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Part and Apart: Issues in Humankind's Relationship to the Natural World[1]

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For most of human history, science and religion, broadly defined, pursued a common task as part of 'the experiment of life,' probing and defining humankind's relationships to the natural world. In the last century that intermingling of effort has diminished and for reasons I do not fully understand, environmental issues are debated by those affected, by government, by environmental activists, and by scientists but seldom by the religious community. In this paper I describe the varied and conflicting images we hold of our relationship to nature, and the roles played by science and religion in their conceptualization. I then speculate on some reasons for the demise of interest in these matters and conclude with an extensive case study from my research on technological hazards, suggesting the kinds of issues requiring a collaborative effort by science and religion.

THE NATURE OF NATURE

The intermingling of science and religion in 'the experiment of life' is clearly revealed in the involved history of humankind's relationship to the natural world. Together we came to consciousness of a natural world separate from ourselves. Together we probed its mysteries and sought to exploit its humanly defined resources. Together we sought to map the complex of systems we call nature and by ordering the parts we sought to grasp the whole. We shared in each of these endeavours while possessing a common flaw, albeit one that would appeal to the dialectician in William Temple. We are both part of and apart from the natural world.

Part and apart

It is the legacy of human consciousness to be forever trapped in such dualities as subject/object, observer/observed, or participant/observer – to be as one with our world, intimate and a part of our world by virtue of our being and separate and apart from it by virtue of our consciousness and reflection. Thus ecologists may tell us of a seamless web of life and poets may sing of it. Yet our own words, scientific and poetic, speak of fundamental contradiction. In our very act of affirming its unity we conceive of and indeed bemoan the separation of humankind from the natural world and by implication the separation of people from their environment.

The dilemma is not effectively bridged either by scientific model or poetic metre. We are apart from nature, forever so, because man and nature are different words and whether we insert hyphens, arrows, or feedback loops, the differentiation still stands. Yet in some special way we know that both the ecologists and poets are right. We are trapped in the reductionism of words and thought at the very moment that we aspire for organic unity.

In the beginning, perhaps, this was not our state. There was a time when nature was just a given. But three other major conceptual images of nature emerged to dominate the uneasy human relationship with the natural world. Nature is viewed variously: as given, as mystery, as dominion, and as system. Each is rooted in our mythic human origin and each persists today.

Nature as given

It is probable that in the beginning, just as today, the most common conceptualization of nature was as given. Nature was synonymous with environment, literally that which surrounds. The need to differentiate nature from artificial environment had to await the creation of a built environment. To the external observer, the human relationship to nature was surely one of dependency – nature was and is the basic life-support system for all species. How conscious our ancestors were of that relationship is of course unknown, but not totally so.

To ask what might have been the conceptualization of nature among the earliest of our human ancestors is not to engage in what Evans-Pritchard (1965) mockingly calls the 'if I were a horse' fallacy – acts of imaginative fancy and projection beyond the realm of credible verification. We have after all some knowledge and some informed speculation about the material basis for life of our ancestors and the observations of current or recent human groups whose livelihood of hunting and gathering surely bears some resemblance to that of our earliest ancestors. We also have a small but growing understanding of the perception of environing objects by infants, which involves a process of differentiation of self and surrounds perhaps not unlike the historic phylogenetic process. Finally, we can draw upon our own experience of humanness to project backwards and still be somewhat more hopeful of results than in projecting onto horses.

From such data, observations, and experience we might conclude that in the beginning the dominant image of nature was as a given – it was there. But consciousness, and thus differentiation from self and species, must quickly evolve. Such consciousness focused on specific natural elements, not on nature as a whole. These would likely be elements that sustained or threatened life but were not so all-enveloping as to be taken for granted (for instance, food as opposed to air). Lucretius seems to capture the distinction as follows.

> When overtaken by night they [the human race] laid their naked bodies on the ground like bristly boars, rolling themselves in leaves and foliage. Nor did they go wailing through the fields to seek the day and the sunlight, fearing the shadows of the night; but quietly and buried in sleep they waited until the sun with red torch should bring light to the sky. For since from infancy they had been used to seeing darkness and sunlight born in

turn, it could not occur to them ever to wonder or to doubt whether eternal night might not hold the earth forever and the light of the sun be withdrawn. But they were troubled rather about the herds of beasts, which often made rest dangerous to these unhappy beings. Driven from home they fled their rocky shelters at the coming of a foaming boar or mighty lion, and at dead of night yielded in terror their leaf-strewn beds to their savage guests. (*De rerum natura* 5, 925–1010; quoted in Lovejoy 1935, 228 – see References at end of this paper)

In terms of direct paleontological evidence there is little for conceptualization of nature until the upper Paleolithic (ca. 40,000 BC) whose 'cave engravings and paintings [and] the burials with their widely varying peculiarities ... [offer] evidence for a complicated and rich ideological world' (Blanc 1961, 119).

How much earlier, preceding the pictorial records of the cave with its magical evocation of the hunt, differentiation did take place is not clear. Some speculations have a quality of immediacy provided by an imaginative (perhaps unbelievable) projection backward of current philosophical concerns.

In the absence of documents (apart from the tools of the 'pebble culture'), it is necessary to try to recapture the psychological state of these first mutants, suddenly separated from the other primates, taking their first hesitating steps in an unknown world ...

