THE PHENOMENON OF INTELLIGENCE AS SEEN BY A LAY-SCIENTIST

by John H. Robertson

Abstract. This paper sees intelligence as certainly not a thing which is the sole prerogative of man but rather as a category of skill, natural to all organisms, integral with their capacity for handling their environment, and increasingly well developed in the higher animals. Intelligence is seen as a natural property of living organisms at their highest levels: a characteristic of living things which is emergent in the same way as, and essentially in parallel with, perception, consciousness, and moral and spiritual sensitivities.

Writing this article as a nonspecialist in any of the scientific areas most closely related to the subject of human intelligence and artificial intelligence, I am well aware that I am an amateur and that some might think me almost a dilettante.[1] But, having made this acknowledgment of my formal situation, I wish to remark, with some seriousness as well as humor, that the impressions of a nonspecialist or amateur are not necessarily always worthless. It is a common saying that "a little knowledge is a dangerous thing," and there is truth in that proverb. Yet we must remember that all our knowledge is little: there are no boundaries to knowledge. What is dangerous, of course, is ill-digested knowledge, that is, knowledge which is patchy, unbalanced, unself-critical, or overconfident. This we must all endeavor humbly to avoid. Also, we must remember that basically truth is *one*, not a plurality: truth is not comprised of the content of all available specialisms superimposed additively together. Truth is one; reality is one thing; God is one; but each specialism picks out (quite properly) from the richness of reality its own selected bundle of components for close examination. The existence of the Science and Religion Forum (and of other organizations through which some papers are contributed to *Zygon*) illustrates a profound

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underlying conviction that valid insights are to be obtained when specialists are in dialogue with one another and with nonspecialists and, further, that some insights are perhaps only to be attained in this way. Thus, if I may stretch the metaphor a little, even a cat may talk to a king.

The Concept of Intelligence

Although trained in one of the exact sciences I find it neither surprising nor disconcerting that there is so much variability in the use of the word intelligence and in the meaning, or lack of meaning, associated with it. The concept of intelligence seems to be as multivariant or multifunctional as, say, the concept of electronegativity or of hard and soft acids and bases, in chemistry. Some concepts are persistently and notoriously impossible to pin down with exact definitions, consistently valid over the whole field of their application; nevertheless such concepts are in some cases widely acknowledged to be pragmatically of considerable value. Attempts to force an exact definition on such concepts (so as to be more "scientific") can be counterproductive. I am not going to start with any exact definition of the word intelligence, but, in seeking for an explicit sense of what could be the useful core of meaning in our tacit understanding of the concept, I believe we gain some insight by observing some of our varied uses of this word in practice.

The word *intelligence* has been with us in the English language for some centuries. We have it from the Latin. Of course, the Greeks had a word for it, too. The concept, more or less well defined, is as old as thinking itself; it is much older, of course, than either the psychologist's *quotient* or the recently coined *artificial intelligence* (AI), and it is not rendered redundant by either of these. In our daily speech and writing we acknowledge freely and frequently that some people are more intelligent than others (sometimes very much so). We do not hesitate to use the concept to refer to animals (my neighbor's dog is particularly intelligent); yet, we find it more applicable, though not uniformly or exclusively so, to the higher species. We also use the word to describe actions or procedures: computers and computer programs are nowadays often referred to as intelligent. I need hardly mention that we have books on intelligent systems and, of course, artificial intelligence. Even an electric motor can be characterized, these days, as "intelligent," as I have noticed recently in the University of Leeds *Reporter*.

With this sort of background and with many other reflections in the recesses of my mind, it seems to this lay-scientist that the concept of intelligence has to do with skill in the handling of those organized or structured relationships with the environment that characterize the organized, structured organism—relationships which, in the more highly developed species, can be increasingly internalized (thinking through problems, prior to action) with concomitantly increasing complexity on the one hand (internally) and effectiveness (externally) on the other. Further, the distinction between ordinary skill and that sort of skill which we feel deserves the adjective *intelligent* is bound up, I believe, with our recognition of purposive behavior. Intelligence is closely allied to consciousness and very intimately tied up with the fundamental features of what we call the mind. My paper will try to justify these views.

