological development and its implementation do not operate in a vacuum, and nanotechnology will be influenced by other scientific developments, social reactions, and local and global politics. The extreme supporters claim that nanotechnology can rebuild the human body from within and effectively abolish death, while its critics fear that instead, it could do away with life, by turning the surface of the Earth into an uninhabitable grey mass. However, the social science reading can help us understand nanotechnology in a better way than technological deterministic view. Nanotechnology in relation to society has to explore the driving forces behind the technology development process and the issues of inequities and economic divides and how society deals with risks under uncertainty. There are further apprehensions about nanotechnology since its closeness to market forces and research is mostly carried by the interests of advanced nations and market forces in corporate laboratories. Nano is a big business. National Science Foundation of USA predicts that nano-related goods and services could be $ 1 trillion market by 2015. It is the fastest growing industry than any other in the recent history.

While nanotechnology offers opportunities for society, it also involves profound social and environmental risks, not only because it is an enabling technology to the biotech industry, but also because it involves atomic manipulation and will make possible the fusing of the biological world and the mechanical. There is a critical need to evaluate the social implications of all nanotechnologies. There is a possibility that domination of nano-robos in every day life will make human intervention difficult, if not impossible. Another risk is that the hazard posed to human life and health by nano particles inhaled in the factory and elsewhere. Environmentalists also question the safety of nanoparticles. The first concerns the biological and chemical effects of nanoparticles on human bodies or natural ecosystems; the second concerns the issue of leakage, spillage, circulation, and concentration of nanoparticles that would cause a hazard to bodies or ecosystems. The potential dangers of nano technology include rampant nano-devices, military weapons, or invasive surveillance. On ethical side, the issues of intellectual property as well as the access of nano technology to developing countries have to be addressed. The public policies to protect our society from harmful developments are another concern based on strong foundations of ethics.

If technology is fascinated towards control and over taking of nature, nanotechnology is mainly concerned with the control of nature at the most basic level, i.e. level of atomic building blocks. However, Nanotechnology has been generating new ethical dilemmas and in future we have to necessarily negotiate with a big deal of uncertainties. The ethical theories have to be reformulated with changing context that had predominantly influenced by nanotechnology. Nanoethics have emerged as a new field of applied ethics that looks at the issues of right and wrong in the development and application of nanotechnology. (Lin and Allhoff, 2007)

3.9 DEMOCRATIZATION OF TECHNOLOGY

Philosophers are concerned about the technology and came with different perspectives of philosophy of technology. Two dominant streams in this regard are theories of technological determinism and social construction. The interface of technology and society and rational and ethical understanding of that situation is the main concern of the philosophers. The Marxists

though find technology as a means of liberation argues for a socialization of its wealth by abolition of classes. They view a harmony between man and nature against the alienation. The phenomenologist Heidegger considers technology is not a simplification of artifacts, but an all encompassing world view that revealing the world. Objects enter into our experience only in so far as we notice their usefulness in the technological system. He also believes that releasing from this needs a new mode of revealing, but he has no idea how revealing come and go. The pragmatic thinker John Dewey considers scientific theories and logic are tools used in a certain social practices. So the success of technology depends upon its usefulness. Herbert Marcuse, the Frankfort school thinker in *One Dimensional Man* (1964) argues that technology leads to a new form of domination in industrial society. He forwards a view that restoration of harmony of man and nature through new science and technology. It requires the abolition of class society. Hebermas contests the Marcuse's new science and technology as a romantic myth. He argues that problems of capitalist modernity are due to obstacles it places in the way of rationalization in its moral- practical sphere. Andrew Feenberg by consolidating these debates in *Questioning Technology* (1999) argues that society is organized around technology. Technological power is the principal form of power in the society. Feenberg's major focus and distinctive position within current debates on technology has an emphasis on democratic potential for the social reconstruction of technology. Feenberg rejects both neutralist positions which see technology as a mere instrument of human practice, amenable to any and all projects and uses, and determinist notions which see it as an instrument of domination in the hands of ruling elites whose very construction determines the uses, limits, and applications of technology. Instead he sees technology as a contested field where individuals and social groups can struggle to influence and change technological design such that the very construction of technology is subject to democratic debate and contestation. He proposes for a possibility of alternative rationalizations, alternative modernity through alternative politics. Feenberg is interested in the possibility of *alternative rationalizations*, particularly forms of rationalization necessary for socialism, which would embody responsibility for humanity. He strongly proposes that a technological society requires a democratic public sphere sensitive to technical affairs.
Most of these perspectives are evolved from the reflections on industrial society. These views have relevance for the context of nanosociety too. Nano technology has not only going to change significantly but also producing inequalities in society through monopoly of technology and control over many nations and social groups. Democratization of the nanotechnology is an immediate concern as raised by the conscious scholars and civil society organizations. Rather negating the technology per se, we can shape the technology with our social and ethical concerns emerged out of our struggles for democracy. Currently, corporations, developed nations, entrepreneurs and technologists are the main driving forces behind nano technology. Mostly the research and its products are market oriented. There is a need to understand the driving forces and the process of decision making in relation to nano technological development. Nano technology is invariably related with information technology and biotechnology. As a result, nanotechnology has become crucial for economic growth of nations. At this juncture, political regulation and consensus is required to control technological change.

