MIND AND MICRO-MECHANISM,

A HUNT FOR THE MISSING THEORY

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MIND AND MICRO-MECHANISM,

A HUNT FOR THE MISSING THEORY

Introductory book ('Book A')
in a series on
Mechanisms of the Mind

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PREFACE

This work ranges over many specialist disciplines: from physics, mathematics and physiology, to psychology, sociology, embryology, and philosophy — including *history and philosophy of science* which has its own separate tradition. This spread of topics creates some obvious communicational problems, so I hope you will excuse me for using fairly elementary language in your own specialty (where no doubt your own specialized vocabulary would get to the point much more quickly). But then, of course, specialized language sometimes embodies old assumptions which may now have become questionable, so maybe such rephrasing is no bad thing in any case.

There are perhaps two reasons for supposing that this account may stimulate some significant developments in our understanding of the mind. Firstly, the suggested account *just might* turn out to be substantially correct, and that would obviously open the way to new applications, plus new research initiatives. But secondly, any such in-depth interdisciplinary[†] study is likely to highlight some questionable assumptions which may have come to be taken as gospel, or not even seen as being assumptions at all. Such a critique can be valuable in its own right, even if the solutions offered are inapplicable.

Wide-ranging though this study may be, one has to draw the line somewhere. The main focus has been on *micro-mechanisms*, as the title proclaims — and this involves ideas about *molecular mechanism*, plus the infra-red activity which one might expect to accompany it. Against that, there was little need here to emphasize middle-scale mechanisms like *synaptic activities*, nor related autonomic matters like mood and emotion, since these are already well documented. Of course such matters do arise here incidentally, if only by way of comparison and symbiosis; and interrelations like this must surely deserve further attention in the future.

Then again, I say nothing at all about *macro* matters, except Descartes' *pineal gland* postulate of 1649. — Not one word about the cerebrum, cerebellum, hippocampus, or amygdala, though clearly any micro-activity must be taking place within such macro-locations. Not even any mention of the distinction between central and peripheral nervous systems (CNS and PNS). Nor is there any need at this stage. These distinctions are clearly important, but first things first, and such matters can be discussed at a later date as the need arises.

Footnotes and index

Misunderstandings are an ever-present danger in a work like this, which is exploring new approaches in several directions simultaneously. This means that it is best to insert footnotes whenever the meaning could be misconstrued. For the same reason, I also offer an unusally detailed index. No doubt misunderstandings will still occur, but let us hope these remain within acceptable bounds. Meanwhile of course, the text has rather more footnotes than usual, but I hope the reader will bear with me on this.

The index is designed *not* to have long lists of unexplained alternative pages, but to guide the reader by means of extensive subsectioning. It is also deliberately designed to offer a second presentation of the same material as the main text — so that any reader already conversant with the background material could perhaps, in principle, reconstruct the whole argument just by studying the index alone. Of course that would be asking a bit much, but it serves as a useful aim; and it should also serve as a quick overview for those who cannot afford the time to plough through the whole heterodox text without quite knowing where it will lead them.

[†] This move to a wider view is an example of Piaget's notion of "decentring", and in practice it requires our thinking to use a "meta-level" to manipulate the sub-concepts — see chapter 8.

In particular, I have tried to arrange that this index serves (to some extent) *as a glossary* — with rather more description than is usual for an index — and offering orderly lists of examples *etc*. where appropriate.

Instead of footnotes, it is possible to tidy such commentary away into *endnotes*, and occasionally I have done this, using letters like: [a, b, c], instead of numerals. But I personally find such inaccessible text very annoying, if only because it is difficult to see just how relevant or irrelevant it may be. So, at the risk of untidiness, it seems best to have such notes ready to hand as footnotes on the same page, even if the reader decides not to consult them. But there *are* limits! It does seem best to resort to endnotes when the entry is only of marginal relevance, or where it is relevant to two-or-more chapters simultaneously — or when its *length* or position would seriously upset the page layout.

Acknowledgments

The background work for this project has extended over many years, so some of the thanks and acknowledgment is due to colleagues from the past, including some I am no longer in contact with, but whose help I value nevertheless. In particular I owe a debt of thanks to the late Professor I.A.Boyd, then of Glasgow University, for his help over the material used in chapters 6 and 7 — but I should add that any misinterpretation of this data, as presented here, is entirely my own.

Thanks are due too, to Professor F.H.George of the (now abolished) Department of *Cybernetics*, at Brunel University, Middlesex. I would also like to thank the staff of the Department of *History and Philosophy of Science* (HPS), at Chelsea College, London — and more recently, the HPS Department at Melbourne University for providing research facilities over several years.

Finally I would like to express my thanks to Ms Sherrill Hallmond of London, for exchanges of thoughts on Piagetian theory over many years; to my daughter Bronwyn for design work and guidance; to my son Declan for technical assistance; and to Dr Valina Rainer for critical comments on the later versions of this present volume.

