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DATED 15th November, 1977

Dear Shri Siddhartha,

Thank you for sending me a copy of your paper - "Appropriate Technology - Some Heresies". I have read it with interest.

With regards,

Yours sincerely,

D.M. Nanjundappa

(D.M. Nanjundappa)

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Dr.P.M.Bhargava
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Molecular Biology

15 NOV 1977

My dear Siddhartha,

I have read with the greatest pleasure your write up on appropriate technology. It has been extremely well done and I think you should publish this in a well read magazine/newspaper after some amplification at a few places (in its present form, the arguments may be just a bit too sophisticated or terse for the average reader). I would be delighted to discuss this further with you when we meet each other next.

With kind regards,

Yours sincerely,

(P.M.Bhargava)

Dr. V.Siddhartha
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N. Siddhartha

World Council of Churches

Seminar on Science & Society

New Delhi 17 - 20 November 1977

Appropriate Technology - Some Heresies

by

V.Siddhartha*
Indian Space Research Organisation (ISRO), Bangalore 560 009.

\- - - - - -

Talk about Appropriate Technology - AT - is the latest growth industry. Like most growth industries, it contributes to employment and to pollution - the cost per work place does not exceed that of a chair, some paper and pencil; the pollution is in the form of vast numbers of ill-conceived notions, cavalier statements and half-baked 'solutions' to (undoubtedly important) problems that deserve far greater respect. However unlike growth industries, the useful output is meagre and rapidly declining in both quantity and quality. The lay reader will, of course, decide for himself whether what follows is a contribution to pollution or to useful output while the Church knows - only too well - how to deal with heretics!

The environment determines 'appropriateness'

All technology that survives in society for longer than the time taken to establish the technology (roughly the gestation period) is 'appropriate' in some sense - otherwise the technology would not survive. It is true that very often the technologies, or more accurately, those who control them, manipulate the environment - physical and societal - in such a way that the probability of survival is greatly enhanced. Although the label 'appropriate' may be thus secured in this fashion by ex-post-facto definition, the very survival of a technology is nevertheless testimony to its 'appropriateness' It follows, therefore that if a society considers the societal impact of a set of technologies already in existence to be undesirable, it should re-orient (if it can - and here is often the rub) the environment+ in which the

---

* The views expressed in this paper are those of the author. They are not to be construed as being reflective of the views of ISRO or the Government of India.

\+ The 'environment' consists of various sets of non-technology policies, the physical environment and other technologies that shape this environment.

technology exists in such a way that these specific technologies cannot survive. There is little point in trying to attack only the source of the particular technologies (R & D, multi-nationals etc.); for, the technologies will re-appear soon after the pressure eases. (Prevention is more cost-effective than cure.).

Conversely, if an embryo-technology is considered desirable in terms/of the best guess about the effects of its large-scale use, the environment (of the technology) should be adjusted in such a way that the particular technology can survive in it. Otherwise, it will not 'take' and self-propogate. At best it will remain isolated in pockets sustained by artificial transfusions of resources from AT enthusiasts who themselves receive their sustenance from non-AT sources!

If the above formulation is correct, it follows that measures of 'appropriateness' are not so much related to the specific technology under consideration but to the environment in which it either exists or is expected to survive (recall that we are talking about time-scales that are longer than the gestation period).

We can now consider the first two questions raised in the background issue-raising paper of Dr. Paul Gregorios. It is clear that appropriateness is not per se a matter of lowering Capital-intensity, Energy-intensity, Scale or Skill-intensity (CESS for short) but a matter of whether the relevant technological gestation times are such that different social and political objectives can be served at different times at different places in different sectors as these objectives change with time, place and sector*.

Implications for Planning+

What does this shift of focus to the gestation-period imply for scientific and technological planning on the one-hand and for socio-economic planning on the other? In brief:

---

* I am specially mentioning 'sector' to remind us of the National Security sector,(a term whose connotations extend beyond what is normally understood by 'Defence') systematically ignored by AT enthusiasts. Security cannot, alas, be guaranteed by means of bows-and-arrows. In this context see pp 24-25 of A.K.Dasgupta: The Economics of Austerity, Oxford University Press, 1975. This tightly argued and concise booklet ought to serve as a basis of the socio-economic policies of any progressive political party which wishes to practise what it professes.

\+ This section has benefitted from a discussion with Prof. A.K.N.Reddy of the Indian Institute of Science.

For Scientific and Technological Planning

When	Then S & T Planning consists of
Socio-economic planning horizons are shorter than Technology Development + implementation gestation period	1. Choice between existing technologies (foreign or Indian) with marginal adjustments for local factor availability (i.e. land, labour, capital and technology) 2. Software/Management, particularly of the kind that shapes general government policies (e.g. in food, housing, transport, communication, education etc.) in the light of known scientific facts. i.e. Science in Policy
Socio-economic planning horizons are longer than Technology Development + implementation gestation periods	1. Technology development programmes including basic research 2. Policy for science. (Including scientific manpower institutions, resource allocation for research programmes etc.)

For socio-economic planning, the implications of finite gestation are that an explicit balance at various levels needs be struck between

(i) the need to keep socio-economic goals and the attendant policies unchanged for the duration of the gestation period

(ii) the right of people to change goals through democratic processes and the need to periodically review the assumptions and data underlying the planned paths and processes of goal attainment and to re-chart these if necessary.

Employment generation

A great deal of man-power using AT already exists in the country; it has been generated domestically. The cycle-rickshaw is only one example. The technological infrastructure in the country is the largest of all the developing countries, save China. There is a Polytechnic in virtually every district of the country. I am convinced that, for technologies for which the basic science is known to exist, if all the relevant policy variables are adjusted and

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implemented so that it becomes socio-economically viable to use labour instead of capital, for the most part, the 'appropriate' technologies will get generated by the existing infrastructure without centralised planning.* In particular, the following policies are musts:

- Ensure that gains in output per man-hour shall not be so distributed between Capital and Labour as to cause a progressive increase in capital intensity in agriculture, in industry and the service sectors. Since managing people (labour) is much more of a nuisance than managing machinery which is relatively docile, only collective ownership of capital by labour can ensure that there is no progressive increase in the use of machinery at the expense of labour+.

- Non-technology policies to stimulate generation of labour-intensive technology must be implemented ahead of the technology generation and held until the technologies are developed and deployed. In the interim, therefore, some production from available, short-gestation, capital-intensive technology will have to be foregone.

AT enthusiasts can help by not importing so-called labour-intensive technologies; some of these are energy inefficient polluting technologies that were 'capital-intensive' in the fifties in the West.

Most of the technologies already exist

For the four basic human needs; food, clothing shelter and health there already exists in India today virtually all the technologies to eliminate destitution. When we have done this, then we can talk of removing poverty. Where there are some gaps (e.g. in housing, particularly rural housing), these will not get filled

---

* In fact such central planning for AT may well result in in-appropriate technologies; for, our capacity to handle information with fidelity is abysmally low; the so-called planning process is insufficiently mature and the socio-political environment too varied in the country in both space and time for central planning to be effective.

\+ The clamour in the Punjab for Combine harvesters is not so much because farmers cannot afford to pay Rs. 12/- a day for harvest labour, but because they consider it well worth the present cost of capital to replace this labour by well-behaved machinery which is always on tap. In this context see H.M.Patel: Rural Development in India, Commerce, 27 August 1977.

unless what is already known is tried out, the deficiencies empirically determined and then removed by local innovation using known basic science by those who are closest to the problem, and by research. But technology cannot solve problems that are socio-economic and political. Indeed it can exacerbate them - in fact, that it what it is meant to do; the removal of poverty implies major changes in the existing socio-political status quo. There is no technology, small or large, that can act as a placatory lollipop to the oppressed and the exploited.

The weak base in biology

The closer one gets to the village, to those who live directly off the land, the closer and more tightly knit is the nexus of relationships between man and his surroundings. If there is one science that characterises this nexus; that can make major contributions to the well-being of the majority of our people; that has the potential of being used in a non-exploitative way, it is biology. We have had many successes in our scientific and technological endeavours (thanks to the vision of J.Nehru) but we have neglected biology although both A.V.Hill in the 1940's and J.B.S. Haldane (an Indian citizen) in the late-fifties identified biology as the science most relevant to India.

Remarkable advances have occurred in biological research since the genetic code was unravelled in the mid-fifties. It is now possible in principle to bio-engineer plants which will fix nitrogen directly from the atmosphere. Photo-synthesis by plants is possibly the best way to use our abundant solar energy. For example, this can provide, locally, algal protein which can be far more efficient in energy, land and water use than pulses or animal protein. This and other possibilities such as energy-supply through photo-synthetic solar-energy conversion* will mean basic research in biology of the very highest quality.

What is needed is quality basic research

We can now address the third-question in the issue-raising paper. If we are really serious about using science for the well-being of our people - about 1000 million in under thirty years - then we must stop regarding technology as primarily

---

* See in this context Seshadri, C.V. "A total-energy and total-materials system using algal cultures", Monograph Series on Engineering of Photosynthetic Systems, Vol. 1, March 1977, A.M.M. Murugappa Chettiar Research Centre, TIAM House, Madras 600 001.

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so much gadgetry to be used in screw-driver like fashion. Scientific research in our country should be oriented to basic research. We have to do basic research at the frontiers of knowledge, particularly in biology. As J.D.Bernal pointed out in 1964, much of so-called applied science is really applied obsolete science.

We cannot afford to be lazy. We cannot be obsolete. Our problems are of such nature and magnitude that they can be solved only

(i) if we apply contemporary science to contemporary problems. This means we must do contemporary science by reference to our own environment.

(ii) if we really believe in science and not in gadgets – or in God.

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OUR UNIQUE PLANET

D. LAL

'It takes a subtle mind to see the obvious'

—*Alfred North Whitehead*

WE live on a fairly large sized planet which is an integral part of the Solar System. The Solar System is a part of our galaxy containing no less than a hundred billion Sun-like stars. Galaxies occur in clusters; sometimes there are a few thousand galaxies in a cluster. This hierarchy of matter in the Universe is seen to persist to the farthest distance we can observe with the largest telescopes. There are estimated to be around a hundred billion galaxies in the universe, whose age is estimated to lie between (15-20) billion years. In this magnanimity of things (matter, space and time), it is most instructive and humbling to contemplate our place in the universe. We will do this here with one very specific perspective — namely, what it takes to make a planet like the Earth, coupled to a Solar System? This would indeed be a very narrow perspective, confined to the immediate environment of the Earth. But even this is so revealing!

How common are the planetary systems? What are the differences between the stars to which they belong? How suitable would Earth be as a habitat for Man if it were much bigger or smaller? How far from the Sun should an ideal planet be to be a suitable living place for Man? We will answer these and other questions in the following primarily physical description of the planet Earth.

UNIQUE FEATURES OF EARTH

As a result of a revolution in the field of earth-sciences within the last two decades, we now know a great deal about the planet

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Earth: how it was formed, and how it evolved through the geological period. Most of this information has been derived from the recent planetary data comprising direct examinations of lunar soil and rocks, and photogeologic studies of Mercury, Mars, Moon and other planets. The Earth differs dramatically from the other planets; even from the Moon, Mercury and Mars, which are considered earth-like. For one, its internal heat engine is still active, and the dynamism of the Earth, its atmosphere, oceans and the earth are all due to the presence of a powerful heat engine in its interior. The heat engine has long since cooled off for Moon, Mercury and Mars, but is still operative for Venus, and the larger planets.

Is the discussion above all a purely academic discussion? No! Our planet harbours an intelligent life, and is capable of sustaining a most diverse populous life for hundreds of millions of years. In contrast, there seems to be no life on other planets, not even in the most primitive forms. Aside from life forms, the terrestrial ocean and the atmosphere stand out in sharp contrast to what is found on other planets.

The planetary studies have shown that in fact no two planets are alike. And in that respect every planet is unique, and our Earth is no exception. However, a closer inspection based on the evolution of the Earth indeed makes it a very unique planet! Put it another way. No other planet can offer what the Earth offers to its inhabitants and, conversely, if life forms were to evolve on other planets, they would be quite different from those on the Earth.

What is unique about the planet, in short, is that it has a very dynamic outer layer which contains both substantial atmosphere as well as hydrosphere. Not just that, it has an equable climate — not too hot, not too cold, and not too fluctuating. You may say that this is all nonsense. One could live on the moon or for that matter inside the Great Red Spot of Jupiter. Of course!

We must therefore look at the problem in proper perspective: what is it that makes our planet unique? And is this planet all that we are concerned with, or do we have to think of the larger universe we live in? These questions set one on to the right course of thought-chain, and scientific enquiry.

PERSPECTIVE 1: EARTH AS A PLANET

Comparative planetology teaches us that the evolution of the Earth was quite similar to other planets in the early stages, but that its large size was primarily responsible for a sustained internal heat engine. This engine drives the 'plate tectonics' which is responsible for ocean floor spreading, the drifting of continents, keeping the continents floating, and is the main driving force for large-scale geochemical recycling. In the absence of plate tectonics, the continental masses would get eroded to the mean elevation of sea level within (10-15) m.y. Mars had an incipient plate tectonics. Mercury and Moon did not have plate tectonics; Venus has certainly had an operational plate tectonics. On the other hand, had the Earth been much larger, the plate tectonics would be there, but it would then have too dense an atmosphere.

The concept of plate tectonics in fact represents one of the exciting grand syntheses of a suite of geological and biological planetary data. It has introduced order in the observed physical processes. In the framework of plate tectonics, continents are kept afloat on 'plates' and mountain building processes occur primarily at the collision boundaries of the plates and the continental margins. Continental drift in the past, and the present locations of epicentres of earthquakes, can be understood in terms of the plate tectonics hypothesis.

In the light of our present day understanding we can even predict how world geography will change 50 m.y. hence, assuming the present day plate movements continue. This future world is shown in fig. 1.

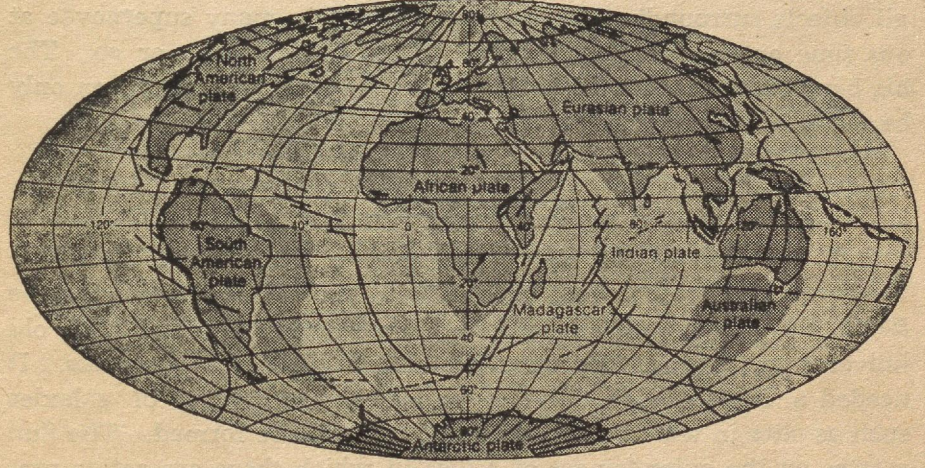

Figure 21-22
World geography as it may look some 50 million years from now if present-day plate movements continue. [After "The Breakup of Pangaea" by R. S. Dietz and J. C. Holden. Copyright © 1970, by Scientific American, Inc. All rights reserved.]

Fig. 1

PERSPECTIVE 2: EARTH IN THE SOLAR SYSTEM

The place of the Earth in the Solar System is a special one. Had the Earth been 5 percent closer to the Sun, it would have had a runaway greenhouse effect within 1 billion years of its formation, leading to high surface temperatures as in the case of Venus. On the other hand, had the Earth been 5 percent farther, it would have had a runaway glaciation within 2 billion years of its formation.

PERSPECTIVE 3: EARTH IN OUR GALAXY

For a long time, an over simplified view of the Earth has been that it is a spherical object, isolated from other planets of the Solar System, albeit receiving sunlight. Colloquially, this highly narrow view would be much like the view of a frog in a well. It would be more appropriate to look upon this as a view of a space passenger who goes to the Moon and considers only the gravitational fields of the Earth and the Moon.

How narrow a view this is, is easy to understand! We can never hope to cut off the Earth from the Universe. Pause, think and look around. Pick a grain of dust or a rock. Breathe. These are all cosmic materials, manufactured in Astronomical Kitchens with the stellar fires.

In fact our culture itself is intimately connected with the big-bang event (15-20) billion years ago, and the subsequent nucleo-synthesis in stars. It is a sobering experience for us to realize that all objects surrounding us were synthesized in many supernovae at one time or the other, in the last fifteen billion years or so. The big bang event made some helium, but the heavier elements can only be made in supernovae.

CONCLUSION

In the light of the above perspectives, the more we consider the conditions which were necessary to produce a planet like the Earth, the greater our amazement. It needed a 15 billion year old universe to produce the stars which produced the elements. It needed a large enough universe to lead to formations of galaxies such as ours in which stars like our Sun could be formed. The Sun rotates on the outer-fringes of a disc in which there are active processes occurring near the centre, explosive and violent on time scales of a few million years, probably enough to wipe off anything which evolved on earth time scales. We have also learnt that the Earth is situated within the Solar System just at the right distance to have the climatic conditions suitable to us. Finally, we also saw that for a planet of the size of the Earth it is necessary to have the right atmosphere as well as plate tectonics to keep its outer surfaces continually renewed by geochemical recycling.