There are consensus and campaigns in civil society from different sections on the issue of nano technology for its future implications to humanity. Their concerns are mainly for democratization of technology and egalitarian social order. It is argued that the point is not that the technologies are bad… [but] the evaluation of powerful new technologies requires broad social discussion and preparation". Sue Mayer(2002), who sees parallels between the emergence of nanotechnology and of genetically modified (GM) 15-20 years ago. The lack of democratic consultation keeps the assessment of any risk within the realm of the 'expert'; the public is then considered ignorant, and the authorities attempt to calm any fears with 'sound science', a concept that to Mayer is shaped "not by scientific facts but by its political, social, economic and cultural context". Mayer's concerns, however, extend beyond the lack of democracy in technological development to the effects that this may have over the safety of nanoparticles for humanity and the environment. Moreover alternatives will not have been explored and the economic benefits of nanotechnology may be less than they would be if the public had been involved in its design. The perceived lack of democratic consultation also raises concerns regarding the control and ownership of the technology, the possibility of its monopolisation and the "implications of corporate control over matter." ETC, *Action Group on Erosion, Technology and Concentration* envisages that the recent trend of the control of technology development being lost to the public arena, the "privatisation of science and a staggering concentration of power in the hands of giant multinational enterprises" will be further reinforced by nanotechnology. In ETC's picture of the future, the "control of the technology will accrue to those with power and the commercialisation of the technology will inevitably give them greater monopoly control". ETC does not trust big business, or governments, to use this knowledge, power and control ethically. Allied to these issues of monopoly and control is the negative vision that nanotechnology will reinforce global inequalities between rich and poor. It dismisses the eradication of poverty as a myth propagated by the enthusiastic nanotechnologists. The commercial forces are purely concerned with profit. Comparing the dawning of a nanotechnology revolution to previous industrial revolutions, ETC raises the question of "a decline in the well-being of poor people and increased disparity between rich and poor", as only those with sufficient wealth may have access to the technology. In other words, ETC predicts a future in which the ruling elite has "unlimited surveillance capacity" at the nanoscale leading to an Orwellian scenario of "Big Cyborg Brother".

Check Your Progress II

Note: Use the space provided for your answers.

1) Explain the nature and scope of nanotechnology.

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2) Critically examine the social and ethical implications of nanotechnology.

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3) Evaluate the perspectives of philosophy of technology with reference to nanotechnology.

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3.10 LET US SUM UP

Nanotechnology is an important development in our society that going to revolutionize our lives in a grand way. Nanotechnology involves working with matter at the atomic or molecular scale. It is a technology of rearranging and processing of atoms and molecules to fabricate materials to nano specifications such as a nanometre. It is a result of convergence of several technologies. Nano technology is set to bring about a fundamental change in several areas- materials science, electronics, information technology, biology, medicine- and is expected to profoundly change the pattern and standard of life of people. Apart from advantages, it has serious social ethical implications. Nanotechnology projects a new world and also brings with it new social problems. From these ethical dilemmas evolved a new discipline called nanoethics. Philosophers are predicting that we have to negotiate with a big deal of uncertainties and chaotic situation with the advent of nanotechnology. Apart from the risks and threats of nanotechnology, control and monopoly of this technology in the hands of advanced nations and corporate companies' interests is another critical concern. Democratization of nanotechnology, in its design and application, is the prime concern in the discourse of philosophy of technology and the struggles from civil society.