But first, an aside. While the concept of intelligence is of long-standing vintage, the notion that intelligence is a property that can be *measured* is a comparatively recent idea and I will digress briefly to give a thumbnail sketch of its history. Note what happens to the concept of intelligence. The advent of Charles Darwin's theory of evolution had many consequences, direct and indirect. One of these was the exaltation of the notion of progress. Taken together with the greatly enhanced regard for measurement, coming from the escalating self-confidence of science, in the latter half of the nineteenth century, this led to interest in the controlled observation of perceptual and manipulative skills, including those we call mental. For example, Francis Galton, who had such a passion for measurement and tests of all kinds, is reputed to have said, "whatever you can, count." Galton, it seems, was the first to invent the idea that intelligence was something measureable. He was so impressed by the informative power of these measurements that he (and others) believed that the human stock could be improved if governments were to offer appropriate inducements to intelligent marriage partners. The first actual application of such a test for a specific social objective was made by the Frenchman Alfred Binet, in 1905. He dropped the sensory and physical elements of Galton's tests, concentrating on those requiring mental ability. He invented the intelligence test as a tool for education to use for grading pupils. In doing this he perceived intelligence to be a function of a child's growth and so came upon the important idea of "mental age." (The simple numerical device for handling this concept, the intelligence quotient, IQ, was invented a little later.) Then came Charles Spearman, who was particularly interested in the processes of thought; he was convinced that intelligence was basically one property of the mind, not a plurality, and postulated a "g" factor (general) for this, with an "s" factor (special) to make allowance for the existence of particular skills alongside basic intellect. Spearman improved the sophistication of the analysis of intelligence tests results, but his preference for a unitary picture seemed only to provoke the opposite development. Louis Thurstone and others made increasing use of factor analysis, until this sort of analysis of results became almost an obsession, with scores of different factors involved. What is interesting here is that attention turned away from the operations of measurement, and whatever might be happening during them, to the analysis of numbers. (Those of us who handle examination marks will agree how fascinating in themselves test scores can become, how pleasing and flattering to the self-image of the examiner to perform elaborate analyses of them!) If one can, at will, test the correlation of any one test with any other, then one is tempted to assume that one's testing procedures barely matter: relevance and irrelevance will all be sorted out in the wash, and regression analyses in sufficient number relieve us of the problem of acquiring more scientific insight into the nature of intelligence itself. That is the temptation. However that may be, the application of IQ tests has had, ever since those beginnings, a rather checkered career, at times almost fanatically espoused by education authorities, at other times in strong disfavor. Innumberable variants of IQ tests have been set up—culture-fair, and so on; and the modifications are going on continuously. Most of us know these well enough. The present position today is, I think, that, while the general concept of IQ is more or less universally accepted, the use of this parameter or whatever it is that the tests for IQ measure is viewed by most of us with a mixture of interest, awe, and distrust.

The Phenomenon of Intelligence in the Biological World

Let me return to the notion of intelligence itself and the phenomenon of intelligence as we see it, I believe, across the whole spectrum of organized systems from the simplest life forms up to the most complex. This section of my paper is a presentation of assorted facts that most of us have met before. My objective is to show you that these facts present a coherent pattern. I shall be stressing repeatedly the organic unity of what we observe.

We are extremely fortunate to be living at a time in the history of the development of physical and biological science, and in the history of the fashions of society, when many of the very remarkable features of the world we live in are being widely publicized in detail and with considerable quality of presentation. I am referring both to the large number of first-class books nowadays available, one of the most readable being John Sparks's *The Discovery of Animal Behaviour* (1982), and to the current popularity of natural science television programs, among which David Attenborough's "Life on Earth" and, before that, J. Bronowski's "Ascent of Man" are the most notable but by no means the only examples. These books and programs allow us to look vicariously through telescopes, spectroscopes, or microscopes; to use radiolocation, infrared, and ultrasound; to travel from one continent to another, sometimes above mountains, sometimes below ground or water with indefinite ease; and to view an enormous spectrum of fact. We are extremely fortunate to have this window on our world.