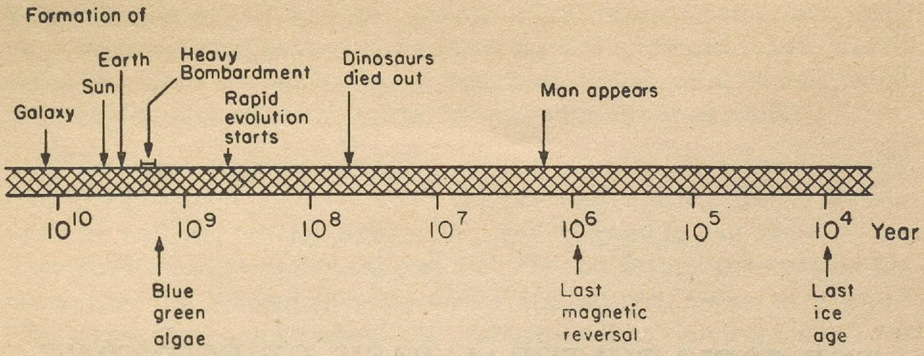

Fig. 2

Fig. 2 shows a chronology of important events including the epochs of formation of our galaxy, Sun and the Earth. Realization of cosmic processes and the unique Earth we have for an abode humbles us. And if anything can humble mankind today, it is only the large universe and its dynamic cycling; the birth and death of stars and galaxies. And above all the realization is overwhelming that in the framework of a timescale of the order of 15 B.Y., the age of the universe, the whole universe had to participate to make man and his planet.

THE SOCIO-CULTURAL BASIS OF ECONOMIC AND ENVIRONMENTAL DISTRESS IN INDIA

A. K. GANGULY

A NATION'S economy is mostly discussed on the basis of per capita productivity, investment potential and returns on investment, resource generation and utilization, employment generation rate, taxation structure and generation of wealth for developmental activities, etc. Current concern on environmental conservation are mostly discussed as educational, regional, technological, scientific and management problems. However, each of these is intimately associated consciously or sub-consciously with the historical and socio-cultural psyche of the nation. As such no single unique prescription of action exists for different countries, nay even for the different socio-cultural entities in the mosaic of a large country like India. The present article is an indicative one, on the common factors rooted in the socio-cultural base, responsible for our economic and environmental distress.

ENUNCIATION OF THE PROBLEM

Deforestation:

In a fervent appeal to the legislators of Kerala State Assembly, Shri K. P. S. Menon (1980) wrote: 'As one who is deeply concerned with the fate of Kerala, I am writing to you about a subject which is, I think, of supreme importance for its future welfare. This is the forest of Silent Valley; .... It is more than an "evergreen forest", it is a kind of environment which few areas in the world are fortunate enough to possess, namely tropical rain forest. Such forests are a treasure house of unknown species and potential

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discoveries of material value. Above all, Kerala's forests have played a large role in preserving us from the droughts and floods which beset the more barren States of Northern India and I cannot think with equanimity of such future for our own State as well.

'The most eminent ecologists in our country state unanimously that the proposed hydro-electric project will destroy Silent Valley with or without "safeguards" .... On examining the issue, I am convinced that the ecological cost for this and future generations far outweighs the limited benefits which the project hopes to confer.' The letter thus emphasized the principle that environmental resources are a trust to be used wisely weighing the short term gains against the possible long term losses.

In an article, Paramasivam, et. al (1980) drew a grim picture of the state of the environment as:

> The great north Indian flash flood that occurred last year (in 1978) and drought conditions prevailing thereafter are indications of a developing desert condition on a sub-continental scale. Deforestation and consequent desertification of Rajasthan and its progress in the fringes have been going on since our historical past. It is a man-made desert. The strip of land on the Konkan slopes of the Western Ghats is one of the high rainfall areas in the country. The soil is fertile and the rains are enough to maintain a perennial greenery on the plains and hills in the area and to enable raising more than one crop by rotation farming. On the contrary, Konkan strip today assumes a very bleak desert-like appearance during the summer months and first flash of heavy monsoon rain washes down the fertile top soil into the sea. Similar situations are obtained also in other parts of India. A casual bird's eye view of the hue of country's landscape during non-monsoon months is a monotonous desert brown, with occasional oasis-like gray spots. This is the cumulative effect of long standing unconcern or ignorance of people of the effects of their activities in the natural environment they lived.

The principal cause for desertification has been traced to the uncompensated commercial exploitation of the forest and the felling of trees to meet the fuel needs of the people for cooking and heating. Desertification started when the removal rate exceeded the natural regeneration rate. There was no matching regenerative effort by people, when the natural rate failed to compensate for the vegetation removed. The process accelerated during the last three decades owing to our agricultural expansion, development programmes and population growth. It is estimated that unless the afforestation work matches the exploitive deforestation, denudation will be complete before the end of the present century (Gupta, et al., 1980).

Drinking Water Supply and Sanitation:

The United Nations launched in the autum of 1980 a global programme on International Drinking Water Supply and Sanitation Decade. The programme aims primarily to achieve a revolution both in terms of health and quality of life in the developing countries of the world. India figures very eminently in this programme. 80% of world diseases are environmental and linked to inadequate and unsafe water and sanitation, with human defecation in the open and its run off into rivers and streams accounting for 50% of the incidents (Olembo, 1980). This is familiar to us in India. Further, in this country there is a continuing social practice of discarding the carcasses of men and animals into rivers. The contribution of this polluting practice to the incidence of maladies has never been assessed.

An International seminar held in Uppsala, Sweden, recently discussed the inhibiting and enhancing factors in the development of rural water supply and sanitation. The seminar put in perspective the technical, cultural, institutional and educational issues inhibiting the UN programme. A key element identified is the need to ensure the direct involvement of users, specifically of the women, in the implementation of the programme. It was found important to restress that rural water supplies will have to develop hand in hand with sanitation (*Ambio*, 1981).

New Issues:

To the understanding of the age old environmental issues, we may add for completeness the modern menacing trends of technological insanitation and consequent pollution of our water bodies, soil and air.

We are thus witness, in the last quarter of the 20th century, to a number of self-destructive activities in the country, damaging, at places irreversibly, the environment at its roots. Many of these are inflicted because of our preoccupation with economic development; the entrepreneurs insisting that action for safety in environment can follow later. It is rather anachronistic that this is happening when the state of scientific and technical knowledge is such as to enable us to gain great sustainable economic prosperity without inflicting on ourselves a polluted present and a self-destroyed tomorrow.

Solution:

The magnitude of each of these problems in India is staggering. A satisfactory solution and sustenance of the solution can only be possible through socio-cultural re-orientation of the people at all levels — the masses, the elites, the affluent and government officials. Re-orientation of the socio-cultural background of the people will of its own require a tremendous educational effort conjointly with the programmes for economic development, environmental regeneration and national health.

In the present study the principal features and dichotomy in the socio-cultural background of the country are highlighted in broad outline. A detailed analysis of the multifaceted socio-cultural factors only can lead us to arrive at solutions to many of our problems, including the restoration of the degenerated environment to a healthy state.

SOCIO-CULTURAL BACKGROUND — ARCHAIC AND HISTORICAL

Urban and Rural:

This ancient land of India today has 80% of its people living in villages and the rest in towns and cities. The two groups understand little of each other; but the management and economy of the country is city centric.

Disparity in Life:

This has been a poverty stricken land through the ages wherein have lived and still live the very affluent few. The socio-cultural pattern evolved the way it has done, in the context of this great disparity in life. Poverty is the greatest polluter (Gandhi, 1972) — social, cultural and environmental. The disparity was imposed often right from birth.

Religiosity, in the socio-cultural practices of both kings and the people was codified by the early law givers, to fit the reality of this disparity. And that gave to society its inherent stability and also its immutability.

Privileged and Commoners:

The evolution of society through historical times could not change the core of the social psychology of such great disparity in living — notwithstanding the appearance and merger of new cultures from outside. The advent of great religious reformers, philosophers and law givers, from time to time, could not substantially alter the acceptability of the ethics of socially imposed disparities. The affluent lived on the labours of the poor to stay rich, brave and religious. The poor depended on the rich to survive as poor, meek and religious. The overwhelming majority understood their lives as naturally preordained; disease, pestilence and famine as natural consequences of the wrath of the divine. It concerned the lords of the land very little to know the conditions and environs in which their subjects lived, so long as dues were paid and law and order were secured. The king's administrators and other managers of the affairs of the rich, were the link between the two economic opposites of society.

Disparity in the opportunities for learning:

The most unique of all the privileges and disparities was having access to the three Rs. and to the precincts of gods. The uniqueness of this disparity lay in the fact that it was not related to economic status but to religion, caste and sex and to combinations thereof. Knowledge accumulated in the consciousness of the chosen few, but the social or institutional apparatus for dissemination of education, or the findings of the knowledgeable was too meagre even for the privileged few. Archaic beliefs and superstitions blended inextricably with all aspects of human thoughts or action and permeated society. Thus autocratic political structure stabilized in a feudal society.

The Elites:

The pupils coming from the schools of great reformers and philosophers created groups from amongst those eligible people who could understand, think anew and be in a position to communicate their thoughts to people. From the king's and rich men's legion and the pupils emerged the elites of society.

The elites were not necessarily rich. They were the erudite, the researchers, creators and appreciators of the finer aspects of life, living, art, science, architecture, literature, law etc. They were the critics, rebel rousers and leaders for ushering in changes in different aspects of life. They commanded respect and influence in society and were often accorded prestigious positions in the courts and parlours of kings, sultans and rich men. They sometimes acted as their think tanks. These elites were the cultural and intellectual bridges between the affluent and the people. Through the processes of preferences of the courts a section of the conforming elites were elected to use their talent in praise and support of the precepts acceptable to their employer. This is a seemingly natural process of selection in a society, much akin to the selection principle in nature.

A few from amongst the elites merged with the people as leaders, and were articulate in bringing about desirable changes in society and for the redress of grievances. The foundation was laid for awakening society for changes. However, many opportunities were missed. Psychological inertia was rationalized by distorted exhortation of behavioural religiosity, submission to existing social norms and fear of the authorities. Education being a prerogative of the elites, the people remained ignorant and could hardly understand the message of their leaders.

The poor, conditioned to their fate, had to stay humble to reap the benefits of humility beyond the present life. The subservient humility of the Indian masses and its rationalization subdued the dignity of normal human reactions to the prevailing conditions of life. In the process, the feed-back voices on conditions prevailing in the psyche of the society to higher ups got muted. Mental link-up of authority with the people became tenuous. Only through chance physical observation could one get glimpses of the environmental and social resultants to ponder.

Villages were to exist then on only as the sources of manual work force and materials, for sustaining the life-style of the affluent and their dependants. The affluent authorities sometimes spent liberally to build places of worship and put up buildings to their glory, further ensuring the religious sentiments of the people. Great acts of piety have often been the paliatives, such as the planting of shady trees along the king's highways and excavation of lakes and canals and digging of wells at appropriate places. The initiative for environmental actions rested with people outside the social fabric of rural India. The great exhortations contained in the scriptures and edicts of noble kings, as brought home to the people by the elite groups were little understood. The perennial concern of the poor consisted of eking out a subsistence for survival through ritualistic obeisance to gods of the environment and animal life.

Environment — Past and Present:

The large majority of people were illiterate then as they are today. The noble exhortations of the scriptures were translated into rituals conveying little meaning, and these too faded away with time. Nature was bountiful and self-correcting to a limit to insults and vandalism. Insensitivity to progressive degradation of the human environment became so deeply permeated that even in recent times the exhortation contained in the Constitution of India did not appear relevant to many in the elite strata of society. The Constitution (1977) lays down in the section on directive principles of state policy: 'The state shall endeavour to protect and improve the environment and to safeguard the forest and wild life of the country' (Article 48A), and 'It shall be the duty of every citizen of India — (g) to protect and improve the natural environment including forests, lakes, rivers and wild life and to have compassion for living creatures' (Art. 51-A).

In his monumental book on *A Manual of Geology of India and Burma*, Pascoe (1964) makes the following observation on the socio-cultural practices in the western ghats: 'Paucity of large trees, except in the damp districts near the sea, is partly due to the cutting of trees to which the accessible forests of India have been subjected to for ages and equally to clearing for temporary cultivation of a rude kind. Perhaps more than all the paucity of old trees is attributable to the practice of burning annually the grass and trees for charcoal at the commencement of the hot season.' A similar situation obtains, because of such practices, in the plains and northern highlands of the Himalayan hills and valleys. Such vandalism is organized and, sometimes, even publicly sponsored as part of economic activity. Such practices are inexorably aiding the growth of the desert on hills even in the highest rainfail area (Cherapunji) of the country.

The continuance of such violence in modern times in a number of developmental projects indicates that in our national efforts environmental issues still matter little. This is happening at a time when resources have dwindled, the population has increased enormously and when we ought to know the implications of such acts better than was realized by people in times gone by. These are only symptoms of a deep malaise which persists in the socio-cultural ethos of the country.

RENASCENCE

Advent of the British:

During the period just prior to the establishment of British colonial authority, the kings, the sultans and their vassals were all busy with their perpetual internecine quarrels. The feuds and the plunder that followed ravaged the land and impoverished the people who could do very little to help matters. New social and exploitive economic laws were enacted in the hope of perpetuating the autocratic feudal regimes. The British could understand very little of the socio-cultural structure and promulgated laws overriding the earlier ones of the native lords. Colonial rule was thus established. The vast colony and its environmental resources were exploited both for the traditional goods as well as for many new ones at an ever enhancing rate for the prosperity of Great Britain. The industrial and technological revolutions were in the offing and the crown colony's resources were developed for the supply of raw materials to the developing technology. The empire builders saw the great potentiality of the colony as a consumer of goods made in England. The indigenous rural technologies were systematically eliminated together with the artisans.

The British evolved an urban-centric, unified, single administrative structure for the efficient management of their own interests in the colony. English was introduced as the language of communication and the administration of the country. A new urban elite emerged to serve the colonial authority and learnt to look up to it for advancement and inspiration. The new elites were further alienated from the heartland of India. The English language and visits to the west, in addition, brought in new social ideas, and centralized productive technologies to this ancient land. The non-fatalistic, socio-cultural attitude of the western psyche and the progress made there were very impressive.

Elitist Movement:

The Renascence came. By and large the movement was of the elites. The movement rejected several of the socio-cultural and inhibitory norms of religion — most eminent was the rejection of the hereditary prerogatives of vocation and accessibility to education based on concepts of caste, creed or sex. The foundation was laid for the emancipation of Indian men and women. The message, however, in effect failed to reach the illiterate masses.

Independence movement:

The movement for political independence flourished as a continuation of the renascence movement. This was predominantly a movement of the disillusioned elitists who dreamt of a resurgent, prosperous India. Political ideas were basically western, so was the latter day economic regeneration strategy. The Father of the nation addressed himself right during the movement towards the problems of dovetailing these new ideas with the socio-cultural background of the country. He initiated concurrently integrated movements for: economic rehabilitation of rural industries, educating the masses to remove the cobwebs of practices that socially separated man from man based on religion or caste, and for ushering in democratic rules in society and government. Perhaps for the first time, the Indian people woke up to realize, after ages of inertia, that things can be changed, and that desirable changes are to be wrought and deserved. These are not pre-ordained.

Independent India:

The government of politically free India adopted secularism and the rule of democracy for administering the country. The leaders gave the country a progressive constitution. Intellectuals came forward to participate in the development of free India. Strategy and priorities sharply preferred the demonstrated techniques and technologies of western countries for laying down the foundation of a modern industrial state. The other basic precepts of the Father of the nation for the integrated rehabilitation of the country were thought to be attainable only after laying the industrial base in the country. The old practices continued in rural India. Urban dwellers made rapid strides in economic progress.

The two Elites again:

The rate at which progress was made in social and economic development in western countries through the development of science and technology seemed extremely convincing to the urban elites. In the process the voice of the other elite group which had a strategy for the urgent and integrated development of the rural poor got submerged. This group could not hold up the examples of other countries for arguing the viability of such an option as a priority. The Gandhian, decentralized economic principle had at its core a recognition of the indigenous socio-cultural condition, the rural economic structure and an attitude of environmental conservation. Consequently, the decentralist groups went back to work in a modest way with the rural poor, while the other planned and developed industries and urban complexes for sustaining the infrastructure of an industrial state. This was a parting of the ways for the time being, although neither of the two schools wanted to reject the other's actions altogether out of hand. The great leaders of industrialization were eager to catapult the new state into a modern state, and opted for large technological projects and scientifiic research. Both indigenous and borrowed resources were getting spent up. It was not clear in the early stages, nor is it clear now, how the benefits of this progress could ever be appropriately distributed to the people, who had also been enthused by the leaders to ask for a better quality of life. Wealth was not being generated at a fast enough rate; employment and welfare activities for the masses had to wait.

Inadequate rate of progress:

The progress was impressive in absolute terms, but in terms of the economic regeneration of the country as a whole, it soon enough showed signs of great shortfalls. Agrarian development in its own right could not be fitted in the ongoing programmes for industrialization.

RECONSIDERATION

Insulation of Planners:

Modern technologies had been trickling into the country even before independence. The country had by then, operating experience with steel plants, river valley projects, textile mills, fertilizer plants, electrical power generating stations etc. Augmentation of these industries and the initiation of a number of new technologies were taken in hand to generate employment and wealth. The early planners did not have the advantage of a comprehensive quantitative survey of the socio-economic conditions and employment structure in the country. Decisions were therefore based on the existing information and extrapolation of the notions that were available amongst the elites. They had by then become urban elites, and through years of insultation had been separated from socio-cultural conditions outside the urban conglomerations. The subsequent generation of elites could make only an intellectual extrapolation of rural economic needs. It was thought that with economic development, social problems would take care of themselves. Concern for environmental degeneration was another intellectual projection, a far cry from the realization of the gravity of the trends.