3.11 KEY WORDS

Nano technology, Nano scale, Atomic rearrangement, Scanning Tunneling Microscopy, Nano particles, ETC group, Philosophy of technology, Technological Determinism, Social construction, Democratization, Public participation

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UNIT 4 NATURE OF NATURE: PHILOSOPHICAL IMPLILCATIONS

Contents

4.0 OBJECTIVES

- To appreciate the evolving nature of humans.
- To realize that our nature is engineered or our nature has become part of our culture.
- To appreciate the radical changes taking place in our self-understanding ("singularity").

4.1 INTRODUCTION

What is unique about contemporary nature? How does culture and nature differ today? Has technology transformed our culture and our nature beyond recognition? Are we at the cross roads in the evolution of culture? In this unit our aim is to show how culture has evolved so awesomely that it has conquered every possible space, including our own human body, our very nature. In other words, given the technological prowess available to humans today, cultural has really radically altered nature and even merged with nature. In such a scenario, we need to evolve new ways of living, relating and experiencing the presence of each other.

In other words, ours have become an "engineered nature." By "engineered nature," I mean a nature that been so artificially and technologically created that it almost eats itself, like the uroboros snake (Fox 1982) Such a substantially different culture, that also encompasses nature, I want to argue, gives rise to different understanding of body, relationship and presence.

So in the first part of this article, we want to focus on the blurred relationship between the real, imaginary and the hyperreal. The hyperreal or vitual, we say, is ambiguous term that connects the real and its opposite and in the process makes reality far more profound than we imagine. In the next section we want to extend this complex relationship to the triads of nature, nurture and culture. Here our specific aim is to show that today culture has to be understood as a larger and complex phenomenon, that includes also its antonym, namely, nature. Because of the technology available to contemporary humans, we have developed our culture so much that it radically alters our nature.

This takes us to the uniqueness that contemporary human experience: the singularity. Here we takes us different kinds of singularities and focuses mainly on the technological singularity, that changes our body profoundly. Such a technologisation of our body has to be placed in the philosophical context of physical body, namely “lived body”, which we undertake in the next section. Then in the final section we take up some related cultural issues like cultural singularity and its implications for body, presence and relationship. Thus our main argument in this article is to show that the very notion of culture has undergone dramatic changes and today we stand at the cross-roads of our culture possessing us almost totally.

4.2 TheREAL, IMAGINARY AND HYPERREAL

In common parlance, 'real' can be an antonym for 'imaginary.' The dictionary definition of 'real' (as an adjective) has following two meanings: (1) NOT ARTIFICIAL, something that is real is actually what it seems to be and not false, artificial or pretended and (2) NOT IMAGINARY, actually existing and not just imagined. In the first case, antonyms of 'real' are 'fake', 'artificial', and so forth. In the second case, I think 'imaginary' can be an antonym of 'real'.

Today many philosophers do not share this view. when photographers say 'photo real' or 'super real', with the word 'real', they mean their images that are actually just in their minds. In this case, 'real' does not actually means 'fact' but more 'real' feeling than 'fact' which they feel about photos. That's why." That is why some of the contemporary thinkers use the term hyperreal, to go beyond the duality between real and imaginary (or artificial).

Hyperreality is used in semiotics and postmodern philosophy to describe a hypothetical inability of consciousness to distinguish reality from fantasy, especially in technologically advanced cultures like ours. Hyperreality is a means to characterize the way consciousness defines what is actually "real" in a world where a multitude of media can radically shape and filter an original event or experience. Some famous theorists of hyperreality include Jean Baudrillard, Albert Borgmann, Daniel Boorstin, and Umberto Eco (Hyperreality 2010).

Most aspects of hyperreality can be thought of as "reality by proxy" (Smiles and Moser 2005). Baudrillard in particular suggests that the world we live in has been replaced by a copy world, where we seek simulated stimuli and nothing more. Baudrillard uses the example of a society whose cartographers create a map so detailed that it covers the very things it was designed to represent (Lane 2009). When the empire declines, the map fades into the landscape and there is neither the representation nor the real remaining – just the hyperreal. Baudrillard's idea of hyperreality was heavily influenced by phenomenology and semiotics.

Thus contemporary society blurs the distinction between real, imaginary and hyperreal. Though for practical purposes such words are still useful, in fact, the blurring of the boundaries between them is a characteristic feature of contemporary society.