The animals surrounding him [mankind] came and went, indefatigably repeating the same actions: hunting, gathering, searching for water, doubling or fleeing to defend themselves against innumerable enemies; for them, periods of rest and activity succeed each other in an unchanging rhythm fixed by the needs for food or sleep, reproduction or protection. Man detaches himself from his surroundings; he feels alone, abandoned, ignorant of everything except that he knows nothing, no longer forced to obey the laws of the clan, from which he feels irremediably cut off. His first feeling thus was existential anxiety, which may even have taken him to the limits of despair. Without previous experience, his consciousness was necessarily rudimentary and rough, yet it was an authentic human consciousness. (Bergounioux 1961, 110–11)

Perhaps it is easier to speculate on infant conceptualizations as an analogy with human evolution. Again the point at which differentiation between self and surrounds takes place is never known, nor how those surrounds are conceptualized. Instinctual responses to outside stimuli take place early, even before birth, and taste preferences are experimentally in evidence shortly afterwards (Jackson and Jackson 1978). By eight to ten weeks after birth there is recognition by infants of a human face (or facsimile thereof) followed by a growing ability to differentiate their own body from others. At approximately five months, the child has a growing ability to differentiate his or her own body from the body of the mother or primary care givers (Kaplan 1978). Active grasping for objects within range of the hands begins early and is mastered by the fifth or sixth month of life. By the tenth month exploration on hands and knees usually takes place, and the full-blown exploration of the world of subsistence work in the course of play or chores may begin as early as year two (Fraiberg 1968). The dominant concerns of the child are with needs, but more than what is needed is explored, touched, and briefly questioned. This explorative curiosity surely applies to adult persons and must have characterized early questioning of nature beyond the elements of need. Thus starlight might be observed and speculated upon by early humans irrespective of actual or supposed functional need.

The acceptance of nature as a given does not imply a lack of knowledge. To be born or to evolve into a sustaining environment, and to then fix on dominant objects or elements based on need and occasional curiosity, easily leads to careful observation and growing knowledge of the needed elements. Elaborate ethnoscientific taxonomies can be elicited in non-literate societies relating to needed natural elements (Conklin 1980). In fact such common knowledge (as opposed to specialist knowledge) actually diminishes with increased technological sophistication (Johnson 1977). The ethnoscientific data also strengthen the view of nature as a given. In a series of seminars held with groups of San-speaking hunters (Bushmen) of Namibia and Botswana, Blurton-Jones and Konner (1976) found their informants had an elaborate ethology of animal behaviour, very strong on observations and description, but very weak on explanation – a position consistent with a 'given' view of nature. Finally, the ethnoscientific data also suggest that the common knowledge is limited to the observable (Page and Richards 1977). Other conceptualizations of nature are needed for that which cannot be seen, either in time past or below or beyond the range of vision.

Nature as mystery

The consciousness of what in nature is needed for life is probably inextricably bound to what is needed for wonder. It is easy to speculate on the origins of wonder: in the fluctuation of supplies of food or water, in human disease and the experience of death, in curious eyes examining star movement or tree growth. Nature as provocateur of wonder is the second major conceptualization – a nature of wonder, of mystery, of sacred object and symbol, and of mystical, singular wholeness.

All of the major 'scientific' (as opposed to theological) theories of early religion appear to be functional and utilitarian. Religion in Evans-Pritchard's summary (1965) arises out of the need to interpret natural phenomena, to discharge emotion, or to maintain social cohesion and community. And ecologically oriented anthropologists would add to the list the maintenance of ecological balance (Rappaport 1968; Harris 1979). Excluded from this rational tradition is the approach of simply taking the religious expression at its word, or of accepting 'supernatural theory.' Setting aside for the moment (but not forgetting) this literal interpretation, we find the utilitarian explanations in conflict as to the role of nature in the world of spirit.

The utilitarian theories provide for a trichotomy of explanation. For example, animistic belief (existence of a soul in natural objects) is explained as either (1) a rationally intended but mistaken proto-scientific explanation for natural process, or (2) a convenient symbol or totem for various psychological or social needs, or (3) a way of regulating human behaviour for the wise use of the natural objects. Similarly, religious imperatives such as the dietary abominations of Leviticus are interpreted as either (1) reflecting the proto-scientific taxonomies of a biblical ethno-science (Douglas 1966), or (2) as a way of differentiating Jews from their neighbours (Douglas 1972; Soler 1979), or (3) as encouraging a utilitarian benefit by outlawing the pig for public health (Maimonides 1881; Ptai 1978) or ecological reasons (Harris 1966).

This lively debate about the origin and function of religious practice may be trans-scientific, as Evans-Pritchard claims, beyond the realm of scientific evidence. But regardless of its origin and function, the phenomenon of nature as wonder and mystery evolves in historic (literate) time in two significant directions. A concept of holistic nature rather than an assembly of natural objects or phenomena emerges. And a Western society majority opts for deciphering the mystery of nature, while most of the world is still immersed in it.

Somewhere in time nature becomes Nature, individual natural elements become a collection of elements and become personified (nature herself, Mother Nature) or systematized (laws of nature). For Williams (1976) 'Nature is perhaps the most complex word in the language [with] three areas of meaning: (i) the essential quality and character of something; (ii) the inherent force which directs either the world or human beings or both; (iii) the material world itself, taken as including or not including human beings.' For both the second and third meanings, nature must become whole, and the earliest sense of wholeness was most probably linked to pantheistic religious expressions, of unitary god(s) who were in, a part of, or encompassing the world.