If the window that present-day science and technology afford us is remarkable, the world that we view through that window is vastly more so. What we see is not fanciful stuff for diversion or entertainment (we have to remind ourselves of this); it is the real world, of which we are a part. It *is* very remarkable, and it is proper for us to wonder at it, as Margaret Boden (1985) has reminded us.

Take the case of the migratory animals. The feats that many of them perform "beggar description and baffle the imagination," as John Sparks has well put it (1982, 45). The behavior of the North American salmon, for instance, is almost incredible. Yet the same kind of saga is true of our European eel, which breeds 2,000 miles away from the rivers here, in the Sargasso Sea, and of the whale, the seal, the turtle, the caribou, the wildebeest, the monarch butterfly, and many, many species of bird. The arctic tern (*Sterna paradisaea*) is perhaps at the top of this league table, often flying annually from arctic ice to antarctic ice, and back—a navigational feat which is astounding, especially across the intervening oceans. How does this little creature do it? Migrating birds have caught the headlines of the scientific press recently because of the confirmation that many species are in fact sensitive to the earth's magnetic field. This idea used to be pure speculation. How could a small, nonmetallic structure detect any weak magnetic force? But microscopic single-domain single-crystals of magnetite, Fe_3O_4, lying in tiny straight chains, were discovered within the cells of a mud-dwelling bacterium (*Spirillum*) and soon after, as expected, in certain cells in the brain tissue of the pigeon and other birds. The basis of magnetic field navigation is now known and the details continue to be explored. Notice that now that this secret is understood, we do not need to cease to be amazed. We need not look for supernatural cognition, or extraphysical or psychic powers any more, but we can still admire the extraordinary skill of the biological machinery that accomplishes these migratory journeys.

Transcontinental journeys seem to us skillful or intelligent because we know that we need skill and intelligence to accomplish such things ourselves. However, there is a wealth of skills, artfulness, and ingenuity to be found in living organisms all the way up and down the phylogenetic ladder. Let us go downwards to the simpler organisms. There are the remarkable termites which assiduously cultivate in their underground chambers a unique species of fungus for food. How do they know? We all admire the spider's web; but one charming detail that I learned recently about baby meadow spiders is that, directly after hatching from their eggs, they climb to the top of the nearest grass blade, raise their abdomens, and spin a length of silk into the air; this soon catches the breeze, lifts the minute spiderlet, and carries it far away to fresh pastures. How does this creature, the size of a pinhead, know that this is a clever thing to do? Lower down, and smaller in size, there is the predacious—or, more correctly, carnivorous—fungus (*Dactylella brochopaga*) which has the practice of snaring nematode worms in the soil. On its long filaments below ground it grows tiny hoops, only three cells in size, whose inside surfaces are very sensitive to touch; when an unfortunate nematode, itself thinner than a hair, happens to try to negotiate one of these rings on its way through the soil, the ring constricts in a fraction of a second, the hapless nematode is caught despite all its convulsive efforts to escape, and its body is then leisurely invaded and digested by the fungus. Still further down the phylogenetic ladder, the apparatus used by the bacteriophage for drilling its way into the bacterium is remarkable and very effective. (Incidentally, the entry of the sperm cell into the ovum is even more dramatic.) Even further into the world of molecules we have to wonder at the superb architecture of the DNA spirals: by the hydrogen-bonded pairing of four different flat-molecule bases (which match in only two connecting configurations and which, in dimensions, are otherwise so interchangeable that they can be stacked like superposed dinner plates up through the core of the sugar and phosphate helix in numbers exceeding tens of millions) and by the patterns of the sequences of those bases these spirals succeed in the encoding, storage, replication, transmission, and application of prodigious quantities of program information.

None of us supposes for a moment that the fungus filaments, still less the DNA spirals, think what they are doing. This is molecular machinery. However, of the efficiency and efficacy of these systems of machinery there is no doubt whatsoever.