4.3 NATURE, NURTURE, CULTURE

The nature versus nurture debate is one of the oldest issues in psychology and in philosophy. The debate centers on the relative contributions of genetic inheritance and environmental factors to human development. Some philosophers such as Plato and Descartes suggested that certain things are inborn, or that they simply occur naturally regardless of environmental influences. Other well-known thinkers such as John Locke believed in what is known as *tabula rasa*, which suggests that the mind begins as a blank slate. According to this notion, everything that we are and all of our knowledge is determined by our experience.

For example, when a person achieves tremendous academic success, did they do so because they are genetically predisposed to be successful or is it a result of an enriched environment? Today, the majority of experts believe that behavior and development are influenced by both nature and nurture. However, the issue still rages on in many areas such as in the debate on the origins of homosexuality and influences on intelligence.

Nature and culture are classical opposites, or complements. It is usually claimed that by nature we are "born that way"; by nurture we learn to become civilized (Nature vs Nature 2011).

In one sense, "nature" refers to everything generated or produced. Etymologically, the Latin *natura* is the source from which all springs forth. For metaphysical naturalists, perhaps also for methodological scientists, nature is all that there is, without contrast class. Nothing non-natural or supernatural exists. Humans evolved within nature and break no natural laws. Another view holds that a straightforward contrast class for nature is culture, which nurtures humans into an inherited linguistic and symbolic system, a worldview, by which they communicate, perpetuate, and develop knowledge. This cultural genius makes possible the deliberate and cumulative, and therefore the extensive, rebuilding of nature. Humans reshape their environments, rather than being themselves morphologically and genetically reshaped to fit their changing environments. Humans come into the world by nature unfinished and become what they become by nurture.

Cultural Transmission

Etymologically, "culture" is related to "cultivate," while "nurture" is related to "nurse" and "nourish," with overtones of rearing and training. Religious persons find their traditions vital in such nurture, and absent from nature.

In contemporary biological and human sciences (anthropology, psychology, sociology), as well as in philosophy, there is much effort to naturalize culture, with equal amounts of resistance to such reduction (if that is what it is). Sociobiologists hold that genetic constraints are the principal determinants of culture; only those people and cultures survive that can place genes in the next generation. Evolutionary psychologists discover that humans have an "adapted mind," a modular mind with multiple survival subroutines more or less instinctive—in contrast to the highly rational *tabula rasa* (empty, pliable mind) once favored by humanist philosophers. Philosophical pragmatists may agree that the mind is mostly a survival tool, even in its cultural education (Barkow et al 1992; Bock 1980; Cavalli-Sforza & Feldman 1981).

Culture remains a major determinant, nevertheless. Information in nature travels intergenerationally on genes; information in culture travels neurally as persons are educated into transmissible cultures. The determinants of animal and plant behavior are never anthropological, political, economic, technological, scientific, philosophical, ethical, or religious. Animal imprinting and limited transmitting of acquired information notwithstanding, humans gain a deliberated modification of nature that separates humans in their cultures from nature, increasingly so in high-technology cultures. Since decoding the human genome, completed in 2001, people stand at the threshold of rebuilding even their own genetic nature (Nature vs Nature 2010).

Beyond Nature-Culture Dualism

Humans have a dual inheritance system, nature and nurture. The intellectual and social heritage of past generations, lived out in the present, reformed and transmitted to the next generation, is regularly decisive. Cultures, especially modern ones, change rapidly in a few decades; the human genome hardly changes in thousands of years. Slow-paced genes are difficult to couple with fast-paced cultures (Plumwood 2002).

A relatively pliable, educable mind is as great an adaptive advantage as is a mind with instinctive routines. The mind is so complex that the number of neurons and their possible connections (with resulting myriads of cultural options) far exceeds the number of genes coding the neural system; so it is impossible for the genes to specify all these connections. Human genes have generated an organism whose behavior results from an education beyond direct genetic control. As more knowledge is loaded into the tradition (fire building, agriculture, writing, weaponry, industrial processes, ethical codes, electronic technology, legal history) the genome selected will be one maximally instructible by the increasingly knowledgeable tradition. This will require a flexible intellect, able to accommodate continual learning speedily, adopting behaviors that are functional in whatever cultures humans find themselves. This is consistent with the unusually long period of child rearing in nuclear families with unusually large-brained babies, found in human evolutionary history and uncharacteristic of any other species (Durham 1991).