Employment and Centralization:

A number of indigenous industries like textile, oil crushing, sugar, leather goods, domestic metal ware, fruit orchards, grinding and dehusking of grains, silk and wollen fabrics etc. that had developed in a scattered manner in the country became centralized as a step towards modernization and the creation of employment. In effect, these industries greatly reduced the existing employment opportunities in the country. They offered opportunities to a few urban technologists and to labour coming from the rural sector. Profit that had hitherto been spontaneously distributed amongst the people through the small scale enterprises, got concentrated in the hands of a few. In the planning process, the creation of employment in the organized urban sector, could be accounted for better than for those workers that have been displaced in the scattered rural sector.

Improvement of rural Technologies:

With this attitude of centralization of development, the new technologists could not bring to bear their knowledge towards development of better technologies in the old enterprises of rural production. The electric power generated was meant for transmission to industrial centres. In spite of the development of a number of hydro-electric projects, the village handloom could not be transformed into an efficient power-loom. Sewing machines could not be introduced as a tool in the hands of rural cobblers. The village oil crusher could not be redesigned for better efficiency nor could the village sugar crusher be run on power. New opportunities for employment were generated at urban centres and labour from the rural area gravitated to the slums of the industrial centres, supervisory staff being provided by the urban technological institutes.

At whose cost: for whose benefit:

The ratio of return versus investment is the prime consideration for evaluating the financial viability of a project. The social impact assessment of projects mostly considers only the positive aspects, and lies low on negative ones. Environmental impact assessment, a new evaluation technique of technology, has yet to be understood in the industrial culture as much as in the rural culture of the country. However, in the decision making process in a welfare state, those responsible for economic projects, when carrying out 'cost' and 'benefit' analysis ought to analyse also 'at whose cost' and 'for whose benefit'. Environmental distress in urban and rural cultures originated primarily from social aspects being overlooked as imponderables. Quantification of such studies of social distribution of cost and benefit would indicate the direction of the flow of the benefits of the projects. All the industries that could be centralized, progressively got centralized primarily for the benefit of urban dwellers and industrial interests. More and more non-traditional technologies came up, further promoting the urbanization of economic efforts.

Decentralized Agriculture:

Agriculture, the major traditional enterprise of rural India escaped centralization. This could not be accomplished perhaps owing to the non-availability of machines, power and fuel. This industry continues to be the largest employer and the kingpin of the country's economy. Since food has to come from agricultural production, planners, technologists and researchers put in their best efforts towards improving upon the old technology of agriculture, notwithstanding its decentralized character. The success achieved, ought to have served as an outstanding pointer as regards the viability of a number of other technologies that might be adapted to the process of decentralized production.

Urban Economy Circuit:

The situation as it exists today is that rural production supplies the raw materials for the finished goods of the centralized economy, the prices of which have often been beyond the buying capacity of the rural people. The price structure of even coal is such that it cannot be paid for by villagers for domestic use. The urban economy has now developed a kind of a closed cycle norm.

Industries and offices are located in the cities. Education is concentrated in the cities. Transport and port facilities are concentrated in the cities. Housing, hospitals and other infrastructural facilities are built in the cities. Technological and medical education and training are also organized to serve the urban centres, and villages go without them. The oil produced and imported, the power produced, the raw materials mined, as also the feed materials for forest and argriculture-based industries, are transported to the cities. Products are mostly consumed in the cities, which account for only

20% of the Indian population. Very little of what is produced in the cities trickles into the rural areas. Inputs flow only in one direction. Wealth generated circulates in the cities. Rural people live on the sale of agricultural produce, the meagre wages of labour employed in mines and money order receipts from the employees in the cities. Little or no wealth is generated for development: such investments into the rural sector as flow from the cities are meant essentially for sustaining the supply and increasing the raw materials production for industries. Production now falls short of the demand even for the cities. In the scarcity market, a manipulative profiteering psychosis ensues. This is believed to be the essence of a colonial economy. Of late, a serious distortion has been apparent in economic activities. From this famished country, green vegetables, fresh fruits, fish, meat, sugar, cereals etc. are exported not so much because these are surplus, left after meeting the needs of the people, but simply because the export of these items earns foreign credits for the import of materials and equipment for the centralized economy. The people, including now also the city dwellers, are priced out owing to the centralized profiteering economy.

It is now well understood by the elites that the population growth rate prevailing in the country is extremely undesirable, but in a poor family's struggle for survival, the high growth rate is still a necessity for sustaining the family economics (Reddy et. al 1980). The productivity and wage structure of the city centric economy is now such that the city people themselves pay for the essential commodities in the profiteering market. A vicious circle of low productivity, high price and low consumption has thus set in.

Shortfalls:

It has to be reckoned that the major shortfalls in mitigating the problems of the Indian economy and environment are basic, elementary and extensive. These are not so much technological or scientific, but are problems of assigning priority, organization and management. This necessitates a reorientation of the culture of present day planners. Take as examples the distress situation prevailing in the environment. In the planned efforts of development, the daily fuel needs in the domestic sector have received very scant attention. The population at large is compelled to resort to tree felling practices for meeting their daily needs for fuel for cooking and heating. In addition the cities also require considerable quantities of fire-wood as domestic fuel (Gupta et. al. 1980). Viewing the urgency of the regeneration of forests in the country, it has to be well understood that forests are primarily essential for maintaining clean air, clean water, fertility of the soil, sub-soil water table at accessible depth and for holding the top soil in position against the erosive forces. Other uses of the forest, both commercial and industrial, are secondary to these primary considerations.

The problem of drinking water and sanitation in India is of a very large dimension and has accumulated through years of inattention to the socio-cultural unhygienic practices and through neglect of the environmental health in the countryside, in towns and cities. A sustainable solution may be obtained through a centralized public health engineering approach in the cities, but it is extremely doubtful if such an approach will ever mitigate the situation in towns and villages.

Educational efforts needed to wean away the people from unhygienic habits are rarely appreciated. In fact the municipal engineering solutions are breaking down even in urban centres. This has been a long standing shortfall in urban development plans. Appropriate technologies amenable to operation and maintenance by the rural poor need to be developed and disseminated.

The magnitude of the environmental problems that need immediate attention is such that no government, however well-intentioned, can meet the challenges of regeneration, by depending only on its administrative and technical apparatus. It needs the enthusiastic participation of the people.

The Department of Environment at the Centre:

Recently a Deptt. of Environment has been constituted by the Union Government — a very important step for providing a nodal agency to attend to environmental matters. The State governments have also been urged to constitute such agencies to work in liaison with the Centre. This agency is in a unique position to bring together the elites working in urban and rural areas to work out the short term and long term actions for rehabilitation of the damaged environment as well as regeneration and improvement of renewable water and forest resources.

While constituting the Deptt. of Environment on the recommendations of the Tewari (1980) committee, the government has not announced acceptance of the series of other well thought out recommendations. The government has yet to spell out an environmental policy.

Regeneration of Environment — some example areas:

In the planners' assessment of the energy needs of the country, the domestic needs of the entire rural sector has been kept out of consideration by the simple observation that this is outside the 'monetised economy'! This is nothing but escapism from facing vital issues. The country possesses the legacy of religious rituals for caring for water and plants, and this has to be relearnt rationally to reeducate the masses to replace the existing practices by progressive ones. The people are receptive to new ideas that are practical in the socio-cultural background and serve their urgent interests. The planners have to be attuned to social and economic conditions in the areas they want to plan for. In such planning, it is imperative for the government to stand committed to a policy, whereby the resources developed through, say, planned fuel forestry, will not be diverted to meet any other interest. This would be essential to ensure the people's confidence and participation. Forest-based industries like paper, timber etc. should thus be allocated land for raising their own forest resources on a sustainable basis. The total land needed for such community and commercial forestry does not exceed five per cent of the land surface of the country. All this can be accomplished on the so called fallow lands available; leave the designated general forests free from felling operations, and scientifically regenerate the denuded forests of hills, valleys and plains.

The cities and villages of even the high rainfall areas of the country, suffer perennially from drought conditions of one kind or the other. Bombay and the Konkan suffer from water shortage since almost all the fresh rain water is allowed to flow into the sea. Large water supply schemes, which are by themselves important, are not always available to augment the domestic water supply in the villages. In such areas the excavations of ponds and lakes and the impoundment of run off should be promoted. Urban centres do not usually plan or go in for such environmental actions. Their reclamation programmes include the filling up of existing depressions and ponds in preference to the corrective re-excavation and impoundment of water.

NEW TRENDS

Hopes:

A very hopeful development has occurred in recent years, in that many youthful elite groups trained in modern science and technology are progressively coming forward to attend to the development of appropriate technologies, in cooperation with rural folk who are amenable to implementing improvements by the application of their rural talent, in such industries as textile manufacture, gur and brown sugar manufacture, ghani oil crushing, nursery and forestry, fruit growing and processing, modern fish breeding, modern animal husbandry, dairy farming and dairy products manufacture, apiaries, biogas generators for fuel and manures, ceramics and pottery, smithery, carpentry, soap making, rope and coir manufacture, tannery and leather goods manufacture, processing of grains and cereals, bakery, baskets and handicrafts manufacture, bullock-cart transport improvement, boat and country craft fabrication, fish net knitting, brick making, improved sanitary latrine fabrication, domestic water purification etc. Many of these are either sponsored or promoted by government agencies. But the total volume of these economic efforts is very much subcritical. The process has to be greatly hastened with simple hygienic and environmental safeguards built into the programme.

The concept of a symbiotic relationship between the urban and rural cultures for all-round development has been largely missed in our economic planning. The urban centres producing the materials and special equipment needed in rural areas, and the rural centres producing resources and much of the finished consumer goods for rural and urban centres, require detailed investigation and planning on an extensive scale, since they constitute complementary national activities.

Many of the new modern industries are amenable to decentralized production in rural areas if in the spirit of symbiotic development the materials and components are made available from urban industries to the rural entrepreneurs. This would employ villagers in the assembly of household electric and electronic goods, entertainment electronics and instruments, assembly of small and medium mechanical equipment and watches; in the manufacture of tooth paste and tooth brushes, of some medicines and medicinal tablets, of lime-bleaching powder and chlorine tablets, of moulded plastic and metal wares, and the manufacture of natural dyes and simple chemicals, of essential oils etc. etc.

Large Scale Enterprise:

These would still enable vast areas of centralized technologies to prosper, such as the ship building industry, steel mills and metallurgical industries, petrochemicals and fertilizer industry, automobiles, aviation and locomotives industry, bulk power industries, arms and ammunition industry, machines, tools and electronics component industry, mining industry, communication industry etc.

The socio-economic culture of the complementary efforts of the urban and rural sectors have limitless possibilities of development for both short term and long term mutual economic benefits.

SOCIO-CULTURAL MATTERS AND PRESENT POLITICS

Inhibition factors:

The desirable economic activities cited do not refer to the inhibitory socio-cultural problems. The primary inhibitions to progress in present day secular India are recognized as religious, caste and regional fanaticism. Together with economic problems these are deeply ingrained in the psyche of the people. The politics of the country is clouded by these factors, so are the administration and many social institutions. The inherited economic culture of the country was exploitive. This culture became strengthened in spite of the government's intention to the contrary. Compulsory and basic education schemes could not be implemented in the context of persistent economic constraints. Formal elementary and higher education, although it did not differentiate between boys and girls, became dominantly city centric. Trends of emancipation of women became discernible only in the cities. The socio-cultural disparity between urban life and village life increased. Except for education, the country's planning does not include strategies for socio-cultural regeneration. The scourge of the dowry system, child marriage, religious and caste persecution continue in the face of the progressive criminal codes of practice enacted to eliminate them. These practices which prevail both amongst the rich and the poor, among urban dwellers and villagers also contribute to the current economic distress. The persistence of the economics of child labour and bonded labour may be attributed to the social and cultural acquiescence accorded to them.

Electioneering:

Many of the elected representatives in our democracy bring to bear in varying measures their preferences for the socio-cultural immoralities in their leadership. Exploitive interests promote the individual leaders and political parties with money and resources to curry favour after elections. Electioneering is fast becoming an investment practice, further distorting implementation of the laws of the land and the economy. In the process, the commercial interests and political will fail to recognize any urgency to attend to the degenerating physical and socio-cultural environment. The two elites, the constructive social workers and expectant people of the country are looking up, askance.

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AIR POLLUTION AND PLANTS

T. N. KHOSHOO

THE life support system on this planet consists of air, water, land, flora and fauna. Normally these are mutually inter-connected and also inter-dependent. The activities of man constitute one single factor which often disrupts the intricate balance among the foregoing constituents of the life support system. In his eagerness (or should we say greed?) to urbanize and industrialize, man has not only destroyed plant cover built up meticulously by nature over millions of years, but also polluted air, water and land, so much so that development has become synonymous with deforestation and desertification, and progress with pollution. Although pollution in air, water and land cannot be delinked from one another, the present account deals only with air pollution in relation to plants. Air constitutes nearly 80% by weight of man's daily intake and he breathes nearly 22,000 times a day. Furthermore, man can live several days without food, a few days without water, but only a few precious minutes without air, because lack of oxygen supply for more than 5 minutes causes irreparable damage to the brain. Therefore, among other things, not only air, but unpolluted air, is vital for plant and animal life, and 'the presence of any solid, liquid or gaseous substances in the atmosphere in such concentrations as may be injurious to human, plant or animal life or property or environment' constitutes air pollution.

SOURCES OF AIR POLLUTION

The major source of air pollution is transportation, and next in order is industry and power generation. The major air pollutant causing the maximum damage, is sulphur dioxide, and others are ozone,

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peroxyacetylnitrate (PAN), nitrogen oxides, fluorides, particulates, etc. While in the world 300 million tonnes of pollutants are emitted annually in the air, India contributes about 10 million tonnes in the form of particulates, sulphur dioxide, carbon monoxide, hydrocarbons, etc. In fact air pollution in India occurs in isolated pockets because industrial production is concentrated in 8-10 large cities. Chembur is regarded as a 'Gas Chamber', which on account of concentration of oil refineries, a fertilizer plant and huge industrial complexes, is perhaps the most polluted area in India.

According to J. M. Dave, the Mathura Refinery (including perhaps the foundry industry in Agra and its environs), will increase acidity in the air from 100 to 200 micrograms per cubic metre, and is likely to cause 'stone cancer' to the Taj Mahal as also pose a threat to life.

DAMAGE TO PLANTS

Damage has been defined as 'identifiable and measurable adverse effect' and plants are rather more sentitive than animals, including man, to pollution. It may, however, be emphasized that the harmful effects of pollution have been experienced both in the geological times owing to lava and ash from volcanoes, and in historical times since the middle ages, particularly from the beginning of the 14th century, when coal began to be used. Brick kiln disease of the mango in Uttar Pradesh has been traced to SO_2 emitted from the brick kilns and has been the cause of many legal battles, some of them won and others lost. However, in recent years there has been considerable resurgence of interest in the subject owing to widespread and alarming reports of the damage caused by air pollution. Although today 'pollution' and 'environment' have become bandwagons and most people regard themselves as specialists in these areas, there are, however, only five research groups working on pollution in relation to plants in India, They are based at the National Botanical Research Institute, Lucknow (K. J. Ahmad); the Institute of Science, Bombay (S. B. Chapekar); Calcutta University, Calcutta (T. M. Das); Banaras Hindu University, Varanasi (D. N. Rao) and Jawaharlal Nehru University, New Delhi (C. K. Varshaney). We must accept the fact that at present knowledge is imprecise in this field and the problem is, indeed, complex.

The response of plants to air pollutants is variable and depends on the individual genotype, age, stage of growth, proximity and concentration of pollutants and duration of the onslaught. It affects opening of stomata (which are the principal doorways for entrance of pollutants and the maximum damage is caused when they are open), photosynthesis (by destruction of pigments), water relations, respiration, individual enzymes and enzyme systems and cell organells. The events leading to pollution injury may be summarized in the following words: Weak acids and oxidants cause osmotic imbalance because of membrane impairment which in turn leads to depletion of cellular resources and affects transpiration and photosynthesis, and finally cause cellular injury or death. This affects both natural and agroecosystems. Reduction in photosynthesis leads to reduction in growth, development, flowering and reproduction and finally affects adversely the productivity and yield of crop plants. The problem falls in the areas of chemistry, biochemistry and plant physiology and is a kind of stress physiology.

Another dimension to the damage to plants by air pollution is its effect on pathogens. Essentially, there are three situations. First, growth and reproduction of pathogens (like stem rust of wheat) is retarded and the incidence of disease is checked. Secondly, the toxic effect on physiology weakens the host and increases its susceptibility to pathogen infection of wood rotting fungi, and also cause necrotic spots which become entry points for pathogens. Thirdly, the presence of pathogens modifies the sensitivity of the host to pollutants, as in the case of sunflower rust which reduces ozone injury, or in other cases such sensitivity may increase with the pathogen infection. Obviously, the interaction between pollution and pathogen infection of host is rather complex and more work is needed to clarify the same.

Ultimately, damage to plants must result in economic loss, of which the exact quantification is rather difficult. Some idea may be obtained from the 1969 data for the USA, compiled by W. W. Heck and C. S. Brandt (1977). While the direct loss of crops and decorative plants was estimated as $135 million, the figure goes to $1 billion if the following points are also taken into consideration; reduction of growth and yield without injury, damage to ecosystem, aesthetically pleasing landscape, turf, etc., and predisposition for pathogen attacks in some cases. This then is the enormity of the economic loss on plants and plant cover in the USA alone.