The great expressions of such beliefs are in the Orient – Hinduism, Buddhism, and Taoism – but there is a Western minority tradition from the nineteenth century onwards in which some British Romantic poets and American transcendentalists find comfort. The culmination of this trend is in the sacralization of pristine nature as wilderness in the late nineteenth century (Graber 1976).

The unity of person and nature in the spirit or the solitude of wilderness does not in itself augur an unchanged natural world. As Tuan (1968) has described, the most humanized of landscapes are found amidst the strongest of oriental unitary and sacred conceptions of nature. But it is in the West that the concept of nature as mystery, although it may be ever-present, is but a muted counterpoint to the prevailing vision of a subservient nature.

Nature as dominion

The theme of nature as human dominion surely precedes the Judaeo-Christian tradition, but nowhere is it given such clarity or such eloquence as in the cosmological myth of the Western world.

> And God said, Let us make man in our image and after our likeness: and let them have dominion over the fish of the sea, and over the fowl of the air, and over the cattle, and over all the earth, and over every creeping thing that creepeth upon the earth. So God created man in his own image, in the image of God created he him; male and female created he them. And God blessed them, and God said unto them, Be fruitful, and multiply, and replenish the earth, and subdue it: and have dominion over the fish of the sea, and over the fowl of the air, and over every living thing that moveth upon the earth. (Genesis 1:26–8; King James Version)

In a powerful essay, the medieval historian Lynn White Jr (1967) found in this concept of dominion the historical roots of our ecologic crisis. The response to his essay, viewed a decade or more later, seems remarkable in the heat it evoked. In his own words: 'I was denounced, not only in print but also on scraps of brown paper thrust anonymously into envelopes, as a junior Anti-Christ, probably in the Kremlin's pay, bent on destroying the true faith' (White 1973, 60).

A flood of literature followed (Schaeffer 1970; Black 1970; Santmire 1970; Barbour 1972, 1973; Passmore 1974) mostly questioning or modifying the White thesis. Two major criticisms emerged. First, the biblical grant of dominion consecrated but did not originate human domination. The manipulation of nature by humankind was well under way about three thousand years ago when the Genesis myth was first set to paper (Passmore 1974). And secondly, White ignored the alternative or complementary role of stewardship posed in the Judaeo-Christian tradition (Black 1970). Passmore queries how really deep the role of stewardship is in that tradition, but does not question the existence of the notion of humankind being God's deputy on earth entrusted with the well-being of the dominion, or the companion Judaeo-Christian idea of co-operation with nature in its improvement. But stewardship and co-operation are clearly minority traditions, and regardless of whether the grant of dominion came before or after the fact of its exercise, the acceptance of human dominion over nature is clear and powerful in Western thought, reinforced by the Baconian–Cartesian revolution (Passmore 1974; Glacken 1967; and Leiss 1972).

For Bacon, 'Man, by the fall, lost at once his state of innocence and his empire over creation, both of which can be partially recovered even in this life, the first by religion and faith, the second by the arts and sciences' (quoted in Glacken 1967, 472). Arts and sciences, in Descartes's words, provide the means of 'ascertaining the force and the action of fire, water, the air, the heavenly bodies, and the skies, of all the physical things that surround us ... and thus make ourselves the lords and masters of nature' (quoted in Glacken 1967, 477).

For the masters and possessors of nature, the task was to decipher its mystery. In that effort a complex, expanding systemic view of nature would emerge. In the Baconian–Cartesian equation of power and knowledge it would strengthen the sense of dominion, but in the wonder and awe of scientific pursuit a new sense of mystery would emerge.

Nature as system

It is widely accepted by students of humanity that most if not all people have systems of belief and thought akin to science. These systems, often differing fundamentally from modern Western science, are collectively labelled ethnoscience, presumably to link them to the ethnographies of which they are a part. Such sciences consist of combinations of theory, method, and fact that purport to observe, classify, and explain the phenomena of nature in an orderly or systematic way. If ethnoscience is almost universal today, surely some prehistoric people would have placed their considerable knowledge of the natural world into a systematic framework somehow linking themselves to the objects or organisms that surround them in a series of functional purposes and relationships.

Central to that linkage may have been God or gods, for as Glacken (1967) notes: 'In ancient or modern times alike, theology and geography have often been closely related studies because they meet at crucial points of human curiosity.' Thus, he goes on,

> The conception of the earth as an orderly harmonious whole, fashioned either for man himself or, less anthropocentrically, for the sake of all life, must be a very ancient one; probably we must seek its ultimate origin in earlier beliefs in the direct personal intervention of the gods in human affairs or in the personification of natural processes in the naming of gods of the crops, and in the old myth of the earth-mother. (p. 36)

And of the Hellenistic age, Glacken wrote: 'The idea that there is a unity and a harmony in nature is probably the most important idea, in its effect on geographical thought, that we have received from the Greeks, even if among them there was no unanimity regarding the nature of this unity and harmony.'

Greek ethnoscience was to range widely over natural phenomena, from a credible (by modern Western science standards) exposition of the hydrologic cycle by Anaxagoras, through the elements of nature of Empedocles (air, earth, fire, and water), to the atomic theories of Leucippus and Democritus.