Critics complain that nature-culture dualism is an undesirable Cartesian legacy (perhaps also a Christian or Greek one). The "versus" in the title of this entry frames the connections wrongly. Nature is the milieu of culture, and supposing our cultures to be in exodus from nature is at the root of our environmental crisis. Culture remains tethered to the biosystem, and the options within built environments, however expanded, provide no release from nature. In fact, ecology always lies in the background of culture; no nurture is adequate that forgets these connections (Rolston 1999).

Perhaps cultural nurturing reinforces natural genetic dispositions for some practices (such as incest avoidance), but not for others (learning nuclear physics). Whether adults have enzymes for digesting fresh milk will determine their pastoral practices. But the differences between the Druids of ancient Britain and the Dravidians in India are nongenetic and to be sought in the radically differentiating historical courses peculiar to these cultures—even though Druids and Indians have a biological nature largely held in common and despite differences in skin color or in blood groups.

Humans are only part of the world in biological, evolutionary, and ecological senses—their nature; but *Homo sapiens* is the only part of the world free to orient itself with a view of the whole, to seek wisdom about who they are and where they are, and to develop their lives on

Earth by means of culture. Such cumulative, ongoing nurture determines outcomes in the uniquely historical behavior of humans, making the critical difference, while human universals, biological, psychological, or social, which are a legacy of nature, have limited explanatory power (Nature vs Nature 2010).

Check Your Progress I
Note: Use the space provided for your answers.s.
1) How is culture and nature related?
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2) What is hyper-real and give its relevance?
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4.4 SINGULARITY IN THE WORLD

In general singularity may be defined as "the quality or condition of being unique". It implies someone or something having a trait or quality "marking one as distinct from others". It is a peculiarity that is unique and essential. In this first part, we want to familiarise ourselves with the general notion of singularity so that we can apply it to technological or engineered singularity.

A General Understanding of Singularity

Seen from this perspective, Big Bang is a singularity. The origin of the universe is a uniquely singular moment, which cannot be compared with any other events. Though scientists are in the dark as to the exact nature of the origin of the universe, they seem to have a very good idea of what took place later on.

Similarly the origin of life may be considered as another singular event. All of us experience life and we know quite a lot of it. Though every experimenters gave a lot of information on the conditions that gave rise to life, the exact origin of life still remain an enigma. With the arrival of genetic engineering and synthetic biology (including the creation of artificial life), it may change. Today we can safely claim that the origin of life, just like the origin of life is a singularity. Abiogenesis or biopoesis is the study of how life arises from inorganic matter through natural processes, and the method by which life on Earth arose. In modern, still somewhat limited understanding, the first living things on Earth are thought to be single cell prokaryotes (lacking a cell nucleus), perhaps evolved from protobionts (organic molecules surrounded by a membrane-like structure). The oldest ancient fossil microbe-like objects are dated to be 3.5 billion years old), approximately one billion years after the formation of the Earth itself roughly 4.7 billion years ago.

When we speak of the third example for singularity, it is still more complex: the origin of human beings? As such here we are on familiar field. Biologists and anthropologists have made significant contributions to the study of human evolution. Though theories vary, we may trace human beings even up to 400,000 years. As to the exact origin of Homo sapiens There are two theories about the origin of modern humans: 1) modern arose in Africa and spread to different continents from there and 2) pre-modern humans migrated from Africa to become modern humans in other parts of the world. Most evidence points to the first theory because of fossils of modern-like humans are found in Africa. Further stone tools, other artifacts and DNA studies support African origin theory.

In short, genetic and fossil evidence suggests that our own species, *Homo sapiens*, first appeared between 150 and 200 thousand years ago in Africa and 40 thousand years ago in Europe (Walkins 2011). By that time human populations exhibit the entire suite of physical characteristics that define anatomically modern humans: a large, rounded brain case; a vertical forehead; a small and flat, or orthognathic, face; reduced brow ridges and a chin.

Understanding Technological Singularity

In mathematics, a singularity is in general a point at which a given mathematical object is not defined, or a point of an exceptional set where it fails to be well-behaved or orderly. For example, the function $f(x) = 1/x$ on the real line has a singularity at $x = 0$, where it explodes to $\pm\infty$ and isn't defined. So disorder, unpredictability and exceptional quality characterizes mathematical singularity.Taking one more step “a technological singularity” may be viewed as “a predicted point in the development of a civilization at which technological progress accelerates beyond the ability of present-day humans to fully comprehend or predict. The Singularity can more specifically refer to the advent of smarter-than-human intelligence, and the cascading technological progress assumed to follow. Whether a singularity will actually occur is a matter of debate.