In the face of these marvels, the reaction of the religious believer has been, in the past, to invoke God's specific creative act for all of them at some point in historical time: "special creation." Today, a majority of Christians, at least on the European side of the Atlantic, have grown out of that position. I am one of these. We recognize that the evidence for a long, slow evolutionary development of life forms, all the way from inanimate matter to ourselves, simply must not be dismissed; also we realize that God's creative action is to be seen, and respected, in the continuous upholding of all these things in their existence. We insist that all of us—all physical things—are alike dependent on God's creative presence, all the time, and that those physical systems with intelligence enough (i.e., ourselves but including, perhaps, in due course some man-made intelligent systems also) are alike responsible to God, as well as to one another, for their behavior. We therefore see the ingenuity of physical/biological systems as having been generated "naturally" by the interplay of evolutionary constraints and opportunities, together with the incessant activity of the particulate world as we know it. Of course, this is how nonreligiously inclined scientists see it too (except that for them it is not "under God"), so there is rather wide agreement between us, at least at the more obviously physical levels.

The Evolving Hierarchy of Intelligence

Once the evolutionary processes are recognized, and once the regeneration (survival) of the structures which are most thermodynamically (kinetically) stable, or best dynamically fitted, is accepted as a genuine insight, then we can see that intelligence is integral to development: the complex structure and super-efficiency of the hydrolytic enzyme, the clever ploys of the infective virus, the mimicry practiced by the bee orchid or butterfly, the hunting techniques, the courtship rituals, the transcontinental migratory journeys, and all the rest are patterns of interactive behavior that have evolved and are stable because of their consistent success, each in their ecological niche. This principle must apply throughout. We do not—we must not—dismiss the wonder of the devices of nature, but we do now see the artfulness of these systems to have been sculptured through time by their surroundings, their neighbors, and their own activities. The skills in coping with the environment which can be seen at every level are the natural, normal outcome of the evolutionary processes as we at present understand them. This is how God's world behaves.

At the lowest level we see relationships which we regard as purely (merely) mechanical. At higher levels we see inbuilt behavior patterns much more complex than simple reflexes and frequently appearing very skillful (e.g., nest-building); these we often call instincts. At higher levels still, behavior becomes increasingly flexible, increasingly perceptive; behavior patterns are seen which are not purely inbuilt but are intelligently matched to the prevailing situations. The transformation is not discontinuous, but gradual; however, it is not trivial but profoundly interesting—precisely for us who study this matter. The hierarchical character of the situation is clear. A bacterium, for example, will move in response to light; it responds to light but not to objects because it can perceive the former but not the latter. A climbing plant responds to light, too, and to touch; it rotates its growing stem to locate a support, twines around it, and climbs onward; but it still does not respond to objects as such since its sensory equipment is too poor and its internal evaluative mechanisms almost nonexistent. A frog, or similar animal, will respond to objects, discriminating one object from another, but not to individuals. A higher animal, such as a monkey, dog, some birds, and so on, will respond to individuals as such, but not to ideas. As we proceed up the ladder each organism has, to be sure, its own idiosyncrasies or sophistication of sensory devices, but, more importantly, each has ever increasing sophistication of the internal organization of its perception, including its own learned patterns, which allow it to relate to its surroundings, or neighbors, or community, or (ultimately) also to itself in the increasingly intelligent way that we observe and in which we ourselves finally participate.