Further elaboration of nature as a system accompanied the birth of modern science, particularly in astronomy but much less so in natural history and earth science, and it was not until

> a group of writers, most of them living in the seventeenth century, and none in the front rank with Newton, Descartes, or Galileo, became interested in natural history, physico-theology, and scientific research, that these

inquiries were identified with further discoveries of the wisdom of the Creator in his individual productions of nature and in the interrelationships he had established among them. Such studies and interpretations of living nature as a whole became the basis for modern ideas of the unity of nature advanced by such men as Count Buffon in the eighteenth century and Darwin in the nineteenth century. Darwinism in turn led to the concept of balance and harmony in nature, the web of life, and then to the recent concept of an ecosystem. (Glacken 1976, 379)

Physico-theology, the study of God in the works of nature, is best exemplified in the work of John Ray (1759) whose *The Wisdom of God Manifested in the Works of Creation* was first published in 1697. The argument is that natural phenomena bespeak a sense of order and purpose that can be properly explained only as the work of a divine artisan. In a famous, often repeated analogy, Ray describes the inferences that must result if we were to discover a clock in what was thought to be a totally uninhabited area. An examination of the clock reveals manufacturing skill and an orderly relationship of parts which work together for a common purpose. We would be forced to conclude that the clock was indeed an artefact, consciously assembled by an intelligent being whose existence must be postulated to account for the clock's presence. Ray then argues that many features of the natural environment have similar characteristics and thus are evidence for the existence of God.

Physico-theology developed gradually in the early Christian church, partially in response to a similar tradition in Greek thought of which Plato's *Timaeus* is the best representative. Ray's example is typical of the Christian physico-theologists in its reliance upon teleology, or the doctrine that there is an ultimate purpose or goal to nature. However, it is not necessary to accept teleology in order to believe that nature is a divine manifestation, and vice versa.

The physico-theologists were not original scientists – at best they were amateurs – but they were zealous synthesizers. Ray's friend William Derham (1798) worked out elementary concepts of the food chain, of the interdependence of all forms of organic life, of the distribution of land forms, and of the role played by physical agents such as streams and winds, and the climatic effects of earth position and axis tilt. Ray anticipated and influenced Linnaeus whose extraordinary acts of ordering, classifying, and naming made real the orderly world of the physico-theologian and laid the basis for extending the web of nature into time as well as space (Eiseley 1958). This would require discarding 'the great chain of being' or 'the scale of nature,' on which all life had been placed and created simultaneously. Time would have to be extended past biblical time. And biological mechanisms for variation and selection would have to be proposed – all of these developments taking place in Darwin's century (Eiseley 1958).

Towards the end of that century, the formal concept that living organisms and their environment comprise an interacting system with well-defined properties emerges in the works of Möbius, Forbes, and others. 'Ecology' was proposed by Haeckel in 1869, and 'ecosystem' by Tansley (1935). And finally the natural system would serve as a model for the abstraction of all systems (von Bertalanffy 1950; Miller 1978).

Image and praxis

In the flow of human thought, these four themes resemble the braided streams of old deltas rather than the incised waters of young uplands. Now diverging, now converging they carry an enormous variety of human concerns.

These flows of thought rise far upstream in the earliest human beginnings. And despite their somewhat chronological presentation, the first rivulets probably arise almost simultaneously. Yet as ancient as their origins are, they are fresh and relevant to the environmental issues and theories of the day.

In their conscious acting upon nature, people choose one of four major alternatives: to preserve, conserve, exploit, or re-create elements of the natural world. Each alternative, in turn, is strongly influenced by one or more conceptualizations of nature and of our divided relationship with the natural world.

By aboriginal fire, by land clearing and draining, by diverting the water courses in their arid margins, by working and reworking the soils, by paving the land, by domesticating plants and animals, and by diffusing or destroying habitats and species, a continuous act of creation unfolds. Much of it is done as it has always been done, with nature as given, in small incremental activities of necessity or occasional curiosity, whose cumulative effect remakes the soils and landscapes of large areas of the world. Such small interventions may retain considerable communion with nature – even today they are consciously seen as carrying out God's design or a secular 'design with nature' (McHarg 1969). Nevertheless today great fear is expressed that such cumulative actions threaten the lives and livelihoods of many in the habitats of the desert margins, mountain foothills, and tropical forests.

The most conscious expressions of dominion are in the form of large-scale works of plan and design. These are expressions of mastery and power, or at the very least the improvement upon and continuance of divine intention by scientific logic or technological possibility. They are not unthinking interventions in the natural world. There are few large-scale endeavours undertaken today in which sophisticated efforts are not made to understand and anticipate the impacts of the new creations. For the new lakes behind tropical dams, the diverted river courses of the Arctic, or the heat islands of urban electric generating stations, efforts are made to trace the linkages to pre-existing natural and human systems and to project the complex interrelationships that will develop. In such undertakings, however, nature is surely objectified and our apartness from it is strongly expressed.

Re-creation overlaps with use. The changes that occur with use are smaller, slower, and perhaps reversible. Exploitation, conservation, and preservation form a continuum of use in which the rate of extinction or pollution determines how we classify the behaviour. In exploitation the change may be irreversible – ores are lost forever, extracted as quickly as energy or economy permits; air and water serve as natural chimneys and sewers destroying the life dependent on their pristine conditions. In conservation the rate of exploitation is adjusted to some optimal level thought to sustain the yield of flow resources or to leave some legacy of stock resources to the future. To leave a full legacy, if only as the option for future exploitation, preservation sets aside wilderness areas, creates natural reserves, and rescues endangered species.