The concept of a technological singularity as it is known today is credited to mathematician Vernor Vinge. His 1993 "Technological Singularity" (Vinge 1993) contains the oft-quoted statement that "Within thirty years, we will have the technological means to create superhuman intelligence. Shortly thereafter, the human era will be ended." In fact singularity is commonly misunderstood to mean technological progress will rise to infinity, as happens in a mathematical singularity. Actually, the term was chosen as a metaphor from physics rather than mathematics: as one approaches the Singularity, models of the future become less reliable.

The Singularity is often seen as the end of human civilization and the birth of a new one. In his essay, Vinge asks why the human era should end, and argues that humans will be transformed during the Singularity to a higher form of intelligence. After the creation of a superhuman intelligence, according to Vinge, present human be regarded as a lower lifeform in comparison to them. Such a singularity is enabled by the exponential technological progress that we witness today. Though all the technologies may not lead to such a singularity, the claim is the convergence of such technology will yield unforeseen developments and consequences. Some of such technologies that facilitate the dawn of technological singularity are:

Artificial intelligence

An artificial intelligence capable of recursively improving itself beyond human intelligence, will invariably cause a technological singularity. Only one such AI, many believe, would be needed to bring about the Singularity. Most Singularitarians believe the creation of such AI is the most likely means by which humanity will reach the Singularity. One of the most anticipated of these technologies for some is the possibility of human intelligence enhancement, including brain-computer interfacing. Direct brain-computer interfaces may potentially improve an individual's memory, computational capacity, communication abilities, and knowledge base. A more traditional human-computer interfaces may also be seen as intelligence augmenting improvements: traditional expert systems, computer systems recognizing and predicting human patterns of behavior, speech and handwriting recognition software, etc.

Nanotechnology

The potential dangers of molecular nanotechnology are widely known even outside of futurologist and transhumanist communities, and many Singularitarians consider human-controlled nanotechnology to be one of the most significant existential risks facing humanity. Therefore they wish that nanotechnology will be used primarily by transhumanists communities. Other technologies like globally-connected high-bandwidth wireless communication fabric, etc., while not likely to cause the Singularity themselves, are regarded as signs of levels of technological advancement assumed to precipitate the Singularity.

Check Your Progress II

Note: Use the space provided for your answers.s.

1) What is the significance of singularity?

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2) What is technological singularity?

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4.5 TECHNOLOGIZATION OF HUMAN NATURE

The drive for technologisation of human nature through Enhance Human Biology has been a characteristic feature of contemporary human beings. Since ancient times we have been involved in it, but in rudimentary ways. Examples of such enhancements are physical and mental training and use of stimulant and mind altering substance. But modern technology with its growing mastery over the human physiology, biochemistry and cognition is in position to transform the human condition, particularly our human body and its relation to the larger world. This takes us to the vital issue of Integration of Technology and Human body. The advance of technology into the human body has two important domains today: 1) therapeutic purpose or 2) performance enhancement To the extent we use the human enhancement technology to further our body, it functions and nature, we can speak of an engineered singularity in the body. The emergence of such a singularity can be traced through three key notions: prosthesis, bionics and fyborgs.

Beginning with Prosthesis

Human Body is on the threshold of undergoing the same fate of Nature in the precious centuries. Technological innovations may soon replace the naturalness of body. In fact in many cases the replacement or substitutes appears better than the original. This is true especially in the case of prosthesis, which may be considered as the first stage in the human intervention in the body. Simple traditional prosthetic devices like crutches, spectacles of the past are simple external extensions of the human body. Today we have evolved and a contemporary prosthesis is an artificial device used to replace a missing body part, such as a limb, tooth, eye, or heart valve. Prostheses are typically used to replace parts lost by injury (traumatic) or missing from birth (congenital) or to supplement defective body parts. Inside the body, artificial heart valves are in common use with artificial hearts and lungs seeing less common use but under active technology development. Other medical devices and aids that can be considered prosthetics include artificial eyes, palatal obdurate, gastric bands, and dentures. Cardiac pacemakers, dental prostheses, implantable pumps to assist the lungs, bionic limbs, steel implants on bones are already embedded in our physical bodies.