To me, as I contemplate this hierarchy of envirnoment-sensitive, environment-interactive organisms, and do so in the context of the essays in this *Zygon* issue produced by the Science and Religion Forum, it seems quite obvious that it is not the development of special sense organs which is most relevant but the organization of the received sense data. The human eye can respond to a mere half-dozen photons, but this is not what makes the human special. Some bacteria detect magnetic fields, fish sense pressure-waves, bees see in the near ultraviolet, some snakes see stereoscopically in heat radiation, and some moths react to as little as 100 molecules ($\sim 10^{-20}$ gram) of their specific pheromone; but these sensitivities do not place these creatures at the top of the development ladder. It is the correlation of sensation with discontinuities of sensation (starts and stops, changes, edges, corners) which leads to pattern recognition; it is the correlation of patterns, and sense with sense, which allows the perception of objects as objects; and it is the correlation of current, organized sensation with stored, organized memory that begins to give an organism what we call intelligence in the handling of its surroundings. At the intermediate levels, and most certainly at the higher ones, there can be no doubt at all that the neural networks of any intelligently behaving organism do contain a representation of the outside world, as that organism perceives and experiences it, and that the organism upgrades and uses that representation continuously. The presence of this internal model of the external world enables the more highly developed organism to perceive and respond to that world in *depth*, that is, not merely at immediate face value; and this is depth not merely in spatial dimensions but in time-sequence depth, in dimensions of relevance, in dimensions of value, in dimensions which, ultimately, we refer to as spiritual in character.

The reader does not need to be particularly critical to note the fluid—perhaps some will say, sloppy—manner in which my remarks have moved from the human to the animal kingdom, to plants, bacteria, and even molecules, tracing correspondences rather than distinctions—distinctions which some perhaps feel are crucial, even inviolable. However, it is central to my understanding of this subject that our insight is better served by a willingness to perceive continuity than by the persistent demarcation of mutually exclusive territories.

Speaking for myself, I do see profound continuities and find them enlightening. Some may be dismayed by my sacrifice of precision. Precision, accuracy, irrefutability—I believe these to be less than divine; in fact, they are magnets to our susceptibilities. Yes, there is loss of precision in my approach, but I would suggest that precision is not always our wisest first objective.

With that, let us return to the facts of life. Consider the albatross, *Diomedia exulans*, in flight. This bird with a wingspan of over ten feet (the largest of any bird) is a sight of great beauty and fascination; it travels almost interminably over the seas of the southern hemisphere, soaring, hovering, gliding, somehow continuously airborne, apparently without effort. In fact, this creature can move through the air for hours without a single wing-beat, riding on the wind. It lives in the air, traveling ceaselessly, not just for days but for years without contact with solid earth. How does it stay aloft so long, so easily? It uses the wind which, in those parts, blows almost continuously; it travels with the wind where its speed is greater, some sixty feet up; then, when it has acquired speed but lost height, it moves lower down and turns into the wind, thereby gaining lift and height, so as to repeat the whole process again. Closer to the sea surface the wind is slower; above it is faster; the recognition of this (invisible) fact, and the clever utilization of it, allows the animal to extract energy almost indefinitely from the moving air. Now, I wish to ask, what is going on in the "mind" of this humble, yet admirable organism? The open sea has no landmarks. Seen from above the wind direction is given by the appearance of the moving waves and the spray that flies from the wave tips. The waves, their shape, and the relative movement of their wind-torn fragments have all to be perceived in depth by this bird's brain—birdbrain as it is. The bird's own height has to be computed, its velocity relative to the water and to the immediately surrounding air must be derived, and these must be continuously (and very rapidly) updated from the incessantly incoming visual, tactile, and auditory data. Does the albatross have a concept of height, or lift, or even of the conservation of momentum? We can say without hesitation that the bird does behave as though it had. Using different terminology, let us agree that this bird shows considerable "tacit" knowledge of these things and that its perception of, behavior in, and employment of its environment can properly be ascribed to inarticulate intelligence.