PLANTS AS INDICATORS

It is possible to use plants as indicators of pollution damage because plants are sensitive biological monitors. However, there is a considerable simulation in visible effects of pollutants, pathogens and even cultural conditions like deficiency symptoms which are purely physiological in character. Therefore, plants can be pollution indicators only when pollution-indicated injury or symptoms are definitive or specific. Obviously, aerial parts, particularly leaves, owing to their location and structure are exposed the maximum to the onslaught, and based on considerable field and laboratory work, it is clear that indicator-value of injury symptomatology is reasonably well established, so much so that three colour atlases on the subject have been published by T. T. Hindavi, J. S. Jacobsen and A. C. Hill; and H. Van Haut and H. Stratmann, all published in 1970. All these are based on data and plants of temperate regions and similar atlases are needed on subtropical/and arid region plants.

Sulphur dioxide, which emanates principally from burning of fossil fuels, causes intercostal necrosis in tobacco. It oxidizes to sulphur trioxide and in the presence of moisture forms sulphuric acid which causes acid rain which corrodes property. Nitrogen oxides affect intercostal areas along the mid rib in tobacco. These arise from internal combustion engines where oxygen and nitrogen are subjected to heat and pressure. Oxidants like ozone cause bleaching on the upper surface near large veins. PAN causes chlorosis and brown necrosis on the upper surface of the leaf in groundnut. Fluorides cause necrosis on local areas along the margin in grape which does not extend to the middle. These arise from industrial processes connected with aluminium, steel, glass, ceramics, etc. Particulates are suspended as dust in the air and arise from cement and lime processes as also from the disposal of agricultural refuse by burning, fly ash, etc. and contains airborne trace elements.

While visible injury symptomatology is one aspect of indicator value of plants, the other is leaf epidermology. The rationale behind the latter is that it is the leaf epidermis that is most exposed, and stomata are the easy entry points of pollutants in higher plants. Work along this direction began in 1973 when G. K. Sharma first studied the epidermis of the white clover growing in rural and urban (polluted) areas of Tennessee. He found low stomatal frequency in the latter which was statistically significant. His studies were followed by several workers notably K. J. Ahmad and his group at NBRI (Lucknow), who, after a statistical analysis of 85 populations of castor from polluted and healthy areas for frequency of epidermal cells, stomata and idioblasts, found that there was a significant increase in their frequency per square mm. Furthermore, the Scanning Electron Miscroscope pictures showed differences in stomata of plants from the two habitats leading to virtual destruction of stomatal apparatus in polluted areas. From these studies, it is clear that the following epidermal features are modifiable: size and frequency of epidermal cells and stomata, subsidiary cells, idioplasts, trichomes, cuticle and wax. However, more data are needed to assess whether these characteristics could be specific for specific pollutants.

There is a good reason that epidermology can become an useful bioindicator of pollution provided a systematic field survey of plants growing in polluted and healthy areas is made. Such studies need to be followed by laboratory studies of different pollutants on the same genotypes and same pollutants on different genotypes, and combination of pollutants to simulate natural conditions. At any rate, epidermal studies may provide first tier assay system and will help in uncovering susceptible plant species as also insensitive/tolerant ones. The former would be useful as bioindicators of pollution, while the latter could be used for landscaping the polluted areas.

Studies are also needed with regard to dust-trapping ability of different species with reference to epidermal features such as size, shape, structure and density of epidermal hair as also wax coating.

LICHENS AND BRYOPHYTES

These groups of lower plants have been utilized abroad, with considerable advantage, as biomonitors of pollution. The particular advantges are: lack of regulatory mechanisms provided by stomata, slow rate of metabolism, perennially exposed plant body, unusual capacity to absorb and concentrate air borne and water soluble materials over long periods of time, sensitivity to very low concentration of polluting agents which is heightened because they never shed their toxin-laden parts, and finally a large surface area to weight ratio e.g. *Parmelia* gives 173-225 grams of plant material per sq. metre which figure for the same area would be many times more in higher plants. As a test system, these plants are the most ideal and have been utilized in monitoring present day pollution by using epiphytic lichens/mosses in wide mesh nylon nets, as also monitor pollution in historical time in relation to human activity. For instance, A. Ruhling and G. Tyler analysed the herbarium material of mosses collected from the same locality in Skane (Sweden) at different times during A.D. 1860 and 1968. They found that during 1860-75 the lead content was nearly 20 ppm which doubled (40-50 ppm) during 1875-1900 but remained more or less static during 1900-50. However, it again galloped (ca 80-90 ppm) during 1950-68. The first increase was correlated with increased use of coal, while the second hike was the result of combustion of lead petrol in western and northern Europe. They also found a gradient in the quantity of lead from woodland to urban habitations as also from North-east to South-west Sweden, which is understandable on account of the increase in human activity and industrialization. The first European Congress on the influence of air pollution on plants and animals held in 1968 passed a resolution in this regard saying that 'cryptogamic ephiphytes should be strongly recommended for general use as biological pollution indicators, because they are so easy to handle and they show vast range of specific sensitivity to air pollutants greatly exceeding that of most higher plants.' Fortunately, India is rather rich in both lichens and mosses, particularly, in the Himalayan belt as also in the hills in Central and South India. The NBRI has recently published a census of lichens and over 2000 species are reported from the country, and we need to use some of the more easily available species for purposes of monitoring pollution.

PLANT CHROMOSOMES

Another test system is provided by plant chromosomes as indicators of genetic hazards of environmental chemicals and pollutants. The system involves analysis of mitotic and meiotic chromosomes with regard to c-mitosis, multi-nucleate cells, unequal condensation, stickiness, interchromated connections, fragmentation, sister-chromatid exchanges and meiotic abberations. However, the relevance of the data emanating from plant chromosomes depends on its correlation with that from mammalian and/or human chromosomes. At any rate, the standard 'Allium Test' can offer a first tier assay system for possible genetic damage from use and spread of environmental chemicals.

GREEN BELTS

The basic premise of regarding plants as mitigators of pollution emanates from the 'ability of plants to remove significant quantities of pollutants from the air without sustaining serious foliar damage or growth retardation.' This concept emanates from works like that of A.C. Hill who in 1977 showed that a continuous cover of alfa alfa under optimal conditions can remove nearly 0.2 tonnes of NO_2 or SO_2 per square mile per day from the air. In this regard actively growing herbaceous plants absorb more pollutants than woody species. Vegetation may thus be a scavenger or a sink of many air borne substances like HF, SO_2, NO_2, O_3, Cl_2, etc.

The leaves with their exposed surface are the primary receptors and their surface features, like hair and wax coating, are potential traps particularly for particulate pollutants. Pollution laden winds flowing over as also through vegetation are slowed down and deposit particulates on the surface. Under Indian conditions, dust trapping capability of plants is a relevant area of work. Furthermore, there is proven ability of some temperate plants like *Betula, Fagus* and *Carpinus* to absorb pollutants like SO_2. The materials on the external surface either react with or perhaps destroy pollutants. The whole process is aided by the fact that plants are self-renewing, and undergo growth and metabolic regenerative processes and shed leaves and other tissues (like bark) periodically, and ultimately in this way it is soil and water that become the final sinks of the pollutants.

This leads to the concept of green belts as sanitary protection to reduce pollution, particularly of particulates. In this connection, large scale afforestation has been advocated by A. K. Ganguli as also D. N. Rao. The latter has recommended planting of *Pithecolobium dulce*, a hardy and quick growing tree, at sites where coal is loaded and unloaded. In general, the characteristics of the trees and shrubs in a green belt should have close canopy, thick strong trunks, rough fissured bark, profuse branching and large densely arranged leaves, so as to increase the receptor area per cubic metre of space.

The effectiveness of the green belt for mitigating the adverse effects of air pollution is, however, debatable. Let us take the case of CO_2 which is a gas directly utilized by plants without further polluting the atmosphere. Furthermore, in its place they release a life-sustaining gas like oxygen. From this point of view, there cannot be more benign an air pollutant than CO_2. There are varying estimates of the increase of CO_2 content in the atmosphere. Some believe that by AD 2150 the level of CO_2 will be 4 to 8 times of the level in the pre-industrial era, others feel that by AD 2025 CO_2 will rise to 14 billion tonnes/year as against 5 billion tonnes/year in 1971-80 and 8 billion tonnes/year in the 1980's. However, there is a general unanimity that the natural balance through absorption by plants and oceans will be affected, and overall CO_2 content of the earth's atmosphere will rise.

The hike in temperature will be the result of a 'Green House-Effect' which allows sunlight, but traps the outgoing heat, leading to warming of the earth. There is a general agreement that temperature will rise by 2°C by AD 2030 and by 6°C by AD 2150. The hike in the temperature will lead to melting of polar ice and rise in sea level by 5 m or so and many coastal cities may have to be abandoned. In turn, this will lead to unprecedented changes in the climate of the world. Most climatologists think such conditions will arrive in about 100 years from now, but some others feel it will take only 50 years. That such an increase will have a differential effect on the climate of different regions of the world is rather certain. On the one hand there is a report published in *Nature* (8 May 1980) based on a document put up for the consideration of the US President's Science Advisor. According to this report, the temperate regions, where most of the developed countries are located, will gain through increased photosynthesis and lead to increased agricultural yields, even though these nations use the maximum amount of fossil fuel and contribute to pollution far more than the developing countries in the subtropical arid zone whose rainfall is likely to decline, leading to possible droughts and decrease in food production and which will be put to overall loss. It is envisaged that there will be a shift in population distribution and there may even be a demand for International compensation. However, during the last Earthscan Symposium (Stockholm, 1981) the opposite opinion has also been expressed, according to which agriculture in the temperate Grain Belt of the USA and the USSR will suffer, while countries like India will stand to gain. This has been contradicted by S. K. Sinha who feels that increased evaporation, owing to rise in temperature, will seriously affect productivity of major crops like rice and wheat in the tropics, and higher temperature and humidity will increase pests and diseases, which may become major causes even of famines.

What is most important is that the hike in CO_2 cannot be absorbed by planting even 1000 billion trees which in itself is a stupendous task. This in no way detracts from the value of green belts for increasing plant cover, with its many attendant advantages like production of woody biomass, amelioration of soil, improvement in its water conservation and a general conditioning effect and improvement of the environment as a whole. Thus, while green belts may help to reduce air pollution, the best method to control pollution is at source, by newer and cleaner sources of energy, pollution-free mass transportation, better fuel and land use, treatment of industrial pollutants, proper disposal and utilization of agricultural and other waste, etc.

PLANT EVOLUTION AND BREEDING

The cardinal points of all organic evolution are mutation, recombination and selection, and throughout evolutionary history, the selective factors have been provided by the changing environment. Judged against this background, pollution is a man-made abnormal component of our natural environment. Pollution has become an integral part of all development and has come to stay in one form or the other. Obviously, it must cause selection pressure on plant populations. A well-known example is the origin of melanic forms of peppered moths, which normally merge with the lichen-covered tree trunks and escape predation by birds. However, once lichens disappeared as a result of pollution, the tree trunks became black owing to deposition of soot. Against such a black background, the peppered forms became very conspicuous. In order to escape predation, melanic forms evolved in historical time which merged with the soot-covered trunks. There are several critical studies made by A. D. Bradshaw, particularly, in Britain, on the evolution of heavy metal tolerant grasses, particularly, aerial copper (near Liverpool) lead, cadmium, etc. Again, this has happened in historical times in nature.

Furthermore, in cultivated crops fluoride-resistant forms of gladiolus, and ozone-resistant types in tobacco and onion are well known. In onion the resistance is conferred by a single dominant gene which controls stomatal movement. In the susceptible forms stomata remain open, while in the resistant forms they are closed in response to ozone in the air.

The variation for pollution resistance is at genotypic, populational and specific levels and it is often a graded series. There is hidden variability in the gene pools and location of suitable variation in base populations is necessary. It is essential to include this parameter for breeding plants for situations where pollution cannot be altogether eliminated. The genetic basis of pollution resistance is still not well understood. Among the possible mechanisms conferring resistance are the type of cuticle, stomata (which regulate the entry of pollutants), and degradation of pollutants into innoccuous byproducts. There is hardly any worthwhile study in this regard in India which could enable the breeding of plants for pollution resistance in order to stabilize the polluted environment. In the first instance, work on plants with short life cycles and high reproductive capacity will be more rewarding.

GENERAL CONSIDERATIONS AND SUGGESTIONS

A few points of general importance may now be considered. Pollution in air, water and land is mutually inseparable as also from increased industrialization and urbanization. Pollution in the air must come down to earth with rain/precipitation or even dry deposition and, along with vegetation, water and land are its major sinks. The best place to control pollution is at source, and there are many dimensions to this problem ranging from biological, physical, chemical, engineering, socio-economical to political, etc. There is, therefore, an urgent need for a long term integrated approach to achieve sustained development leading to an harmonious balance between the needs of society on the one hand, and natural environment on the other. Essentially, a balance has to be struck betwen two opposing, or sometimes even contradictory, demands.

Some suggestions that emerge from the foregoing discussion are:

(i) There is need for round the year pollution monitoring of metropolitan cities and industrial towns so as to lay environmental quality standards for each pollutant, as also the extent and nature of the pollutant needed to be reduced at source, and the nature of legislative measures for containment of pollution.

(ii) Systematic screening of our plants for pollution susceptibility or tolerance/resistance needs to be undertaken so as to un-cover tolerant/insensitive/resistant species for landscaping polluted areas, and susceptible/sensitive species as bioindicators. Such studies need to be undertaken with the help of mobile monitoring vans. This should be followed by laboratory studies involving detailed work on morphological, physiological and biochemical studies. Such studies, once undertaken in a planned manner, may ultimately enable us to devise injury control measures. In addition, the role of pollution in host-parasite interaction needs to be understood in greater detail.

(iii) A survey of the extent and nature of damage caused to natural and agroecosystems needs to be undertaken with a view to estimating the economic loss due to air-pollution.

(iv) Green belts, particularly of the tolerant/resistant species need to be planted around urban and industrial complexes as also of species capable of trapping dust. Such plantings will provide many intangible benefits by way of conditioning of local environment.

(v) Breeding for pollution resistance, particularly of horticultural crops grown outside habitation and on highways where industrial and traffic pollution is the maximum needs to be taken up. This has to be done before such areas become totally inhospitable for cultivation of horticultural plants.

(vi) An awareness programme needs to be organized because there is a general feeling, even among the educated Indians, that anti-pollutionists are 'prophets of doom'. They feel that there is no pollution in India and according to them undue stress given to pollution and other environmental problems will harm the industrial development of the country. However, actual data show that all our industrial cities are in no way less polluted than those in the western world, the only difference perhaps is that pollution in India occurs in isolated pockets.

The atmosphere of the earth is a common heritage and in spoiling this, the developed countries are making a far greater contribution by discharging a greater quantity and diversity of pollutants in the atmosphere including outer space. In fact they treat the sky as a sewer.

(vii) The problems and threats of air pollution are global, because air does not recognize political boundaries. For instance, the 'Newsweek' of 9th March, 1981 carries a report that 'Canadian officials say that Prime Minister Pierre Trudeau and his aides will stress environmental problems in meetings with Ronald Reagan, who visits Canada next week on his first Presidential trip outside the United States. The Canadians are concerned about US Industrial pollutants that drift into that country as "acid rain", which can destroy vegetation and marine life. The Canadians will also argue that the United States isn't fulfilling its share of an agreement between the neighbouring nations to reduce pollution in the Great Lakes'.

Perhaps, in time to come, air pollution may become an overriding reason for peaceful co-existence of all nations, and let us hope a commonality of approach may evolve for combating this man-made menace.

HUMAN BRAIN CONTROL AND SĀDHANA

GEETA TALUKDER

INDIANS have long been interested in the finer functions of the mind. Perhaps the climate or the vastness of landscape or some innate factors have helped Indian minds to be more introspective and to turn to abstract cogitation rather than events in the world without. Thus mathematics, astronomy and astrology have developed faster than alchemy, physics or anatomy. The use of psychotropic drugs and hypnosis has been more popular than the development of alcoholic beverage or antibiotics.

Be this as it may, the behaviour, responses and control of the mind have been the goals of many. The world, although said to be composed of variegated sights and substances, is still believed to be ephemeral and a consequence of primal energy forces which are controlled by a single indivisible substance common to all substances — living or apparently non-living. The human being also possesses the *atman* within and is superior to the other living forms in that he alone is capable of regulating his mind to realize the self within and the outward reality. These thoughts, being extremely abstract and often intangible, have been given various names and descriptions, often allegorical. Scientific proof may be lacking, except the proof of feeling. That the feeling of the man itself can also be a tool in realization of scientific facts has only now been accepted by a few proponents of extra-sensory perception and its like. The time has perhaps come to separate the wheat from the chaff — as has been done by numerous religious and learned persons in the past — in the background of the knowledge of modern physiology and psychology.

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It has been accepted that the *atman* can control not only the body but also its responses to the external environment. The *chitta* or mind is extremely susceptible to the stimuli from the external environment and is often moved like a boat tossed by waves or a 'chariot pulled by several horses'. It has been advised that the way to attain any goal, spiritual or material, lies in the control of the *pravrittis* or feelings concentrated by a process known as *sadhana* which comprises *yama, niyama, pranayama, dharana, dhyana* and finally *samadhi*. The methods of various types of *sadhana* are often given in many texts in the most bizarre forms. Yet others appear reasonable as they seem to be directed to the development of healthier bodies or a better memory. Still others are said to lead man to the highest happiness above all ephemeral joys. In general, it has been propounded that sensations proceed through the body through electrical impulses leading into the spinal column. Here they proceed up through various centres or *chakras* to the base of the brain and finally into the brain itself. By judicious control of the impulses, the external motor activities like the movement of the limbs, chest, respiration, eye movements and even the activity of the heart, respiration and vocalization can be controlled. Further, more intense concentrative effort results in a state of supraconsciousness or *samadhi* — which is the final goal.