Bionics and More

In general bionics (which may also be known as biomimicry) is the application of biological methods and systems found in nature to the study and design of engineering systems and modern technology. It implies utilizing electronic devices and mechanical parts to assist humans in performing difficult, dangerous, or intricate tasks, as by supplementing or duplicating parts of the body.The word bionic coined by Jack E. Steele in 1958, possibly originating from the Greek word βίον (*bíon*), meaning 'unit of life' and the suffix -ic, meaning 'like' or 'in the manner of', hence 'like life'. Some dictionaries, however, explain the word as being formed as a portmanteau from biology + electronics.

The transfer of technology between lifeforms and manufactures is, according to proponents of bionic technology, highly desirable because evolutionary pressure typically forces living organisms, including fauna and flora, to become highly optimized and efficient. A classical example is the development of dirt- and water-repellent paint (coating) from the observation that the surface of the lotus flower plant is practically unsticky ("Lotus effect").

Fyborg and the Future

The "natural artificialization of body," traced to the very ancients is the clothing and ornamentation covering human's 'state of nature'. From the fine cloths we wear, we are moving towards wearable computers and communicative machines Similarly from the healing of the sick bodies we speak of intervention in the healthy bodies to prevent sickness. This takes us to the world of cyborgs and fyborgs.

The word *cyborg* (1960) is short form for *cybernetic organism* and it refers to an organism that is part-human, part-robot. Technology does not just approach the body but enters the space of our body and then we become cyborgs. Transhumanists claim that since we make use of technology in our everyday life, we are at least fyborgs or functioning cyborgs. For instance, Gregory Stock, the director of the Program on Medicine, Technology, and Society at *University of California, Los Angeles*, approaches humans from two starting points (Stock 2003): one is mechanical and the other biological. On the mechanical side, he is clearly convinced that cyborgs are not the way humans are going to extend and enhance their range of abilities. He argues instead that we are more likely to become "fyborgs" by developing extracorporeal electromechanical devices to improve and widen the scope of existing sense and effector organs (Spier 2002).

It was Alexander Chislenko who coined the term "fyborg" to differentiate between the man-machine creations of science fiction and the everyday ways we extend ourselves using technologies such as eyeglasses, hearing aids, and cell phones. In fact, to varying degrees, many enhancement enthusiasts believe that we have become biological organism functionally supplemented with technological extensions and so are fyborgs or organism that has become a kind of cyborg by extending its senses and abilities using technology .

But it is interesting to read the Fyborg Self-Test

Are you dependent on technology to the extent that you could not survive without it?

Would you reject a lifestyle free of any technology even if you could endure it?

Would you feel embarrassed and "dehumanized" if somebody removed your artificial covers (clothing) and exposed your natural biological body in public?

Do you consider your bank deposits a more important personal resource storage system than your fat deposits?

Do you identify yourself and judge other people more by possessions, ability to manipulate tools and positions in the technological and social systems than primary biological features?

Do you spend more time thinking about — and discussing — your external "possessions" and "accessories" than your internal "parts"?

If you answered "yes" to most of these questions, please accept my congratulations (and/or condolences): you are already a cyborg! (Chislenko 1995)

Further, futurists with their techno-exuberance promises a golden future. Some instances are illustrative. The famous author Ray Kurzweil holds (Kurzweil 1999): ‘We will enhance our brain gradually through direct connections with machines and intelligence until the essence of our thinking has fully migrated to the far more capable and reliable new machinery.’

Kevin Warwick, made a great leap in 1998 with his first glass-encased chip implant just beneath the skin of his upper arm. It enabled the computer to monitor his presence by radio signal as he moved about his department. In fact, his experience led him to emotionally identify with his implant as he felt that he and the computer were working in complete harmony.

Similarly, Thad Starner of Massachusetts Institute of Technology, dresses in a wearable computer and lives connected to the Internet using a miniature computer terminal at all times. His device is the first stage of what he calls "the BodyNet, a computer network wired through human bodies"(Maguire and McGee 1999).

Steve Mann, a professor of electrical and computer engineering at the University of Toronto, has developed an Internet-connected computer that he has dubbed "WearCam." By combining wireless communication with information systems, WearCam allows one to augment and enhance experiences and, through networking, share them with others.