Underlying these choices is an overlapping of concepts as dominion leads to exploitation, stewardship or system to conservation, system and mystery to preservation. In both exploitation and conservation we inevitably stand apart from nature. Only in preservation can we seek to reclaim our organic place in nature and both images of system and mystery encourage us to do so. Almost all of us experience dominion and mystery, apart and part, simultaneously. In dominion we affirm our separateness, in mystery we seek unity, and in system we hope somehow to find a promised bridge.

Science and religion diverge

This then is my recounting of the emergence of four distinct views of the human relationship to nature. Throughout my tale, religion and science are intimately involved, often in one and the same person. But in the post-Darwinian age the weaving of science and religion unravels.

Thus today, although religiously based charitable and social action groups abound, there are few that are dedicated to environmental action. For example, in a recent listing (National Wildlife Federation 1978) of 378 Canadian and U.S. citizen groups and international agencies concerned with natural resource use and management only one appears to have a religious base: the St Hubert Society of America, dedicated to the principles and traditions of good sportmanship and hunting.

Except for a flurry of outrage at Lynn White's indictment of the Judaeo-Christian tradition as the root of the ecological crisis (1967), theology says little in the way of advocacy for nature. When the church in my country does take a stand on issues related to the natural world, for example in the nuclear power debate (National Council of the Churches of Christ 1974, 1975), the advocacy relates primarily to issues of war, economic injustice, and human health.[2] This emphasis is in sharp contrast with the stand of scientists such as Rachel Carson, Barry Commoner, and Paul Ehrlich who emerged as powerful advocates and strong allies of the secular nature spiritualists and the emerging environmental movement.

Why in this century after William Temple's birth the intermingled roles of science and religion in defining the human relationship to the natural world should be abandoned is beyond my knowledge but may emerge in the proceedings of this conference. Indeed, not everyone will acknowledge that it has been abandoned. Our conference chairman, for example, tells me that there is a continuing involvement in environmental issues within the church in Canada and Dr Peacocke has given me examples of interest in England and Scotland. Nonetheless there has been a diminution of interest overall and I can at least speculate upon some causes.

By Darwin's time the 'gifted amateur' of both science and religion gives way to the age of specialization in each field. Churchmen no longer write the natural history of places such as Selborne (White 1897). Some of the church goes into opposition with science when evolutionary theory appears to undermine the literal statements of the sacred myths, and other segments go into isolation; there are separate domains for science and religion. Finally, a powerful secular spiritualism based on nature develops its own mystique at the same time as the worldly concerns of the organized religions seem to focus on the relationship between people and social classes, ethnic groups, and nations.

But surely the task is not completed, and an enduring order, natural or otherwise, has not been achieved. Our conflicting relationship with the natural world persists, heightened by our appreciation of the human power to disrupt the very nature within which our lives are embedded. There is a special class of issues that science and religion must jointly address. They emerge at the leading edge of environmental issues where fact diminishes, uncertainty looms large, and value judgment is needed. Permit me to use the work of our research group on technological hazards to illustrate and let me apologize beforehand that my data are primarily from the United States.

COPING WITH HAZARDS: A CASE STUDY

In a recent U.S. poll, 78 per cent of the public surveyed agreed that 'people are subject to more risk today than they were twenty years ago,' and only 6 per cent agreed that there was less risk. Further, some 55 per cent agreed with the statement that 'the risks to society from serious scientific and technological advances will be somewhat greater 20 years from now than they are today,' while only 18 per cent felt the risks will be somewhat less (Harris 1980).

As a scientist with the factual data at my command, I can't support this view but the basis for these perceptions is easily understood. There is literally a 'hazard of the week' in the media and some forty to fifty new or newly discovered hazards are discussed annually in leading newspapers and periodicals (Kates 1977). Nuclear weaponry proliferates, there are some hundred thousand chemicals in commerce, as there are some twenty thousand separate consumer products. And added to these technological hazards are the social hazards of crime and unemployment.

The burden of technological hazard, the subject of our research group's analysis, is considerable. In the United States alone, the estimated social costs of hazards associated with the manufacture and use of technology, including property damage, losses of productivity from illness or death, and most but not all of the costs of control, amounted, in 1979, to between $179 and $283 billion (equivalent to 7.8 to 12.4 per cent of GNP; Tuller, forthcoming). Similarly, 15 to 25 per cent of annual human mortality is associated with various technologies. No similar analyses have been done elsewhere in the world, but there is every reason to believe that similar patterns of damage and loss would be found in most industrialized countries and in certain areas of developing countries where they might even be greater.

In contrast to social cost and human mortality, the ecosystem impacts, while conceivably the most important in the long term, are difficult to quantify. Death certificates are not filled out for the millions of non-human living organisms related to each other by complex chains of interdependence. At best, only a few crude indicators are available. One indicator is species extinction, particularly of birds and mammals. Current rates of known extinction of bird and mammalian species (slightly less than one per year) are estimated to be ten to fifteen times larger than those at the beginning of the industrial revolution. About one-half of these extinctions appear to be directly related to technology (Harriss, Hohenemser, and Kates 1978). If we include all of the estimated two to twenty million (average ten million; Ehrlich and Ehrlich 1981) existing species of all forms of life, then it is estimated that one million species will be extinct by the end of the century, at a rate of one a day currently and one an hour at the end of the period (Myers 1979).