TRANSMISSION OF SENSATIONS IN THE HUMAN BRAIN

How far are such concepts supported by science at present? Anatomically in man, the spinal column has a central canal tapering to an end below and communicating all the way above with hollow cavities in the brain and with the sac surrounding the brain and spinal cord containing cerebrospinal fluid. The spinal column is composed of nerve tracts arising to the brain stem and the brain (cerebrum) that is located on top of the brain stem. This cerebrum has a cortical area composed of multiple layers of nerve cells and their branches which synapse with each other and with the incoming and outgoing fibres leading down the brain stem.

Man exists in the midst of a sea of sensory perceptions — light, sound, taste, smell, temperature and so on. He perceives them through the specialized nerve fibre ends of the sensory nerves which are appropriately called receptors. There are millions of receptors distributed all over the body and inside the organs and in all parts of the body. These are highly specific and are of various types — *mechanoreceptors* which detect mechanical deformity of adjacent cells; *thermoreceptors* which detect changes in temperature; *nociceptors* detecting chemical or physical tissue damage; *electromagnetic* receptors the effect of light in the retina, and *chemoreceptors* changes in taste, smell, oxygen and carbon dioxide levels, glucose levels and osmolarity of the area adjacent. These receptors respond by a process akin to electrical receptors and pass the impulse along the nerve root to the cells which lie in the spinal column. Thus, although the sensory end organ may be at the tip of the toe, the nerve root will carry the impulse right up the leg to the parent cell located in the spinal cord. Thus, millions of channels of impulses enter the cord. Here the relay is passed on to the next nerve fibre which crosses to the opposite side and moves up the cord uninterrupted upto the base of the spinal column, appropriately called the brain stem, on which the cerebral cortex rests. There it ends in its parent cell which in turn passes the impulse along the dendrites of cells of the cerebral cortex.

Here, again, there is systematization in the sense that intense feelings of pain, touch, temperature, tickle and itch and sexual sensations are evaluated or 'felt' in the lower regions of the brain stem in the thalamus. The finer touch fibres on the hand are passed through the thalamus onto the cerebral cortex in an area just behind the crown of the head — called the sensory area I. Here every part of the body is accurately represented. If any part of this area is damaged, the corresponding area on the *opposite* side of the body will suffer sensory loss. However, the loss is of the finer sensations, so that one would not be able to differentiate between small degrees of pressure, touch or temperature, like the texture of a cloth, the shape of two objects or the weight of two pieces of stone. The pricking type of pain is also lost (Fig. 1).

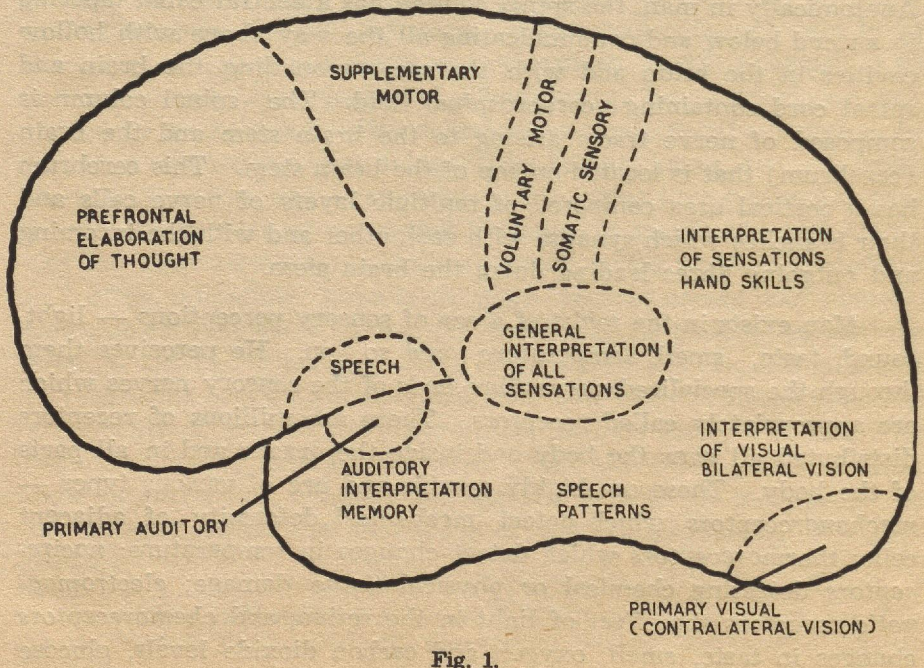

Fig. 1.

The senses of vision, hearing, smell and taste also move through the thalamus to areas in the brain — the occipital cortex for sight, temporal lobe for sound, hippocampal and uncinate gyri of the medial side for taste and smell. The cortex as before appears to be more concerned with complex associations. For example, stimulating the visual cortex electrically leads to auras of light which may be coloured or assume simple forms like stars and lines while the stimulation of the auditory cortex causes the person to hear complex sound notes.

COMPUTERIZATION OF SENSORY PERCEPTIONS

In the human cerebral cortex the different sensations bombarding different areas initiate reactions in adjacent cells and 'association areas' are formed. Thus the auditory area associates with an area responsible for speech. The taste and smell areas collaborate with the areas responsible for hunger and thirst. The large area behind the sensory cortex acts as a sensory association centre where the memories are formed and sensations coded. Stimulation of certain areas has led to the perception of whole scenes or to the hearing of pieces of music or entire speeches. It may be possible to stimulate these areas at will selectively. This must be the way memories are revived and facts recalled, imposed on new facts and recorded. The fact that this process of synthesis and analysis is carried out from infancy onwards and that, in case one half of the brain is damaged in early life, the other part may take over — may indicate that the sensations of the cerebral cortex can be reoriented.

Visceral and sexual impulses are perceived lower down in the brain stem and sectioning of the cord often does not affect them. The cerebral cortex can thus regulate the so-called vital functions as well. Physiologists and neurologists have studied the brain through selective destruction of areas or selective stimulation of undamaged areas and observation of effects in animals and men. Modern advancements in neurosurgery have also shown the effects of surgery on damage to different parts of the brain itself.

Earlier, theologists probably depended on the observations on a section of the spinal cord in animals and the effects of psychic stimulation in man. The central canal was termed the *susumna* and the sensory and motor tracts of the spinal cord the *ida* and *pingala nadis*. That the sacral plexus existed was known and the centres for regulation of the sexual and alimentary areas more or less defined. However, the allegory of a coiled snake the *kundalini* existing in the spinal canal does not bear substantiation, as the spinal canal is an hollow structure with no sensory or motor function. Control of sensations and motor activities are routed through the tracts. However, the *chakras* may be likened to the centres of activity — the most evolved being in the cortex where the parent neuronal cell occurs. It must be emphasized however that animals cannot be correlated with humans in all cases as the human brain is much more developed and this applies more to the temporal and frontal areas of the cerebral cortex.

INHIBITORY ACTIVITY OF THE BRAIN

Indian yogis had probably evaluated the functional capacity of the central nervous system by activating the inhibitory capacity. They had asserted that with judicious use of various exercises *pranayamas* and *asanas* the activity of certain areas could be cut off. The necessity of diet and posture is emphasized. The spinal column, kept straight with the weight evenly distributed, prevents strain. The control of respiratory activity by *kumbhaka*, *puraka* and *rechaka* helps to regulate the circulatory system as well. This facilitates *dharana* or fixation of an idea and *dhyana*, concentration or conception. The latter could be a face, an object or even a spot of light. The activity of the spinal cord is then brought gradually upto the level of the heart, to the vocal cords and finally into the brain itself. Various sensations and visual and auditory auras are described in the process. The final step is said to be difficult to attain and even more difficult to describe and may be likened to the superconscious state. Here motor functions are completely inhibited and vital functions may be suspended.

Such inhibitory activity finds correlation in the recent findings on the role of inhibitory chemicals in brain activity. In peripheral nerves parallel with stimulatory chemicals, inhibitory fibres are also seen to exist. The sympathetic and parasympathetic fibres have long been known to act in the regulation of visceral activity. While one stimulates the heart beat or gut movement the other actively inhibits it. Similarly areas in the brain stimulating appetite and depressing it, lie close to each other.

Single clusters of cells secreting morphine-like substance inhibiting pain have been demonstrated in the brain itself in large numbers. These chemicals are probably responsible for the lack of immediate pain after a major accident or amputation or are the ones responsive to acupuncture stimulation. Thus inhibition of sensory effect is an innate character of the central nervous system. Whether this is under the control of the will is the matter in question.

ORGANIZATION OF THOUGHT AND WILLPOWER

What is will power? If it means the control of motor or muscular activity, then the centres controlling it are located in the cerebral cortex right in front of the sensory area. Here every part of the body is represented, matching the sensory area. Lesions give rise to paralysis of that part of the body, as happens in cerebral injury or haemorrhage. Impulses of this area go down the spinal cord *via* the thalamus down the spinal cord along with the sensory fibres. They finally terminate in the motor end plates in the muscles. Thus each brain cell has a direct connection with a muscle fibre which can be stimulated to activity.

The regulation of activity occurs by association fibres. The area in front of the motor area is the supplementary motor area which controls all motor activity through the thalamus. Here lesions may cause defects of specific functions. For example, a person may have the normal muscle of speech, he may know perfectly what and how to vocalize, but may become incapable of making the co-ordinated movements necessary for speech.

EFFECT OF EMOTIONS

Some of the main factors affecting cerebral activity are emotions, like fear, anger, hunger and sorrow. While Western thought has usually exaggerated their effects, Eastern ideas have tried to underplay them. An area above the basal nuclei but below and deep inside the cerebral cortex, known as the limbic system, has been said to be the seat of emotions. The constriction of pupils of the eye, the blood pressure, hunger, satiety, thirst and water conservation are regulated here usually through the stimulatory or inhibitory activity of hormones of the endocrine glands. Pain caused by deprivation and pleasure by avoidance of noxious stimuli have been found to be governed by this area, perhaps the seat of Freudian thoughts. Suppression of this area causes loss of fear, emotional reactivity and hunger. Stimulation has caused increased wakefulness, alertness and excitement. Does this denote that this region is the seat of creative thought? The answer is unfortunately in the negative as the activity is totally emotion-oriented and non-productive.

The difference between man and the highest non-human primate lies mainly in the size of the area in front of the motor cortex — the prefrontal area. Long called the 'silent area' owing to its apparent non-function — it is the site of higher intellect or *buddhi*. Persons affected by maniac disorders have had this area ablated with improvement of mania, but leaving them with no capacity of independent thought. It has been said that all new thoughts, new ideas and correlated activities arise in this area. Its close connections with the motor and sensory areas gives it the capacity to regulate activity according to necessity. An outstanding feature of a person who has lost his prefrontal area is the ease with which he can be distracted and also his loss of recent memory. Thus, elaboration of thought and planning are attributed to this part of the brain.

THOUGHT, MEMORY, LEARNING AND CONSCIOUSNESS

An instant of awareness, involving a visual scene, a mathematical equation or a note of music may be said to represent a thought. The awareness of thought itself is consciousness, while memory is the capacity to recall a thought. Learning is the capacity to store memories. Could these be correlated to *mana, ahankara, chitta* and *buddhi*? The control of all these activities, whatever their nosology, lies in the cerebral cortex and depends on completeness of contacts between the thalamus and the sensory and motor functions. The objective of *sadhana* is apparently to facilitate these connections. The cerebral cortex cerebrates or thinks out all the functions in advance and intellect is far from being an abstract substance. The brain has been compared to a super-computer but this concept is too simplistic. The brain of man is capable of independent theorization unconnected to immediate sensory impulses or rooted memory. Verbal, visual, auditory and even extra-sensory perceptions are correlated to work out problems and the data output can also be altered, controlled, added or deleted completely! The capacity of mustering all motor and sensory activity to reach a goal is seen in the baby learning to talk or walk just as much as it is observed in a scientist struggling to analyse copious data. The idea of all *sadhana* is evidently concentration on a thought with inhibition of sensory input and motor output. Could the visions, experienced of past or future events, the sound of music and similar phenomena be due to cerebral activity untrammelled by sensory and motor functions?

HYPNOSIS AND SLEEP

Hypnotic drugs and general anaesthesia also depress the motor and sensory activity. Individuals in deep coma after strokes or accidents may live in a state of suspended animation. Some persons under anaesthesia or coma have, moreover, reported sights or incidents not perceptible through their sensory organs in that state. This could possibly denote cerebral activity brought out by association with hitherto unknown sense organs.

Sleep, on the contrary, is a natural phenomenon required for restoration of overactivated brain cells. Deep sleep is associated with delta waves in the electroencephalograph. The origin of these waves is cerebral with absence of spinothalamic activity. This is interspersed with REM waves in the EEG corresponding to spinal and thalamic activity and this is associated with dreams.

Could *samadhi* be correlated with coma, anaesthesia or deep sleep? If the reports of true *samadhi* observed in a few *sadhakas* are to be believed the difference is marked. In coma and anaesthesia sensory and motor functions are inhibited and there is also loss of dreams or visions denoting loss of cortical activity as well. In sleep vital functions like respiration persist but in *samadhi* there appears to be suppression at the suprathalamic region as the vital activities like respiration, pulse and conjunctival reflex may be suspended. However, feelings of freedom, flight, flashes of light and visions have been reported. Some hallucinogenic drugs may also give rise to sensations of lightness and freedom and such drugs have been used by *sadhus* to facilitate meditation.

Indiscriminate use of these drugs, along with weird *asanas*, diet and *acharas*, has reduced the science of yoga and sadhana to a popular fetish of little intrinsic scientific value. The popularity often is due to the fact that it assures increased physical, including sexual and digestive, prowess and delays senescence. The habit of 'cutting off' at spinal or hypothalamic levels by will, helped by drugs and *asanas*, may help physical activity but can offer little else. The result could best be an exceptionally healthy body capable of performing peculiar feats and perhaps even retard apparent ageing. However, the person would likely as not remain just that — a healthy spinal animal. It is a well known fact that all persons capable of intense cerebration and original thoughts are far from physical giants. Examples, religious and non-religious, easily come to mind. Does this denote that the *sadhana* of all these men and women were directed more to those areas of the brain where motor and sensory activities could be controlled at will? Excellence in any sphere of activity is commonly held to be the result of *sadhana* in that particular sphere and the capacity of supreme concentration on a point or project has always yielded the best results.

The concept of sensations and emotions ruling the mind has to be changed to take into account the above ideas. Since even small actions like vocalizing a vowel or writing an alphabet needs inhibition and excitation of the brain in an infant, cannot an adult with judicious intelligent use of such activity surmount the lower pain-pleasure cycle and rise to the supraconscious state? A thorough evaluation of the capacity of *asanas, acharas, niyama* and *tapasya* in the activation of the inhibitory cutouts of the brain needs to be looked into. Perhaps the *bibhuti* so yearned for by us is the complete power to control the functions of the body and mind. In this context one can quote many beautiful *shlokas* regarding the efficacy of withdrawal of one's senses to attain a state of supra-conscious bliss. One such appears to be particularly apt:

> 'As the turtle withdraws its limbs into the shell, the yogin withdraws from all external senses and concentrates on the atman.'
>
> —*Gita*, II.5

DOES SCIENCE REFUTE RELIGION?

P. M. BHARGAVA

SCIENCE and religion both concern us, and intimately so. For, in the world of today, we cannot do without science, and religion has been woven into the very fabric of our society for centuries. But, then, you may ask, what *is* the problem? Indeed, there would be no problem if they — religion and science — complemented or supplemented each other. It turns out that they do not, even though many would like them to; some people even make valiant attempts to make it appear so, regardless of the truth.

What I would like to do in today's talk is to dwell upon this contradiction — that is, the contradiction between science and religion. What I hope to be able to show is that there is an *inherent* incompatibility between science and certain aspects of religion, especially the dogmatic part that gives a particular religion its identity.

EVOLUTION OF RELIGION AND SCIENCE

One may, of course, ask: Why is it necessary to compare or contrast religion and science? It is necessary to do so for at least one important reason, that is, the fact that religion, all through the history of man, has attempted to answer the same questions as science has. The origins of both religion and science can be traced to the evolution of intelligence in man. Intelligence is just another name for the ability to ask questions. One can, therefore, surmise that, in the remote past, when man came to be endowed with intelligence, he must have asked himself questions — questions of at least four kinds. First, questions about the non-living material he saw around him, such as water, air, earth and minerals. Secondly, questions about the physical phenomena he witnessed, such as light, heat,

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sound, thunder and lightning. Thirdly, questions about the extra-terrestrial objects and phenomena he observed, such as the periodical rising of the sun, the moon and the stars; the passage of the planets through the various constellations and, of course, the eclipses. And fourthly, questions about the living things that he saw around him, for example, the recurrent phenomena of birth, disease and death. All these phenomena, which now come under the purview of the four basic sciences — chemistry, physics, astronomy and biology — must, indeed, have intrigued early man. How did he then go about finding the answers? The method of science had not developed, and the whole logic and logistics that we have today for answering such questions, did not exist at that time. What did the primitive man then do? He used his intelligence to construct self-consistent systems of beliefs such that once you accepted certain premises entirely on faith, and without questioning, answers that were plausible, at least at that time, emerged. It is this kind of effort that perhaps led to the development of religion, both pagan and codified — the codified religions including Hinduism, Buddhism, Judaism, Christianity and Islam. However, as the total fund of human knowledge increased, a time came when man began to *question* the basic premises of religion. Out of this questioning, perhaps, crystallised what we today know, formally, as the method of science. It soon became apparent that this method could not only be used as a tool which would satisfy human curiosity much more than religion had done so far, but it also opened up new areas for investigation that had so far been hidden or even prohibited. The phenomenon snow-balled from the thirteenth century onwards, and we had Roger Bacon, Leonardo da Vinci, Copernicus, Francis Bacon, Galileo, René Descartes and Newton, amongst others, to give new dimensions to the method of science — to the newly developed art of questioning. The answers that emerged did not demand acceptance on the basis of faith alone; moreover, they were testable and verifiable, and did not depend on the whims and fancies — or the likes and dislikes — of an individual or a group of individuals. Soon, science became a competitor to religion and, often, came into direct conflict with it. We had in the 16th and 17th centuries, the conflict between Copernicus and Galileo on one side and the Church on the other. More recently, in the last century, the Church waged another major battle — this time again the Darwinian theory of evolution which was so ably extended by Thomas Huxley to the evolution of man.