Again, some computer visionaries speak of implantable computer chips acting as actuators that will enhance `our memory, ability to acquire a language without learning, recognize people that we have not met. They promise that computer implants on brain can restore memory losses and give sight to the blind, hearing to the deaf. So G. Q. Maguire Jr and Ellen M. McGee promises: “These bioelectronic developments, combined with progress in facilitating interfaces between neural tissues and substrate micro probes, are setting the stage for implantable brain chips. The first steps have already been taken in research on the cochlear implant and on retinal vision. Cochlear implants enable totally deaf people to hear sound by directly stimulating the auditory nerve. In a similar way, retinal implantable chips for prosthetic vision may restore vision to the blind” (Dobelle, Mladejovsky and Girvin 2011).

These developments may leads to an almost total technologisation of the human body. All thinkers are not enamored by such a scenario. However, Pat Roy Mooney, executive director of ETC, a technology watchdog group, he Right and winner of Livelihood Award (the "*Alternative Nobel Prize*") blows the whistle and sings a cautionary **Note:** “Particles of that size can go

anywhere they please. They pass the entire immune system, they can pass the blood-brain barrier, and they can go into the spinal cord" (Robbins 2004).
Therefore we have reasons to be cautious. Some critiques speak of an impending "hive mind" for the future humanity, that is, a group mind with almost complete loss of individual self and identity. Without seeming to be antediluvian, we still need to raise certain issues: In the process of its technologisation, is the human body reduced to an appendix. Is science fiction becoming a reality? Are we really aware of the some of the serious consequences of intervening in our own body?

4.6 NATURE OF NATURE

Confronted with today's technology and artifacts, something extraordinary is happening. Human culture, or more precisely technology, is intervening in the human nature (body) causing changes that were unimaginable even twenty years ago. Today we are at stand at the threshold of re-creating our own bodies and thus re-making our own nature. So the cultural singularity will soon arrive and we are at the moment witnessing the pangs of the new child-birth: the merging of nature and nurture. Such a merger, resulting from cultural singularity, hopefully will impact our lives – in fact our enhanced lives or existence – tremendously. Technological innovations are not merely healing our bodily functions, but enhancing them dramatically. Some of such enhancements will make the distinction between nature and nurture, almost redundant. This implies that our culture is capable of radically altering our nurture and making it truly part of an inter-twined and mutually enriching reality.
Further, as technology advances further, our cultural pre-conditions will change. We can imagine feed-back mechanisms between advanced technologically driven culture and our pre-given nature, which together constitute a highly complex and undifferentiated reality, where the body is directly linked to technology and vice-versa. In such a context, the meaning and significance of the body – and of our nature - will be quite different. The body that transmits presence and relationship between persons will be vastly enhanced technologically, and so it is conceivable that the very understanding we have of presence and relationship will be changed. As such we this will have consequences on the way humans relate to each other, after the cultural singularity. We may really have to talk of a culture that is invaded and enhanced by technology!
This will radically change the way we understand our human body. Long ago, we ceased to understand human body merely as a material object of scientific study. Phenomenology has made us aware of the uniqueness of the body. But the technological and cultural singularity urges us to understand our bodily differently and in the process the culture form part of our (bodily) existence is also very much reshaped and re-moulded. One special question that we need to raise is: Will such engineered singularity and culture enable us to broaden our consciousness? Only if we can wider our perception of reality and broaden our consciousness can we claim that we are truly progressing, at least at the non-technological (or spiritual) realm. Thus the uniqueness of our contemporary society is that we are at the threshold of, let us say, "overcoming ourselves," whereby our culture almost behaves like the uroborous snake, that is eating itself. In this very process, an all-encompassing culture may emerge that affects our very existence, understanding and even search meaning and significance.

Check Your Progress III

Note: Use the space provided for your answers.s.

1) "Today nature is indistinguishable from culture." Do you agree?

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2) What is the importance of cyborgs and fyborgs?
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4.7 LET US SUM UP

In this unit we saw how human nature is radically changing and is becoming part of our culture. Today our technology has made it possible that we mould our own nature.

4.8 KEY WORDS

Bionics: Having anatomical structures or physiological processes that are replaced or enhanced by electronic or mechanical components

Cyborg: A cyborg is a cybernetic organism (i.e. an organism that has both artificial and natural systems). The term was coined in 1960 when Manfred Clynes and Nathan Kline used it in an article about the advantages of self-regulating human-machine systems in outer space.

Fyborg: A human who has certain physiological processes aided or controlled by mechanical or electronic devices

Prosthesis: An artificial body part, such as a leg, a heart, or a breast implant.

Singularity: The quality or condition of being singular or unique, where the normal laws do not apply.

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