A second measure of ecosystem impact is productivity or the ability of ecosystems to produce organic material from inorganic materials and sunlight. Using as an indicator of productivity the changing magnitude of the land biomass, recent estimates (made with great uncertainty) indicate a net annual decline of 0.2 to 2 per cent in global land mass, about three-quarters of which is technologically related (Woodwell et al. 1978). Other indicators are the world-wide declines in natural resource productivity, marked by rising real prices and declines in production of forest lumber and fish (Ridker and Watson 1980).

None the less, there is cause for cautious optimism regarding some technological hazards. There is surely a time lag between the employment of new technologies and the identification of their hazardous impacts, but the period seems to be decreasing (Kasperson 1977). For most acute effects and for some chronic ones as well, there is either improvement or at least no sign of worsening. Accidental death rates have declined in the United States despite increased use of technological devices, and significant improvement has been made in reducing the concentration of three of five major pollutants in the air. Thus for technologies whose consequences are immediate, whose sources are identifiable, and whose mechanisms are reasonably well understood, the problem of achieving a tolerable level of risk, though expensive and challenging, is acceptable, a concomitant to the widespread beneficial use of modern technology.

More difficult to deal with are acute hazards of a rare catastrophic nature, or slow and cumulative hazards of great persistence, spread, or toxicity. In a recent comparison of ninety-three technological hazards we have identified five sets of hazards and independent underlying dimensions, four of which represent types that are difficult to cope with. These four are: intentional biocides, the persistent, delayed teratogens, the rare catastrophes, and diffuse global threats. The fifth group, which we call the common killers, is composed of such hazards as automobiles or household drugs.

The *intentional biocides* derive their lethality from the great toxicity innate in the design of technologies meant to hurt living organisms: humans (in the case of weapons), insects (pesticides), vegetation (herbicides and chainsaws), bacteria and viruses (drugs). Highly efficient, these technologies are usually narrowly targeted and access to them is restricted. But if by error of design or application or by intention they drift off target, they are enormously dangerous. Thus in our time we have already experienced nuclear fallout, massive fungicide poisoning in Iraq, and world-wide antibiotic-resistant strains of venereal disease, and these threats are still increasing.

Persistent, delayed teratogens and mutagens comprise a class of hazards whose inherent danger arises from a combination of characteristics each of which though threatening is manageable by itself. It is the combination of long life for the material, long delay until consequences appear, and transgenerational impact that makes them so hazardous. Long-lasting metals such as antimony, cadmium, lead, mercury, molybdenum, and selenium have man-made fluxes between five and eighty times those found in nature; all of these elements persist almost forever and cause serious disruption to living organisms; they can accumulate slowly in the biosphere and several are mutagenic (Harriss and Hohenemser 1978). Heavy metals and radiation, the other major source of persistent mutagens, have already caused numerous poisoning episodes and a few major epidemics such as one of Minimata disease and the seed grain mass poisoning in Iraq.

For most of the *rare catastrophes* the mechanisms are well understood: a jumbo jet collision, the collapse of a dam, a nuclear reactor accident, a liquid natural gas (LNG) tank explosion, or the fall of a satellite. We have already experienced a number of major dam failures, one jumbo jet collision, a single LNG tank explosion, and near misses with satellites and nuclear reactors. For some catastrophes, such as the accidental creation of a virulent micro-organism through hybrid or recombinant DNA technology, the threat while real is almost impossible to assess reliably or perhaps even to verify if it did occur.

Finally there are the *diffuse global threats* caused by materials disbursed world-wide that slowly but steadily accumulate, mainly in or through the atmosphere, and threaten to change the climate, destroy the protective ozone layer, or increase the acidity of precipitation. The threats are identifiable but much scientific uncertainty still remains regarding the speed at which they are evolving, their sources, the mechanisms involved, and their impacts.

Note that to date each of these four groups of hazards is threatening in its potential rather than actual record of human and ecosystem injury. Each group poses a different sort of threat based on very different criteria of intrinsic hazardousness. And, finally, we have studied only ninety-three hazards involving several hundred individual technologies, but the list of hazardous components, products, or processes numbers in the hundreds of thousands.

Issues for science and religion

Do we need to do everything we do because it is to someone's advantage or do we do it simply because we can? Is all of this large burden of technological hazard necessary? Where the harm of a technology clearly outweighs its value to society, the answer is 'no.' We no longer manufacture thalidomide or legally hunt the blue whale. But it is seldom that the balance between harm and value can be simply and clearly struck. Thus we use DDT and SSTs in some countries and not in others, and ban the pesticide Leptophos in the United States and not in Canada.

We strike these different balances for a variety of reasons to do with different societal needs, risks, and influences, but also because of an inherent uncertainty about how harm occurs and how much technologies are worth. A new quasi-discipline of risk–benefit analysis has arisen to deal with such questions and thereby poses the first of the issues that exemplify matters of joint concern.