R. R. Traill

Melbourne, November 1999

Digital Version, December 2004

Error corrections and notation-amendments to the original printing are listed overleaf. Note that any *"HTML" translations* of this file may encounter sequence-disruptions in Chapter 8. My apologies in advance for these or any other *new text-problems* which may have crept in.

The above credits do not mention those who offered more casual discussion. Most of these have been acknowledged in the following volume — “Book B”.

R. R. Traill

Melbourne, December 2004

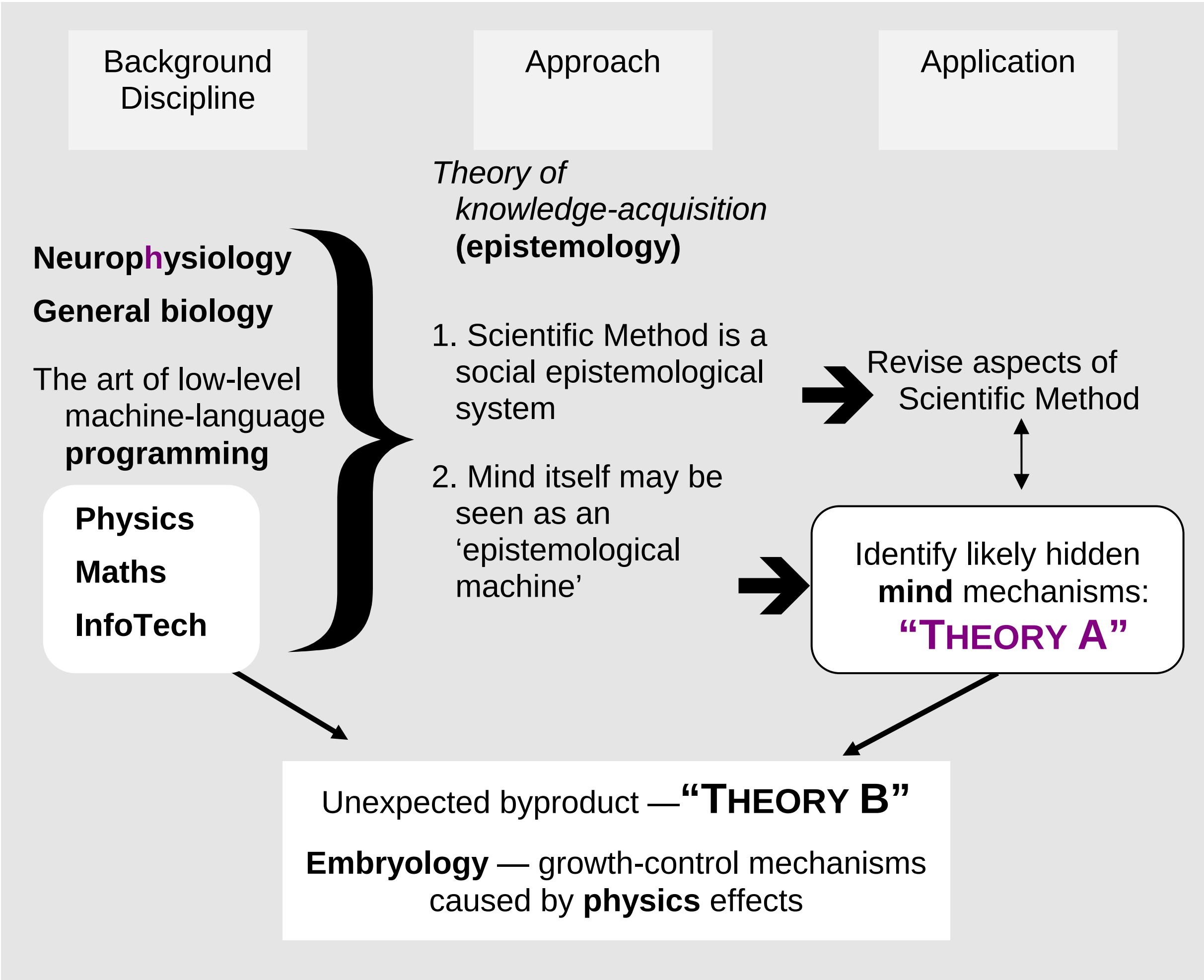
ERRATA IN HARD-COPY		
ERROR TYPE	ORIGINAL 1999 VERSION	CORRECTED 2004 VERSION
(1) Index refs to endnotes, page 98	"82"	"98(…)"
(2) Index refs to endnotes, page 99	missing	"99(…)"
(3) Top of page 15 decimal errors. (The effect of the errors was to *understate* the "incompatibility" point being made there).	"wavelengths of *2.5 to 1* ***mm*** — wavelengths in the near infra-red range, with frequencies just above ***10^8*** *cycles/sec*, so that each cycle lasts for a mere ***10^{-8}*** *sec* or less. Note that this makes any such cycle[34] *100000 times briefer* than the millisecond blip of conventional neuro-synaptic theory."	"wavelengths of *2.5 to 1* ***µm*** — wavelengths in the near infra-red range, with frequencies just above ***10^{14}*** *cycles/sec*, so that each cycle lasts for a mere ***10^{-14}*** *sec* or less. Note that this makes any such cycle[34] *100,000,**000,000*** *times briefer* than the millisecond blip of conventional neuro-synaptic theory."
(4) fig. 7:6, page 53; — (3 times)	"diagonal"	"diameter"
(5) trivia	[punctuation, spelling, etc.]	[see violet-coloured items in the digital version]