Human Intelligence

What then of the human animal, Homo sapiens? To this lay-scientist, it seems that human intelligence is a phenomenon (or activity) that operates in quite the same way as other animal intelligence, having the same basis of sense experience, the same genius for insight into the meaning of sense experience (what I have called "perception in depth"), and the same pleasure in this achievement. Human sense organs are not particularly outstanding, but the capacity of the human brain to digest and retain vast quantities of sense data, correlating and discriminating almost unstoppably, gradually allows us humans to perceive our surroundings not only in the sort of depth that our humbler animal cousins do but in degrees of depth that far outstrip the perception of all other species. I say "gradually" because, as we all know, this build-up in depth of perception (which we call understanding) does grow steadily and continuously from near zero in the newborn infant to a level matching that of the higher animals (in about a year) and then, without a break, on beyond that—to the point at which we here recognize ourselves to be—and on still further. In this remarkable extension of awareness one feature of particular importance is, of course, the employment of words, that is, the use of certain quite arbitrary and simple perceptions to represent complex perceptions, thereby enabling the growing mind to cope with the latter by handling just the former. Together with our enormous memory storage and greatly extended facility for internal representation, this device (symbolization), which is not in fact unique to humans but is uniquely exploitable by creatures of the brain size that we have, enables us to perceive so much, in such detail, and in such elaborate, highly organized reference to context, both in space and in time, that we are soon (in the course of a year or two) aware of *ourselves*, of the *future* and the *past* as distinct from the present, of *obligations* and *responsibilities*, and, before long, also of *God*. By the time this stage is reached, intelligence is now *articulate* and *conscious*; the perceptions that it handles can be said to be *concepts* consciously held; the activity that does all this is called the *mind*; and the intelligent organism is properly spoken of, and accepted by his or her fellows in the community, as a *person*. The deepening of our perception continues steadily while we grow from infancy to childhood, through adolescence to adulthood, and on; and we become aware of *community*, of *ideals*, of *values*, of *tragedy*, of *beauty*, of *love*—and of a thousand other concepts which, to us as persons, matter intensely.

Donald M. MacKay (1985) has already written about persons. The notion of persons must arise, as I see it, whenever sufficiently intelligent agents are aware of one another and are behaving in relation to one another. Religious thinkers speak and write on the concept of the soul. That concept arises, as I see it, when we are considering the most fundamental of our awarenesses: the awareness of God, our response to God, and God's love (as we in the Christian faith believe) for each of us. For my part, what I have tried to say is that intelligence is a quality of all interacting organisms, integral with their development, from primitive to very complex, and that consciousness stems from it, not the other way round.

INTELLIGENCE AND UNDERSTANDING

"The tongue of the wise uses knowledge correctly but the mouth of fools pours out foolishness." I hope that it is not the latter part of this proverb which you will feel characterizes the paper you have been reading. Our present age is truly an age of knowledge. Prodigious amounts of knowledge are in our possession, in our books, and in our libraries. Our libraries grow more or less exponentially as textbooks, journals, reviews, new terminologies, new acronyms, and even whole new sciences proliferate. Prodigious amounts of knowledge are nowadays in our hands and, to a lesser extent, in our minds. Even to try to know in detail one part of one part of the total is to try to become encyclopedic.

While knowledge is a marvelous thing, it is possible to have too much. In particular, knowledge is not the same thing as understanding. There is nothing new in this observation. The point has been neatly encapsulated in the well-known cliché about the forest and the trees. It is possible to miss seeing the forest not only despite perceiving its constituent trees but even owing to that perception. Simple as this cliché is, the principle it points to is of profound importance for us. For the question as to just what the forest is, or what exactly is to be taken as the forest when we are faced with a host of assorted trees, is a question which repeats itself not only in all areas of perception but also at all levels. In fact, you will notice, the principle is precisely about the distinction between levels, drawing attention explicitly to the conflict that can exist between differently aimed approaches and, implicitly, to the independent validity of different vocabularies and different approaches at those different levels. We must not forget that the Science and Religion Forum and *Zygon* exist to foster dialogue across boundaries between alternative specialisms and differing interpretations.

It does sometimes happen that even a fool can see, or cause others to see, a useful forest not seen before. It is this that I hope my remarks may in some measure help to do.

NOTE

1. Seen from a professional's point of view, I am an amateur in the areas cognate to the subject of this paper, being neither a zoologist, nor psychologist, nor any form of biologist, nor philosopher nor theologian. Professionally I am an academic chemist, specialized in the field of structural X-ray crystallography, which lies broadly between chemistry and physics.

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