As science opened up new vistas, religion soon became a hinderance to its progress, and led to the persecution of scientists. Copernicus had to recant because he said that it was not the sun that goes round the earth, but the earth that goes round the sun. Galileo, a follower of Copernicus, died in prison on account of holding on to Copernican beliefs. And, before Galileo, Bruno was burnt at the stake for reasoned dissent. As recently as a hundred years ago, Darwin and Huxley were laughed at by an uneasy Church for saying that man has evolved from 'lower' creatures, and not put on the earth as an act of creation. However there was a redeeming feature for science too. Whenever a conflict arose between science and religion, the explanation provided by science through the use of the method of science, was eventually *always* found to be more appealing to reason. Science, therefore, grew up, so to say, as a competitor to religion, and the battle still continues on many fronts. Clearly, then, there is sufficient justification for comparing (or contrasting) science and religion.

Let us now get on to specific points of comparison and contrast. A good way to do so would be through a comparison of the definitions and the attributes that are widely accepted, of both religion and science — hoping of course that semantics will neither rule the roost nor come in the way.

ATTRIBUTES OF RELIGION AND SCIENCE

Religion is defined variously as service in adulation of God as expressed in forms of worship, a system of faith and worship, and an awareness or conviction of the existence of a supreme being that arouses reverence and the will to obey. The existence of the supernatural — that is, something which is beyond the laws of science — is implicit in religion, no matter what definition one accepts. In all religions, there is also provision for the supernatural to take the form of what appears to be natural. Thus, Messiahs or Avatars are born on this earth, and God takes the shape of man or even other creatures, as is supposed to be the case with some of the incarnations of Vishnu. It is this inherent belief that underlies religion, which has led to the emergence of various forms and shapes of godmen — be it Maharishi Mahesh Yogi, Shri Satya Sai Baba, Acharya Rajneesh, or what have you. These godmen would like others to believe that they have supernatural powers which cannot be understood by other men, and that their statements and actions must, therefore, be accepted by others without questioning. Science, on the other hand, does not accept the existence of a high priest, a godman or any other authority that cannot be questioned. In fact, science denies the existence of the supernatural and magic, which is the very essence of religion. One often witnesses or hears about events which, in the opinion of those who are religious, can have only a supernatural explanation — that is, an explanation outside the scope of the scientific method. In the view of science, all such events — assuming they have ever occurred (which, at times, is doubtful) — do have a scientific explanation, often simple and ingenious.

Religion is based on revelation. Indeed, revelation is *the* method of religion. Truth was revealed to, and not discovered by, all the religious leaders of the past — be it Moses or Mohammad, Christ or Buddha, Mahavir or Aurobindo. The method of science that the scientists use, has no place for revelations of that kind. It consists of distinct steps: the framing of a question on the basis of careful observation or a careful analysis of existing data; the formulation of a *testable* hypothesis; the doing of experiments; and, finally, arriving at the answer by using existing knowledge and logical reasoning. One may, of course, in certain circumstances, omit one or the other of the steps of hypothesis and experiment, but that is not really important. What *is* important is that the method of science has a built-in corrective and that the conclusions that one arrives at by using this method are verifiable and repeatable. For example, I can set up a time reaction in which two colourless solutions when mixed with each other at time zero, will turn violet all of a sudden at 19 seconds. It will take exactly the same time for the mixture to turn violet, no matter who does the mixing — a child, a man or a woman; an Indian, a Chinese or an African; a Brahmin or an Untouchable; a Punjabi or a Tamilian — and no matter what you may personally wish to happen. Neither a particular confluence of planets, nor the will of all the godmen in the world, can increase this timing of 19 seconds to, say, 30 seconds, or decrease it to, say, 9 seconds.

Another important attribute of science is that it allows one to make testable predictions. It was the scientists' ability to make predictions with considerable certainty and accuracy, that allowed man to land on the moon. Indeed, in the one grand experiment that the first manned landing on the moon constituted, an enormous number of predictions made by scientists in a vast variety of fields came true. If one of these predictions had gone wrong, there would have been disaster. Science has, in fact, allowed us to predict chemical elements, fundamental particles, planets, biological species, and a host of other exciting new objects and phenomena. For example, the great Russian chemist, Mendeleev, predicted, in the middle of the last century, the existence of the elements gallium, scandium, and germanium. For gallium, he said that when the element is discovered, it would be found to melt with the heat of the hand. Its melting point, when the element was actually discovered, was found to be about 30°C. Pauli, in 1930, predicted the existence of the fundamental particle, neutrino, which is now very much in the news. It was discovered in 1956. Murray Gellmann who, like Pauli, was awarded a Nobel Prize, predicted the existence of another exotic fundamental particle, omega minus, in 1962.

This particle was discovered a couple of years later by Samios. The existence of planets, Neptune and Pluto, was predicted. In fact, in the case of Pluto, the exact place in the sky where it should be found, on the fateful night in March 1930 when it was discovered, had been correctly predicted. Darwin's theory of evolution predicted the existence of Latimeria, a fish, and Pithecanthropus erectus and Oreopithecus, two ancestors of man. Both the fish and the human ancestors were discovered subsequently — the fish as a live specimen and our ancestors as skeletons. Both were found to have the characteristics predicted by Darwin and his followers. Today, we can predict that Halley's comet will be visible from the earth in 1986, and that elements with atomic numbers 114 and 126 when discovered will be found to be stable in contrast to all other transuranium elements, that is, elements with atomic numbers greater than 92, which have been discovered since 1940 and found to be, as predicted, unstable. In the entire history of religion there has not been a single such prediction, made on the basis of religion, that has subsequently come true. Here is, therefore, an important point of contrast between science and religion — science can allow us to make testable predictions; religion cannot.

DYNAMISM OF SCIENCE

In science all truths are truths by consensus. Of course, the consensus has to be reached among people who are knowledgeable in the area concerned and have formed their opinion by using the method of science. The consensus must be arrived at after such individuals have verified the results personally, or satisfied themselves adequately about the validity of the experiments and of the logic which led to the particular truth. As time passes and the sum total of knowledge in the particular field increases, the chances that the initial agreement of opinion will prove to be wrong, of course, diminish. Nevertheless, I repeat, all truths at any given time in science are truths by consensus — a consensus among scientists. On the other hand, religious truths represent an opinion usually of one religious leader, at most of a few. Moreover, these opinions are rigid. Changing them implies establishing another religion, or at least a sect. Therefore, a given religion, by definition, is static, unlike science which is dynamic and changes with time as more and more evidence comes forth. In fact, it is often said that science progresses by disproving. At least two Nobel Prizes were awarded for discoveries which were subsequently proven to be incorrect. However, in both these cases the persons concerned deserved to receive the Nobel Prize because, had they not made their discovery, the truth as we know it today, would not have been discovered at the time it was. Science is, therefore, evolutionary, which religion is not. Science has a built-in corrective, which religion does not have.

In science, a new theory must explain all that was explained by the old theory plus something that could not be explained by the earlier theory. The new theory, in addition, should be capable of making predictions which could not be made on the basis of the old theory, and some of these predictions should, indeed, have been tested and turned out to be right. For example, Einsteinian physics made predictions which Newtonian physics could not, and explained events and phenomena which the earlier physics could not. Thus, the interconversion of mass and energy, the bending of light in the presence of a large gravitational field, the existence of black holes, and the dependence of the mass of an object on its speed, were all predicted by Einstein and later on substantiated. None of these predictions was possible on the basis of Newtonian physics. That is why we consider Einsteinian physics an improvement over Newtonian physics from which it actually evolved. Contrast this situation with that which obtained in religion, where no religion can be said to be an improvement over any earlier religion. If you say something to the contrary — that one religion is an improvement over another — you might have a riot!

All new knowledge in science must be consistent with known and established observations. On the other hand, religious dogma (including the so called miracles, for example, the materialization of objects by the wave of ones hands) is often inconsistent with known and established observations.

Science progresses through modification of a part of the existing knowledge and not by the replacement of the entire body of the existing knowledge. A new religion, on the contrary, often attempts to replace fully the existing religions.

The growth of scientific knowledge is a continuous process. Science is, therefore, evolutionary. A religion once founded continues substantially unchanged.

RELIGION AND SCIENCE — CONTRASTS

Another important difference between science and religion is that while science is forward-looking, religion is somewhat backward-looking. For example, for the followers of science, the more modern the text, the better it is. On the other hand, religious texts on which the followers of religion depend, are, generally ancient. In the case of science, the scientists of the present time matter the most; in the case of religion, the *founders* of the religion who lived in the remote past matter the most. For the followers of science, the events of *today* and the likely events of *tomorrow* are the events of the greatest concern; for the followers of religion, the religious events of the past are the events of the greatest concern. The techniques used in science keep on improving with time, and the impetus for this improvement comes from within the framework of the method of science. On the other hand, religious customs and practices do not basically change with time. Whatever changes are brought about are due to forces external to the religion — such as science itself.

An important attribute of science is the right to question. Knowledge advances and science progresses *because* people exercise their right to question. By contrast, religion demands an unquestioned acceptance of its tenets and dogma. If you question, it must be only to seek clarification and not to doubt.

A scientist can say without any feeling of guilt or shame, 'I do not know'. It would be disastrous for a religious leader to say 'I do not know'; he would simply lose his following. By definition he knows all. Every major religious leader of the past — the founder of every religion — had answers to every question that one may ever ask. Science would consider such a claim as hypocrisy and deceit.

INTERNATIONALISM AND PAROCHIALISM

Another important difference between science and religion is that while science is truly international, religion is not. Scientists all over the world use the same method, that is, the method of science. They employ the same techniques, use the same materials, and publish frequently in the same journals. They are increasingly beginning to use the same language — that is, English — and they form a truly international community in which the professional links are at least as strong as any other link. Contrast this internationalism of science with the parochialism of religion. There are many religions and they differ from one another in many respects. The activities of a particular religion are carried out in isolation of the other religions: in fact, people of other religions are often prohibited from participating. There is little communication between various religions and, therefore, no common language. Religious customs and practices differ enormously, often fundamentally, from religion to religion. Religion, in fact, divides people while science unites them.

Having said all this, one may now ask 'what about values', which, indeed, are an integral part of all religions. Aren't they good? — that is, good for us. Indeed they are; but such values are not a special characteristic of any particular religion. They are, in fact, common to all religions. Every religion asks you not to kill your fellow-men, to be kind to them, to care for them. Every religion prescribes human compassion, truthfulness, integrity and honesty. A particular religion receives its identity not from these values, but from dogma. A religion bereft of its dogma is no longer a religion. It is, in fact, the dogmatic part of religion that contradicts science, and it is this dogmatic part that I have referred to in all that I have said so far.

I must, here, of course, mention that dogma does not arise from religion alone. Custom, convention, tradition — occasionaly science too — may lead to the establishment of a dogma. It is just that religion has been the most important source of dogma. Therefore, one is justified in saying that religion and science do not mix.

I must here also add that most values derived from religion that are universally cherished, are compatible with science. These values can be arrived at through a scientific argument as well. In fact, one advantage of using science and not religion as the basis of determining whether a value system is beneficial to man or not, is that in science nothing is immutable. Therefore, the scientific assay for a value system would allow a change in it — a change which emerges logically and naturally from the environment. Religion, by contrast, demands immutability of a value system.

CONFLICTING VIEWS

Towards the end, let me cite some specific examples of contradiction between science and religion. Today, we understand, reasonably well, what might have been the likely origin of the universe. It is generally accepted by scientists that the universe came into existence about 18 billion years ago, and they can trace the history of the universe backwards to nearly 10^{47} (power) of a second just after the event of its formation — called the 'big bang' by the astronomers. In this scheme, there is no need to postulate the existence of god, as one must do in religion.

Today, scientists can say with considerable certainty, that life on our planet evolved from non-living materials. After the formation of the earth, complex chemical substances were slowly formed from the simple chemical substances that were contained in the primordial atmosphere; such a 'chemical' evolution eventually dovetailed into the biological evolution. On the other hand, all religions demand the acceptance of the belief that man (and, in the case of some religions, other forms of life as well, including women) were put on this earth by God through a deliberate act of creation.

Some of the religious leaders of the past were supposed to have been born through immaculate conception — an idea which is utterly incompatible with the scientific truth about reproduction. And virtually every religion postulates some kind of life after death. The concept of soul is common to all religions. On the other hand, a scientist may ask the question: 'Where has the soul been if you can bring a dead man back to life?', as indeed you do when you take out the heart of a person and replace it with the heart of another person.

SCIENTIFIC LAWS

Today, it is possible to grow a whole plant from a single cell of the plant. Such cloning is, no doubt, theoretically possible even for higher organisms, such as man, and it is only a matter of time before it will be done. In the case of a mouse, it has indeed been done recently. It is now also possible to fertilize a human egg with a human sperm in a test-tube, under controlled conditions. We understand a great deal of what happens during such processes. In fact, today, one can say with confidence that all phenomena associated with life and the life processes, must have an explanation in the laws of physics and chemistry. Indeed, if one can explain satisfactorily the life-associated phenomena, the extra-terrestrial phenomena, the physical phenomena, and the nature of the non-living materials, and if one can provide a scientific basis for values, where is the need for religion? On the contrary, history tells us that unquestioned acceptance of religion, and of all that religion demands, must lead to the perpetration of untruths. In contemporary history, it is religion that has wooed science and not vice versa. Maharishi Mahesh Yogi and so many others of his breed, all the time seek the blessings of science in support of their claims. The scientists never need to invoke religion in support of *their* claims. Scientific truths do not need a prop. Religion does — at least today!

To end, let me say that one important fundamental characteristic of science is that it is not evangelistic; it does not seek to convert people, unlike many religions. People must, therefore, be permitted their beliefs, religious or otherwise, in any free society, and I will stake everything to defend the right of every individual to believe in the religion he wishes — as long as his (or her) beliefs do not hurt others. However, to say that religion and science are compatible or that one derives from the other, or supports the other, must be considered wishful thinking at best, and a travesty of the truth at worst.

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APPROPRIATE TECHNOLOGY – SOME HERESIES

V. SIDDHARTHA*

TALK about Appropriate Technology — AT — is the latest growth industry. Like most growth industries, it contributes to employment and to pollution — the cost per work place does not exceed that of a chair, some paper and pencil; the pollution is in the form of vast numbers of ill-conceived notions, cavalier statements and half-baked 'solutions' to (undoubtedly important) problems that deserve far greater respect. However, unlike growth industries, the useful output is meagre and rapidly declining in both quantity and quality. The reader will of course decide for himself whether what follows is a contribution to pollution or to useful output.

THE ENVIRONMENT DETERMINES 'APPROPRIATENESS'

All technology that survives in society for longer than the time taken to establish the technology (roughly the gestation period) is 'appropriate' in some sense, otherwise the technology would not survive. It is true that very often the technologies, or more accurately, those who control them, manipulate the environment — physical and societal — in such a way that the probability of survival is greatly enhanced. Although the label 'appropriate' may be thus secured in this fashion by *ex-post-facto* definition, the very survival of a technology is nevertheless testimony to its 'appropriateness'. Now the total 'environment' of a technology consists of various sets of non-technology policies, the physical environment *and* other technologies

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* The views in this paper were first expressed at a seminar on Science & Society organized by the World Council of Churches in New Delhi, 17-20 November 1977. They are those of the author. They are not to be construed as being reflective of the views of ISRO or the Government of India.

that shape this environment. It follows, therefore, that if a society considers the societal impact of a set of technologies already in existence to be *undesirable,* it should re-orient (if it can — and here often is the rub) this total *environment* in which the technology exists in such a way that these specific technologies cannot survive. There is little point in trying to attack only the *source* of the particular technologies (R&D, multi-nationals, etc.); for, the technologies will reappear soon after the pressure eases. (Prevention is more cost-effective than cure).

Conversely, if an embryo-technology is considered desirable in terms of the best guess about the effects of its large-scale use, then the environment (of the technology) should be adjusted in such a way that the particular technology can survive in it. Otherwise, it will not 'take' and self-propagate. At best it will remain isolated in pockets sustained by artificial transfusions of resources from AT enthusiasts who themselves receive their sustenance from non-AT sources!

If the above formulation is correct, it follows that measures of 'appropriateness' are not so much related to the specific technology under consideration but to the *environment* in which it either exists or is expected to survive (recall that we are talking about time-scales that are longer than the gestation period).