'... *and How Much for Your Grandmother?*' (Adams 1974)

Inherent in most societal choices about coping with hazards is the valuation of a human life. Despite the argument that life is priceless and can never be valued, both explicit and implicit valuations are being made all the time. Juries and courts give awards to heirs for the loss of life. My university currently values my life at two times my annual salary, and more if I die accidentally.

More common, however, is the implicit valuation that takes the form of expenditures to prevent life loss or to save an endangered life, or as compensation for increased risk (Graham and Vaupel 1981). The U.S. Nuclear Regulatory Commission is currently willing to require a utility to expend up to $5 million per life saved in measures employed to prevent radiation exposure, while the U.S. Department of Transportation is unwilling to order the expenditure of $13,000 per life saved through requiring the use of airbags.

Two major techniques for setting a price on a life are currently employed: willingness-to-pay and the human capital approach. In the first instance, life or at least life-saving is viewed as though it were a commodity in a market in which consumers or decision makers are willing to spend or receive various amounts for life-saving or life-risking activities. Life is worth what the market – be it economic or political – is willing to pay. In the second case, life is worth what it can produce, and lost earnings from premature death are the basic measure of valuation.

The issue of life valuation is only one of a family of related issues. Some are issues of equality – are lives in the future less valued than lives today? Some are issues of perception – are many people dying together valued more than the same number dying singly? or is a cancer death more dreadful than a drug overdose? All are issues that should encourage our collaboration. Human life is too valuable to be valued only by those who find it easy to do so.

'*Would we miss the snail darter?*' (Ehrlich and Ehrlich 1981)

If the valuation of human life poses knotty questions to both science and religion, then the valuation of non-human life may be even more troubling, bringing us into direct confrontation with our relationship to the natural world. At any moment of time it is difficult to be sanguine about the valuation of human life: the memory of the Holocaust is still too fresh, the threat of nuclear holocaust too real, the existence of capital punishment too common. Yet clearly we are at a moment in time when a pervasive effort is being made to extend our evaluations of human life to the life of other organisms: to the human foetus, to animals, and to other species.

Human population increase and technology have vastly accelerated the extinction of species. The gentle balance between new species evolution and old species extinction which seemed to favour overall the proliferation of species is being reversed (Myers 1979; Ehrlich and Ehrlich 1981). An extinction of species, the biological doomsayers' claim, as great as the disappearance of the dinosaurs sixty million years ago, is at hand.

There are four major arguments for the preservation of species (Ehrlich and Ehrlich 1981): ethical, esthetic, economic, and ecological. Other species should be preserved because they have a right to existence, because they are beautiful, because their sustained yield is valuable, and because they are necessary to human life-support systems. None of the utilitarian arguments (economic, ecological) seem sufficiently compelling to protect the entire range of threatened life, particularly insects, fish, and plants. Only a serious extension of human rights to non-human life can slow the rate of human-induced extinction.

The abominations of Prometheus

Balancing risks and benefits is one way of coping with hazards; averting them is another. The fine balancing exemplified by life valuation may be beyond our skill or morality and the measure of harm may be beyond our science. In the face of great uncertainty, most societies employ some measure of aversion simply to reduce the anxiety they must cope with. In short, they rely on taboos. All cultures contain taboos both sacred and profane and the most universal taboos relate to the most elementary needs: life, sex, food.

Taboos are easily recognized as such in so-called primitive societies, but are made sacred when they are part of the world's great religions and are ignored when embedded so deeply in one's native culture as to constitute habit or law. Thus 'primitive' efforts to avoid the risk of defilement are labelled as taboo, but similar efforts in our culture to avoid the risk of disease are called preventive medicine. Or in many countries where organized killing is sanctioned (war, capital punishment), self-killing is prohibited and the suicide taboo is part of the law.

There are a few recognized taboos for hazards: it is illegal in the United States to add a carcinogen to food (although legal to add one to air or water), or to eliminate an entire species of living things through the development of a large project such as a dam or highway. In both cases the decision to give the taboo the force of law was not made by weighing costs and benefits; rather it was a simple imperative – thou shall not add carcinogens to food or eliminate species with government projects.

Taken by themselves out of the context of the whole, taboos don't necessarily make sense. Our need for technological taboos rests not on our inability to cope with any specific hazard but on our inability to cope collectively with all of them. Drawing a line by preserving the snail darter endangered by the Tellico Dam in Tennessee may be marginally meaningless, but drawing a line somewhere may be fundamental to human survival. Science can help in selecting candidates for aversion by identifying particularly hazardous technologies or behaviour, but credible taboos require reference to higher principles.

Three-dimensional justice

The hazard burden is large in the aggregate but is manageable if shared fairly. Unfortunately, the distribution of risks and that of benefits from most technologies are not concordant; either risk or benefit may be concentrated and the other diffuse. The family of issues that arise from these discrepancies is called equity or fairness issues. In our own research we have been exploring the issue of equity or fairness in three contexts: locus, legacy, and labour–laity. The first inquires about geographical equity – in whose backyard will the noxious fumes or traffic be found? The second considers temporal equity and pursues the problem of intergenerational justice for long-lasting risks, primarily hazardous wastes and the risk of resource or technology scarcity. The third relates to social class, in this case workers and their occupational hazards as compared with the general public which is uninvolved in production or the use of a specific technology. We have studied the first two equity issues primarily in the context of the disposal of radioactive waste, and by extension of all long-lived hazardous waste.