It is thus clear that appropriateness is not *per se* a matter of lowering Capital-intensity, Energy-intensity, Scale or Skill-intensity (CESS for short) but a matter of whether the relevant technological gestation times are such that different social and political objectives can be served at different times at different places in different sectors *as these objectives change with time, place, and sector.**

IMPLICATIONS FOR PLANNING†

What does this shift of focus to the gestation-period imply for scientific and technological planning on the one hand and for socio-economic planning on the other? In brief:

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* I am specially mentioning 'sector' to remind us of the National Security sector, (a term whose connotations extend beyond what is normally understood by 'Defence') systematically ignored by AT enthusiasts. Security cannot, alas, be guaranteed by means of bows-and-arrows. In this context see pp. 24-25 of A. K. Dasgupta: *The Economics of Austerity,* Oxford University Press, 1975. This tightly argued and concise booklet ought to serve as a basis of the socio-economic policies of any progressive political party which wishes to practise what it professes.

† This section has benefited from a discussion with Prof. A. K. N. Reddy of the Indian Institute of Science, who is not, however, responsible for the views expressed therein.

FOR SCIENTIFIC AND TECHNOLOGICAL PLANNING

When	*Then S&T Planning consists of*
Socio-economic planning horizons are shorter than technology development + implementation gestation period	1. Choice between existing technologies (foreign or Indian) with marginal adjustments for local factor availability (i.e land, labour, capital and technology). 2. Software/Management, particularly of the kind that shapes general government policies (e.g. in food, housing, transport, communication, education etc.) in the light of known scientific facts, i.e., Science *in* Policy.
Socio-economic planning horizons are longer than technology development + implementation gestation periods	1. Technology development programmes *including* basic research. 2. Policy for science. (Including scientific manpower, institutions, resource allocation for research programmes, etc.).

For *socio-economic planning*, the implications of finite gestation are that an *explicit* balance at various levels needs be struck between—

(i) the need to keep socio-economic goals and the attendant policies unchanged for the duration of the gestation period.

(ii) the right of people to change goals through democratic processes and the need to review periodically the assumptions and data underlying the planned paths and processes of goal attainment and to re-chart these if necessary.

EMPLOYMENT GENERATION

A great deal of manpower using AT already exists in the country; *it has been generated domestically.* The cycle-rickshaw is only one example. The technological infrastructure in the country is the largest of all the developing countries, save China. There is a polytechnic in virtually every *district* of the country. I am convinced that, *for technologies for which the basic science is known to exist*, if all the relevant policy variables are adjusted and *implemented* so that it becomes socio-economically viable to use labour instead of capital, for the most part, the 'appropriate' technologies will get generated by the existing infrastructure without centralized planning.* In particular, the following policies are musts:

> Ensure that gains in output per man-hour shall not be so distributed between Capital and Labour as to cause a progressive increase in capital intensity in agriculture, in industry and the service sectors. Since managing people (labour) is much more of a nuisance than managing machinery which is relatively docile, only collective *local* ownership of capital *by* labour can ensure that there is no progressive increase in the use of machinery at the expense of labour.†
>
> Non-technology policies to stimulate generation of labour-intensive technology must be implemented *ahead* of the technology generation *and held* until the technologies are developed and deployed. In the interim, therefore, some production from available, short-gestation, capital-intensive technology will have to be foregone.

AT enthusiasts can help by *not importing* so-called labour-intensive technologies; some of these are energy-inefficient polluting technologies that were 'capital-intensive' in the fifties in the West.

MOST OF THE TECHNOLOGIES ALREADY EXIST

For the four basic human needs; food, clothing, shelter and health, there already exists in India today virtually all the technologies to eliminate *destitution*. When we have done this, then we can talk of removing *poverty*. Where there are some gaps (e.g. in housing, particularly rural housing), these will not get filled unless what is already known is tried out, the deficiencies empirically determined, and then removed by local innovation using known basic science by those who are closest to the problem; and by research. But technology cannot solve problems that are socio-economic and

* In fact such central planning for AT may well result in *in*-appropriate technologies; for, our capacity to handle information with fidelity is abysmally low; the so-called planning process is insufficiently mature and the socio-political environment too varied in the country in both space and time for central planning to be effective.

† The clamour in the Punjab not so long ago for combine harvesters was not so much because farmers cannot afford to pay Rs. 12/- a day for harvest labour, but because they consider it well worth the present cost of capital to replace this labour by well-behaved machinery which is always on tap. In this context see H. M. Patel: "Rural Development in India", *Commerce*, 27 August 1977.

political. Indeed it can exacerbate them — in fact that is what it is *meant* to do; the removal of poverty implies major changes in the existing socio-political *status quo*. *There is no technology, small or large, that can act as a placatory lollipop to the oppressed and the exploited.*

THE WEAK BASE IN BIOLOGY

The closer one gets to the village, to those who live directly off the land, the closer and more tightly knit is the nexus of relationships between man and his surroundings. If there is one science that characterises this nexus that can make major contributions to the well-being of the majority of our people; that has the potential of being used in a non-exploitative way, it is *biology*. We have had many successes in our scientific and technological endeavours, thanks to the vision of J. Nehru, but we have neglected biology, although both A. V. Hill in the 1940's and J. B. S. Haldane (an Indian citizen) in the late fifties identified biology as the science most relevant to India.

Remarkable advances have occurred in biological research since the genetic code was unravelled in the mid-fifties. It is now possible in principle to bio-engineer plants which will fix nitrogen directly from the atmosphere. Photo-synthesis by plants is possibly the best way to use our abundant solar energy. For example, this can provide, locally, algal protein which can be far more efficient in energy, land and water use than pulses or animal protein. This and other possibilities such as energy-supply through photo-synthetic solar-energy conversion* will mean *basic research* in biology of the very highest quality.

WHAT IS NEEDED IS QUALITY BASIC RESEARCH

If we are really serious about using *science* for the well-being of our people — about 1000 million in under thirty years — then we must stop regarding technology as primarily so much gadgetry to be used in screw-driver like fashion. Scientific research in our country should be oriented to basic research. We have to do *basic* research at the frontiers of knowledge, particularly in biology. As J. D. Bernal pointed out in 1964, much so-called applied science is really applied *obsolete* science.

* See in this context Seshadri, C. V. "A total-energy and total-materials system using algal cultures", Monograph Series on Engineering of Photosynthetic Systems, Vol. 1, March 1977, A. M. M. Murugappa Chettiar Research Centre, TIAM House, Madras-600-001.

We cannot afford to be lazy. We cannot be obsolete. Our problems are of such nature and magnitude that they can be solved only:—

(i) if we apply contemporary *science* to contemporary problems. This means we must do contemporary science by reference to our own environment.

(ii) if we really believe in *science* and not in imported gadgets and the ideas behind them.

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VIEWS .... NEWS .....

SPECIAL MATERIALS AND PROCESS DEVELOPMENT AT TROMBAY

SOCIETY has undergone a spectacular change in the last three centuries. Large scale industrialization and advanced styles of living have been the prominent features of this change. With this all round growth, national and world demands for energy have been steadily rising. In the present century, natural gas and oil, in addition to coal and wood, have been the major sources of energy. In recent years nuclear energy has also come into prominence, and is envisioned as a major supplier of future demands of power. At the same time, attempts are being made to generate power by newer techniques utilizing conventional fuel. Magneto Hydro Dynamics (MHD), a high temperature plasma-based technique for direct conversion of thermal energy into electrical energy, is a very promising approach and has aroused active interest as a practical method for electric power generation on an industrial scale.

Progress in the generation and distribution of electric power has been possible mainly because of the advances in materials science and technology. The Metallurgy Division of the Bhabha Atomic Research Centre (BARC), Bombay, has been engaged in research and development (R & D) pertaining to special metals, alloys and materials of importance to the nuclear, aerospace, electronics and chemical process industries. R & D activity in the Division has continuously aimed at newer, improved and cost effective processes for the extraction and refining of rare metals, and special materials, namely zirconium (Zr), titanium (Ti), niobium (Nb), tantalum (Ta), beryllium (Be), hafnium (Hf), the rare-earths, boron carbide, to mention a few. In the last two and half decades, the Division has undertaken and completed a number of projects, leading to the industrial production of these materials. The Division has also been providing vital services (materials development, supply of special materials, consultancy services to mineral beneficiation and corrosion, metallurgical testing and failure analysis of engineering components) to other Divisions in BARC and units of the Department of Atomic Energy (DAE) and Government organizations. In continuation of these efforts, the Division is also currently engaged in a materials development programme, for MHD power generation systems. These systems require special and metallic coated ceramics for plasma duct and special metals and alloys for making powerful magnets. The Division has carried out investigations on (i) metallization of ceramics, (ii) reclamation/refining of Zr and Ti, and (iii) super conducting materials, and there has been significant progress in some of these areas. A brief review of these activities is presented here.

The materials that go into the making of an MHD duct are of two types, an electrically conducting material for the electrodes, and insulating material for thermal insulation. In the Indian programme, ETP copper as the electrode material and sintered alumina blocks, as the linings in the insulation wall, have been selected. Both these materials are designed for water cooling by copper modules. In the case of alumina, this apparently simple process has presented numerous technological problems. The conventional moly-manganese process for metallising alumina, which involves the use of very high temperatures (1400-1500°C) in a moist hydrogen atmosphere, invariably led to very high diffusion of molybdenum into alumina thus affecting its insulating properties. After evaluation of a number of other techniques like the gas metal eutectic method, and processes involving glassy or polycrystalline intermediate layers available for metallisation of ceramics, a novel technique for direct bonding of nickel to sintered alumina has been developed. The technique is essentially based on an electroless nickel deposition process, operating at slightly elevated temperatures of 75-80°C and using a newer bath developed in the Division. It does not involve the use of electricity, but instead uses a chemical reducing agent and a chelating agent to get controlled deposition of nickel. The electroless nickel (EN) coatings have excellent soldering and brazing characteristics.

The bonding (which is mainly mechanical) of EN coatings on alumina is excellent, tensile bond strength being more than the cold rupture strength of alumina used. Diffusion of EN into alumina is practically negligible.

EN coatings, using the newer developed bath, have also been used as protective coatings on copper electrodes for protection against wear, abrasion, corrosion and oxidation. The tips of these copper electrodes are to be in direct contact with hot moving plasma — a natural gas plasma having oxygen enrichment upto 50% and containing 'seed' material (for increased conduction purpose). Hence this protection step. The EN, which is essentially a nickel-phosphorus alloy, has unusual lubricity and has very high hardness especially after precipitation hardening at elevated temperatures.

EN bonded sintered alumina blocks as well as EN coated copper electrodes have performed very satisfactorily in the actual testing of the MHD test channel at the existing U-02 facility in the U.S.S.R.

The metals zirconium and titanium have assumed great strategic importance for diverse applications specially in nuclear engineering, aerospace, and chemical industries. Zircaloy, an alloy of hafnium-free zirconium with tin, (iron and chromium), is the chosen structural material for fuel cladding and other core materials in the boiling and pressurized water reactors in the Indian nuclear energy programme. Titanium metal and its alloys, because of high specific strength and chemical inertness to most of the corrosive media, have well established applications in aerospace, naval engineering and the chemical process industries.

The large scale production of zirconium and titanium fabricated components entails also the generation of a good amount of metal scrap. Recovery of the metal values from such scrap is very essential in the interest of overall process economy. The Metallurgy Division, BARC, has developed an electrometallurgical route, namely fused salt electrorefining, for refining and reclaiming zirconium and titanium in pure form, from process scrap. The process provides a direct route for getting high purity and ductile metal from scrap, without any intermediate processing, and is simpler than other alternatives.

The electrolytic process is carried out in a bath of $NaClK_2ZrF_6$ at 850°C for Zr and $NaCl\text{-}TiCl_2$ at 830°C for Ti. Special cells, hermetically sealed, have been designed to carry out the process with the total exclusion of air and in a noble gas atmosphere. The process operates quite efficiently.

The MHD generators require high magnetic fields. As the power output is proportional to the square of magnetic induction, the magnetic induction should be high. Superconducting magnets are most advantageous for the purpose, as these are coreless, consume negligible power and generate strong fields. The potential superconducting materials for this application are Nb_3Sn and Nb-Ti.

A programme has been initiated to generate the know-how on the production and fabrication of Nb-Ti and Nb_3Sn superconducting alloys. The first phase of the programme has been concerned with the development of Nb-Ti superconductors. The processing steps have been standardized for Nb-50Ti alloy. Copper cladded single core Nb-50Ti wire fabricated in the Division has shown a current carrying capacity of 5×10^4 amp/cm^2 at 4°K, upto a magnetic field of 40 Kg — a performance which is well comparable to that of the materials commercially available abroad. Larger scale melting and fabrication of the super conducting alloys is currently being investigated. (Superconducting magnets are also of importance for accelerator and fusion reactor programme).

The MHD technique for the generation of electric power is closely linked with the development of suitable materials and is in an evolving stage. Large scale production of the required materials and extensive field tests are required for the establishment of this technology on a firm footing. While the problems are of challenging proportions, metallurgists and materials scientists are successfully striving to solve them.

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EVOLUTION REINVOKED

THE theory of evolution is now over a century old. The theory is based on the basic tenets of the struggle for existance, and the survival of the fittest. There has sprung up, in recent times, a movement by a section of the people against this long accepted theory. The movement is by creationists who deny the geological evidence for a world billions of years old, the fossil evidence for the gradual appearance of new species and the biological evidence for the evolution of man from the lower primates.

The old, old fight of religion versus science to explain the mysteries of nature is still on, with added legal flavour. As far back as 1928, John Scopes, a school teacher in Tennessee was fined $100 for teaching the Evolution theory in the classroom. State law forbidding the teaching of evolution in U.S. public schools was invalidated only in 1968.

Just around this time, a new drive against evolution was launched by members of the Creation Research Society whose motto was 'realigment of science based on theistic creation concepts.' The creationist movement has been working through state legislatures in the U.S.A. for laws that would give the Bible 'equal time' with Darwin. Such legislation had been introduced in 15 States. Textbook committees are pressurized to discuss the concept of origin or creation of man as a 'theory' not 'scientific fact' and give equal attention to 'other theories including the Genesis account in the Bible.' The Bible is declared to be a reference work. Now there is a counter move against the 'equal time' concept since it ignores the separation of Church and State.

The theory of evolution is itself now stirred up by experts in the field. For the past 40 years the study of evolutionary biology has been dominated by the Modern synthesis, a term coined by Julian Huxley in 1942. This theory explains Darwinism in terms of population biology and genetics. According to modern synthesis, evolution occurs at a slow pace, with small changes accumulating over periods of many million years yielding to origin of species and steadily advancing lineages. The fossil records however do not document a smooth transition from old morphologies to new ones. There is in general an absence of transitional stages. Since fossilization of old forms is a chancy event this argument is used to explain the gaps.

According to an emerging picture of evolutionary change, there are periods of stasis when individual species remain virtually unchanged, punctuated by abrupt events at which a descendant species arises from the original stock i.e. speciation. This theory is called punctuated equilibrium. However, the abrupt event is in paleontological terms and is equivalent to many thousands of years.

The objectives of the theory of evolution are what they always were. To account for the diversity of species as well as for their similarities and differences and also account for the fossil record.

The term evolution implies that the pattern of living things at any time is determined by the pattern of living things at an earlier time and the environmental influences in the interval.

The theory of evolution is consistent with the data Darwin had access to more than a century ago and it remains largely consistent with the phenomena today. In Darwin's time phylogenetic relationships between different forms were inferred from their morphology. Now molecular biology has given an independent and more accurate method of establishing relationships between species and groups of species. The result is a striking confirmation of the general character of relationships suggested by Darwin and his contemporaries. The evolution theory has also survived a long succession of discoveries bearing on the mechanism of inheritance — the rediscovery of Mendelism, the discovery of chromosomes, recognition of genes, etc., unlike any similar wide base theory.

Evolution operates at three major levels: populations change as the tendency of certain genes increases or decreases among their members; new species arise by the splitting of descendant populations from their ancestors, and evolutionary trends occur because some species are more successful than others in branching and persisting. Besides natural selection and adaptation it is now suggested that other mechanisms may have a role to play. Randomness is suggested as an agent of evolutionary change. In this context, the adjective random refers to changes that arise with no determined orientation. According to Charles Darwin, populations must first develop a large amount of heritable variation to provide raw material for the later action of natural selection. The raw material for evolutionary change arises by a process of random mutation. He excluded the importance of change or randomness from the second part, since he thought that the order prevalent in the world could not be the work of chance. Recent thinking however suggests that random processes may do more than simply provide the raw variability for natural selection to act upon. They themselves may select.

Therefore in the period of over a century since the appearance of Darwin's *Origin of Species,* the science of evolution has provided a solution to many questions and has raised an equal number of queries. There are questions which are still not satisfactorily answered e.g. the rate or tempo of evolution, the mode of evolutionary change and the constraints on the physical form of new organisms. In the main, the theory of evolution is accepted. The strongest evidence for the occurence of evolution is the examination of its alternatives. As Bertrand Russell said, 'it is always possible to conjecture that the world came into existence only five minutes ago, complete with my memories and holes in my socks.'

—*M. J. S.*

FEWER BUT SAFER DRUGS

PRIOR to the 1960s, there existed a state of laissez-faire in the field of drug sales. Practically any drug that could be manufactured could be marketed without having to prove its safety or effectiveness. The Thalidomide disaster of 1961 proved to be a turning point in the history of drug regulation. As may be recalled, in the course of this international tragedy, the drug thalidomide, taken as a sedative and antiemetic by pregnant women, caused gross malformations in their offspring. As a result of the teratogenic effect of thalidomide, between three to four thousand malformed babies were born in Europe in a period of three years from 1959-1961. As an aftermath of this event legislation was formulated in various countries to control the clinical investigation and human experimentation of new drugs.