There is widespread technical optimism that radioactive wastes can be effectively managed, that is, assembled, processed, and stored in ways that limit the risk to levels well below that of naturally occurring radiation (Aikin, Harrison, and Hare 1977). However, except for one proposal to bury high-level radioactive waste in equally spaced holes drilled in almost everybody's backyard (Cohen 1977; Ringwood 1980), all proposals to deal with such waste involve concentrating the risk on an area and population considerably smaller than would benefit from the nuclear power production. And from this principle emerges a wide range of social and political problems that have effectively outdistanced progress towards a technical solution (R. Kasperson 1979). Faced with the pressing need for storage of radioactive and other hazardous wastes, there is increasing recognition of these equity issues and some modest exploration of both compensatory and procedural mechanisms for achieving greater fairness.

For radioactive wastes, at least, there is also widespread popular recognition of the intertemporal equity problem; the long half-life of radioactive fission products and actinides is an active subject in the nuclear debate. Despite much lip service, however, future generations have little standing. In U.S. law at least there is hardly any precedent for providing such standing beyond the immediate generation (Green, forthcoming). While there have been novel suggestions for providing future generations with public advocates akin to guardians (Maynard et al. 1976), none have been implemented and few spokespersons for the future have been forthcoming. The U.S. Environmental Protection Agency has proposed a rule that specifically considers future generations, namely not to burden the future with risks exceeding those to the present generation, but it too has not become part of administrative law (U.S. Environmental Protection Agency 1978).

The equity issues between labour and laity is not even on the public agenda, even though we have found it a significant and widespread problem (Derr et al., 1981). In forty out of the ninety-three hazards we studied both workers and the general public are at risk. In 75 per cent of these cases, workers were exposed to hazards at concentrations ten times or more greater than were the public. This differential exposure is matched by differential protection. Occupational standards of protection are generally set at about the level of minimal observed harm, while standards for the public are ten to a thousand times below that level. Surprisingly, even in such countries as Sweden or the USSR where stricter occupational standards have been enacted, the differential between labour and laity still persists, albeit at a more restrictive level. At stake in such differential exposure is a substantial toll of life and livelihood. The toll from accidents is well known. In the United States, for example, 11.6 per cent of 103,000 accidental deaths in the period studied were work related, as were 7 to 15 per cent of 75,000,000 injuries. Much disputed is the toll of occupational illness and disease, which is surely substantial, including estimates of 1 to 38 per cent of 387,000 deaths due to cancer. Some 17.6 per cent of fifteen million disabled adults attribute their condition to work-related accidents or disease.

Since the differential is rarely noted, it is not often called into question. But four major principles of justice have been or could be invoked in its defence: (1) utility – whereby the sum of human betterment is greater because of the differential, (2) ability – whereby workers are more physically able, skilled, or trained to tolerate greater risk, (3) compensation – whereby workers are paid to bear risks, and (4) consent – whereby workers are informed of the risks and voluntarily accept them.

There are two aspects to these claims: are they true and are they just? As scientists we can examine their veracity – the economics of differential social cost, the relative vulnerability of workers and publics, the risk premium involved in compensation, or the information workers have about risk. But even if all the claims were true, the issue of justice remains. For example, in the United States we do not permit individuals to sell their kidneys (only to donate them). Why should we permit workers to sell fractions of their lives (or to have greater fractions taken from them)?

In all three types of equity issues the limits of science in clarifying the factual issue are quickly reached and issues of justice emerge. Ian Barbour (forthcoming) notes that unlike secular society, the Judaeo-Christian tradition gives standing to future generations or posterity. Equity issues of hazards and resources are prime claimants for a renewed science–religion effort.

CONCLUSION

In the chapter entitled 'The Sacramental Universe' in *Nature, Man and God*, William Temple finds in 'the principle in which belief in sacraments reposes ... a clue to the understanding of the relation of spirit to matter in the universe' (p. 486). To relate spirit to matter was a major goal of his, to somehow inject the 'life of the spirit ... characterized by determination by the good' into the physical world of mechanical forces and chemical compounds. In the absence of the spirit, he feared that 'the unity of man's life is broken; the material world, with all man's economic activity, becomes a happy hunting ground for uncurbed acquisitiveness, and religion becomes a refined occupation for the leisure of the mystical.'

In the consideration of nature, the dualism that Temple seeks to resolve is more complicated. The 'determination by the good' is complicated by the grant of dominion over nature and the material world of living systems is a biological world more complex than 'chemical compounds and mechanical forces.' Thus dominion, system, and mystery are intertwined and none is the unique domain of science or religion.

Now, no more than in the past, today's environmental issues should be informed by both the 'determination by the efficient' and the 'determination by the good.' In many fortunate cases the efficient may concur with the good and the choice is simplified. But in others, such as in the valuation of human life, the selective avoidance of hazardous technology, or issues of equity, the good may be less efficient. And in the issues of conflict between some humans and other life, the good has yet to be defined. If William Temple were alive today, wouldn't he be interested in these questions?

NOTES

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2 Reviewers have called my attention to several exceptions to this generalization, an example of which is the Religion/Environment project of the Sigurd Olson Environmental Institute at Northland College, Ashland, Wisconsin,

that 'seeks to explore the spiritual dimensions of caring for the earth, the concept of stewardship of nature, and kinship of all created beings.'

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