In England a committee on safety of drugs — the Dunlop Committee — was set up to improve the safety testing of drugs. The controls were at first voluntary but were later made statutory. A new drug needed a licence for marketing, which in turn required a submission of data on efficacy and the toxicity quality of the new drug, which was required to be submitted to the Committee on safety of Medicine. In the U.S.A. there was an ammendment to the Food and Drugs act.

In the subsequent years, despite the attempts at control of drug safety, there occurred instances of inadequate testing. After being approved by the safety Committee and released in the market, some drugs were found to have adverse effects. Regulations became more stringent and newer, more drug sensitive tests were introduced. As a result both the time and money required to put a new drug on the market have increased. Compared to 20 years ago, it now takes three times as long from the discovery to the marketing of a new drug. The number of new drugs that reach the market each year has been halved. In India, for instance, only new drugs were approved by the drug controller for manufacture during the period April-October 1980-81, as compared to 35 in the previous year. For every drug that reaches the public, several fall at the stage of clinical trial and many hundreds at earlier stages of testing. But the drugs that do reach the public are undoubtedly safer than they used to be.

The regulatory agencies have been blamed by the drug industry for escalating the cost of new medicines and their dwindling numbers. The Food & Drug Administration of the U.S. has been referred to as a sort of reverse Mr. Micawber of *David Copperfield*, perpetually waiting 'for something to turn *down*.'

No drug can be termed completely 'safe'. Any medicine administered is bound to have effects on the body other than the one for which it is intended. The battery of prescribed tests for new drugs have inherent limitations. Animal trials can suggest but cannot predict what may happen in man. Participation in a clinical trial of a drug is not as full proof as to enable detection of side effects of a low incidence. A balance has to be struck therefore between the time and money spent on the stages upto and through the clinical trial of a drug and the ability of such tests to detect undesirable effects. A lengthy approval process delays the benefits an important drug can provide to the public.

Although the regulations for drug control vary from country to country, there are certain basic procedures which are common. A new drug is put through a series of laboratory tests to determine the type and degree of action it has. These tests are conducted on selected animal species for specified periods, and acute and chronic toxicity, pharmacology, efficacy, etc., are determined. The drug may also be administered to healthy human volunteers to observe its effect in the human system and to determine any adverse effects. The results are submitted to the drug authorities to seek permission for a clinical trial. In a clinical trial, a number of patients, who have given their informed consent, are given the drug to check its effectiveness at the selected dosage and for ill-effects if any. Next, the patients suffering from the condition for which the drug is recommended undergo the clinical trial with adequately matched controls. The results of the trial are submitted for permission to market the drug.

In India, the Central Drug Standard Control organization is the body responsible for controlling the entry of new drugs on the market. The standards of control vary from country to country. The Food & Drugs Administration (FDA) of the U.S. is one of the strictest agencies in the world. Many instances occur of drugs banned abroad being freely available in India and other countries with less stringent regulations.

Despite these initial controls, there is a dire need to monitor the drugs once they are in full scale use. This however requires a cumbersome bureaucratic mechanism. In England, for post marketing control, a scheme called Retrospective Assessment of Drug Safety (RADS) had been proposed, but was found to be too expensive. In the U.S., although the FDA does undertake some amount of postmarketing surveillance, an independent body to take up this work more thoroughly has been suggested. This monitoring body would study the delayed side effects, rare effects, interaction between drugs and combinations of diseases and also the unexpected therapeutic effect of drugs already in the market.

The route from discovery to dispensing of drugs is thus fraught with regulations, which however must be welcomed by the public as protective measures guarding them from tragedies such as that of thalidomide.

—M. J. S.

ARTIFICIAL PHOTOSYNTHESIS

PHOTOSYNTHESIS, the reliable and efficient capture of light energy for converting water, carbon dioxide and minerals, into oxygen and energy-rich compounds has received a great deal of attention from research workers since it was discovered in the 18th century. It is the foundation upon which human and animal life depends. Besides being the basis of all food chains, past and present photosynthesis provides us with most of our energy resources in the form of fossil fuels and wood. Understanding the process of photosynthesis could enable us to improve our plants, especially their ability to use solar energy, water and nutrient resources efficiently.

Recent research on photosynthesis points to photorespiration, a wasteful part of plant metabolism, as a key process in which genetic engineering might have a valuable application. However, the question remains whether plants with superior photosynthetic efficiency will yield more in agricultural practice. The relationship is not direct but most researchers are optimistic. Moreover it is now known that essential processes like nitrogen fixation in leguminous plants are governed by photosynthesis. Many activities in the plant root are governed by activity in the leaves. It is expected therefore that improving photosynthetic efficiency will be a prerequisite for improving the efficiency of mineral nutrition in crop plants.

The process of photosynthesis has been studied by some researchers using isolated photosynthetic centres from the bacteria like *Rhodopseudomonas sphaeroides*. The study of the photochemical mechanism has urged other scientists to mimic nature and attempt to create artificial reaction centres resembling the natural ones in the vital parameters of reactions rates and efficiency. In the constructed system, the natural bacteriophyll (bacterial chlorophyll) has its counterpart in pyrochlorophyll, which is more stable against irreversible photo oxidation. An alcohol derivative of pheophytin acts as the electron acceptor. The electrons are transferred with a high quantum of efficiency comparable to the natural system. In both the natural and artificial system, the transfer occurs in less than 6 pico-seconds, and the neutral ground state is achieved in 10-20 nanoseconds.

In another experiment by photochemists the first step of plant photosynthesis has been simulated in a synthetic molecule. In plant photosynthesis the first step is the excitation of chlorophyll molecule which then releases an electron that travels across the reaction centre to an acceptor molecule. In the experiment, the transfer was done, using a single molecule called P-Q which is a porphyrin (P) linked to a quinone (Q) by a chain of carbons and hydrogens.

When the molecule is exposed to light, an intramolecular electron transfer occurs from the P to the Q end, completing the simulated first step of photosynthesis.

For the electron transfer to occur, the molecule P-Q must be placed in an environment similar to the protein reaction centre in plants. These experiments used a frozen methanol plus 2 percent chloroform solution maintained at a temperature close to the melting point of methanol. The possibility of devising a solar cell using P-Q molecule may prove to be more efficient and commercially viable but after much more work is done in the field.

Various other steps of the process of photosynthesis are also being worked out. The enzymes involved in the biochemical pathway are also being isolated and studied. The elucidation of these mechanisms may have numerous applications in the future. The ability to mimic nature's exquisite energy trapping system thus holds a lot of promise.

—*M. J. S.*

INTERFERON

EVER since its discovery in 1957, Interferon has been the stuff of researchers' dreams — as a panacea for many ills caused by viral infections and as a weapon against cancer. Interferon is a protein manufactured by virus-infected animal cells. It acts on neighbouring uninfected cells to render them resistant to a broad spectrum of viruses. Its potent anti-viral activity initiated a flood of laboratory research in the 1960's, out of which came an awareness of Interferon's anti-tumour activity.

In the twenty-four years since Interferon was discovered by Alick Isaacs and Jean Lindemann at the National Institute of Medical Research in England, several more facts of interferon have come to light. Many vertebrates and not just man (as was previously believed) produce interferon. Interferon is however species-specific i.e. interferon produced by one animal species induces the greatest protection in cells of the same species. Moreover two other types of interferon in addition to leukocyte interferon (IFN α) have now been isolated. One is IFNβ or fibroblast interferon which is produced by fibroblasts or connective tissue cells and the other is FNγ also called immune interferon or T-cell interferon produced by the T-lymphocytes or cells involved in the body's defensive immunity against disease. The effect of interferon has also been found to be varied. Not only does it protect cells from virus infection, but it can stop cells dividing in tissue culture or in the bone marrow; increase the expression on tumour cells of cell surface antigens (foreign proteins that induce the immune response), and either activate or inhibit B lymphocytes and natural killer cells — 2 types of cells which participate in immunological reactions.

The original excitement about interferon revolved around its action against viruses. Experiments with animals showed that injection of interferon could prevent virus infection. Further experiments showed that human interferon could prevent infections of human skin with vaccinia (the virus used to vaccinate against smallpox), colds caused by rhinoviruses, herpes virus infections of the eye, chicken-pox and zoster.

It is however in cancer that interferon has evoked the greatest interest. Ion Gresser at the Institute de Recherches Scientifiques sur le Cancer, France, suggested over a decade ago that interferon inhibited cancer growth in experimental animals. At that time oncologists (cancer specialists) supposed that some cancers were caused by viruses which could explain interferon's potency. Since then it has also been suggested that the anti-tumour effect of interferon may be the result of its direct inhibitory action on rapidly dividing cancer cells. Other work indicates that interferon boosts the body's own immune system to fight off the cancer cells. Interferon is also said to trigger off the body's natural killer cells which move in to attack the cancer. In addition, the most important aspect of interferon in cancer is its lack of toxicity which makes it an attractive form of cancer therapy, particularly in combination with other forms of treatment. Conventional anti-cancer drugs work by being more toxic to cancer cells than they are to normal cells and thus often have serious side effects.

The first systematic attempt to study the antitumour effects of interferon in man were made by Hans Strander et al at the Karolinska Hospital in Sweden. In 1971, they tested interferon therapy on 35 patients with osteogenic sarcoma, a highly malignant bone cancer which afflicts young people between the ages of 10 to 25. Almost two-thirds of the patients showed no fresh growths after 2 years. Even though the number of patients in the study was too small to provide statistically convincing results, the beneficial effect of interferon did become apparent. Interferon-induced regression of tumours has also been demonstrated in patients with multiple myeloma and breast cancer in studies carried but by J. J. Gutterman and his colleagues at Houston, USA. Although the non-randomized and uncontrolled nature of Gutterman's study have been the butt of criticism, his impressive results prompted the American Cancer Society to give strong support for his proposal for the $ 2 million ACS programme in which some 150 patients are being treated at ten centres throughout the USA.

Interferon has also been shown to be beneficial in treating juvenile laryngeal papilloma, some cases of myelomatosis and Hodkin's disease.

Clinical studies of interferon so far have involved small numbers of patients. Many more patients will have to be evaluated before a clear verdict of interferon's efficiency can be reached. Large-scale clinical studies of interferon are however hampered by the lack of sufficient material. Most of the trials carried out so far have used human leukocyte interferon produced at the laboratory of Dr. Cantell in Finland, from a by-product of blood donations — the 'buffy coat' which contains all the white blood cells or leukocytes of the blood.

Researchers the world over have thus tooled up to develop alternative sources. One approach has been to induce the manufacture of interferon in human fibroblasts grown in large numbers in tissue culture. Another more promising source is human lymphoblastoid cells (immature cells of the lymphatic system).

Other laboratories have looked into the possibilities of recombinant DNA technology to ease the interferon-supply problem. Dr. Charles Weissmann's group at the University of Zurich and the genetic engineering firm Biogen, Geneva, were the first to claim success in engineering the *E-Eoli* bacterium to produce interferon. Biogen's process will however have to undergo considerable improvement before it can be employed on large-scale production of the drug. A larger supply of the drug could enable the present small-scale isolated clinical studies to be replaced by more extensive ones.

With several countries joining the interferon band-wagon it is time to set up international, well-coordinated, controlled studies of a drug which may well turn out to be the wonder drug against cancer.

—*N. A. P.*

WORM POWER — A WRIGGLY REMEDY TO ENVIRONMENTAL PROBLEMS

LONG renowned as nature's best fishing bait, the lowly earthworm is slowly creeping its way to a brighter future. The value of the earthworm as a vital component of fertile soil and its efficiency in converting organic wastes into valuable resources is gradually being realized.

Research in agriculture indicates that introducing large numbers of earthworms in agricultural land increases yields of crops such as wheat, millet, and soyabeans to a considerable extent. Earthworms consume soil, process it and excrete the remainder. In doing this they help in keeping the soil at a neutral pH — a condition which allows plants and microbes to thrive. The excretory material or *castings* of earthworms which consist of organic matter, also help to maintain the neutrality of the soil.

In the process of transporting mineral and subsoil components from the deeper layers of the soil to near the surface, earthworms transform these compounds into nutrients which can be used more readily by plants. Chemical analysis of earthworm castings reveal much higher contents of elements, such as magnesium, nitrogen, phosphorous, and potassium than that of the surrounding soil. The constant burrowing, mixing and digesting of the soil by earthworms improves its composition so that it contains larger aggregates such as clumps of silt, clay and sand particles. These aggregates constitute an essential part of productive soil, encouraging plant growth. Earthworms also increase the retentive capacity of the soil for air and water by rendering the soil loose. The introduction of earthworms into a test plot for a month has been shown to increase the rate at which the soil can absorb water by over 300%!

Earthworms are also being harnessed to transform the organic part of residential and commercial trash, sludge and agricultural by-products into castings. The process known as Vermicomposting yields valuable castings which are being put to use as organic fertilizer in farms and gardens. Countries such as the U.S., Canada and Japan are making use of Vermicomposting as a supplement to existing solid waste processing systems. Vermicomposting plants that can process refuse are thus being set up in small cities in these countries. As population pressure and ecological limitations are on the increase, plants such as these offer economic means of waste disposal.

Earthworms might also prove useful as monitors of pollution. The bodies of earthworms can absorb and retain relatively high amounts of heavy metals from the soil they ingest. This makes them excellent indicators of pollution. Heavy metals not only retard plant growth but they can be dangerous to man if they enter the food chain.

The possibility of using earthworms as a source of human protein is also under consideration in countries such as the U.S. The idea, though unpalatable, does have substance, for dried earthworms have been found to consist of up to 72% protein by weight. Moreover they also contain amino acids such as arginine and tryptophan which other proteins in the diet lack.

The lowly earthworm which forms a small but important link in the life chain does show promise of alleviating man's ecological woes.

—*N. A. P.*

THE HARD-DRINKING AUTOMOBILES OF BRAZIL

THE rapidly rising cost of gasoline has made the use of alcohol as a fuel either in its pure form or blended with petrol to produce gasohol, increasingly attractive in several countries. Brazil's advanced alcohol programme is the world's first large-scale coordinated programme to substitute petroleum with fuel alcohol. Launched by the Brazilian government in 1975, in response to the sharp increase in world oil prices which precipitated economic problems in the country, the Proalcohol project as the programme is known, is a commitment to wean the country's petroleum-intensive vehicular sector to alcohol produced from sugarcane and other crops.

By 1978, Brazil had saved over 1.6 million litres of gasoline by alcohol substitution. Moreover, the country's target of reaching a production figure of 10.7 billion litres of alcohol a year by 1985, will entail a substitution of about 40% of the country's gasoline consumption.

Thus by 1980, practically all the country's states and territories were using an alcohol/gasoline blend containing 20% alcohol — an alcoholic level for which no modifications of automobiles are required. The ultimate goal of Brazilian motorists is to fuel their cars with pure alcohol, since the pump price for pure alcohol is practically half that for blended alcohol. There are now over 200 pure alcohol pumps in the main cities to service the 200,000 odd pure alcohol cars that have started plying the roads. A substantial number of these cars have been specially constructed, whereas the remaining are standard models converted to make them suitable for the use of alcohol.

The utilization of alcohol in Brazil can be traced back to 1931 when the government of the day decreed an ethanol addition of 5% to imported gasoline. This was further stimulated during World War II when oil supplies to Brazil fell to the minimal. In addition to the country's experience with alcohol fuel, the emergence of alcohol as a high priority ingredient in Brazil's energy programme is also related to alcohol's superiority to gasoline as motor fuel, as it is non-polluting. Moreover, it can be produced not only from sugarcane but also from crops such as sweet sorghum, babussa palm and cassava.

The production of alcohol from sugarcane involves crushing the cane in huge mangles. The resulting sugar solution is then diluted and treated with a yeast culture. The liquor is kept in huge vats at ambient temperatures until fermentation is complete. The yeast culture Saccharomyces cerevisiae used in the Proalcohol Project acts on the glucose molecules, producing two moles of ethyl alcohol and two moles of carbon dioxide per mole of glucose. After mechanical filtration, the fermented mass is subjected to fractional distillation in indigenously constructed fractionating columns when ethyl alcohol is taken off at 78°C. The hydrated alcohol so obtained contains a maximum of 96% ethanol and is used directly as a fuel substitute in all-alcohol vehicles where a water content of upto 10% is permissible. For a blend with gasoline, however, the alcohol is rendered completely anhydrous. This is achieved by azeotropic distillation with benzene or hexane. The use of sugarcane as a basic feedstock results in a net energy gain, as the cane not only provides the basic fermentable sugars but also the *bagasse* (the fibrous residue of cane) fuel for running the distillation process.

Increasing emphasis is being placed on the use of cassava or manioc for large scale production of alcohol under the Proalcohol project, as Brazil is the world's largest producer of this root crop. Moreover, unlike cane sugar, cassava has a much wider land potential and needs less stringent agronomic requirements. Depending on the variety, the root of the cassava plant contains 20-40% starch for alcohol feedstock. The starch content has however to be converted enzymatically to sugar before it can be fermented to alcohol.

The Brazilian alcohol programme is having a wide impact on the country. It provides a major and inexhaustible source of energy, thereby reducing the severe economic effects of foreign oil import. It is also generating a large number of jobs, especially for the rural populace. The programme has also given a boost to the country's self-confidence, and Brazil has now started exporting its technology, notably its blending technology, to developing and developed countries alike. With a further increases in the price of oil becoming inevitable, Brazil's alcohol programme holds promise of being a model for an energy-hungry and oil-short world.

—*N. A. P.*

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