REVISIONS OF NOTATION		
NOTATION TYPE	ORIGINAL 1999 VERSION	AMENDED 2004 VERSION
(i) The shorthand names for books in this series. [The use of "zero" turned out to be confusing]	"Book **0**" (1999) — introductory "Book **1**" (2000) — Main 1 "Book **2**" (……) — Main 2 "Book **3**" (……) — Main 3	"Book **A**" (1999) "Book **B**" (2000) "Book **C**" (……) "Book **D**" (……)
(ii) The symbol for the thickness of myelin. Applies to Section 7.4 (p.54), and Index.	"d"	"m"

 — ISBN 0 9577737 0 6

1. A New Attack on the Problems of Understanding the Mind

1.1 *An overview of this interdisciplinary project*



1.2 *Just what is wrong with our present ideas about the mind?*

We now have quite a reasonable understanding of nerves, and yet we do not yet really understand the brain and its "mind" — the basis of our deeper thought processes, and our human foibles.[1] What then are the obstacles here?

In fact there is an obvious dilemma which cannot easily be solved:

- On the one hand, we *cannot observe* any thought micro-processes of the human mind/brain.
- But then our strict "scientific method" has usually demanded *full observability* at all times, even when that is not feasible.

[1] It is fashionable to point to *consciousness* also as an unsolved problem of the mind, and to speculate on its nature. Of course that is indeed a proper topic for investigation, but I shall not emphasize it here because I feel that there is little scope for real progress on consciousness until we have first solved these other, less glamorous psychological issues like creative thought. If we do get to that stage, we will then be better equipped to tackle that thorny problem. Indeed the nature of consciousness *might* even become self-evident then, given the new perspective; but don't count on it!

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Table 1-A: Mind (details unknown), compared with two other learning systems

KNOWLEDGE-SYSTEM	Coding Medium	*What* is encoded?	Main Validity Tests
GENETICS & EVOLUTION (c)	DNA	recipes for physical traits like: eye-colour, head-size at birth, pelvis size (as mother)	coherence of traits: • among themselves, • with environment.
INDIVIDUAL MIND/BRAIN (b)	?	?	?
SOCIETY, INCLUDING SCIENCE (a)	words & symbols: on paper, or spoken, or subvocal thought etc.	ideas, supposed models of reality	coherence of ideas: • among themselves, • with environment.

Impasse inevitably! — This logjam effectively abandons in-depth mind/brain studies as being beyond the competence of science, leaving the field mainly to either: *philosophers*[2] (who will often not be deeply conversant with biological or physical niceties, even though their contributions may be helpful otherwise) — or much worse, the field will be left to *charlatans*.

Then there could well be the extra obstacle of a false lead:
• Given our enforced ignorance due to the impasse, we have usually imagined that the brain "simply absorbs" input in the same way as a computer or tape-recorder does: *passively* using some elaborately pre-designed "recording device". However Darwinian biology would suggest something quite different, involving *active random initiatives,* and *self-organization*.

1.3 Prospects for detective-work on mind theory?

The present project sets out to solve this threefold puzzle, with the hope of advancing from mysticism to understanding.

Let us look first at the formal problem in general, *and then* compare some of its contexts.

Consider the generalized problem of gaining knowledge, starting from scratch, with no designer nor any teacher at that initial stage — *a seemingly impossible task, so we tend to deny it* by tacitly expecting to find designers and teachers within nature.

And now consider two different contexts in which this takes place:

(a) **knowledge in the scientific community**, with a history of thousands of years; and
(b) **knowledge within the individual** — apparently begun anew for each lifetime, but helped by strategies built into the genes and customs of our species as it evolved.

Note that in both cases some system (a person or society) has to acquire knowledge by learning, but the real dilemma is that our system must first *learn how to learn*. This same problem of "knowledge from scratch" arose in the 1850s in relation to explaining:
(c) **evolution** — again with no designer nor teacher.
My main contention is that *in all these three cases* there are mechanisms probably embodying *a similar underlying strategy*. As argued in chapter 4, this strategy would be something like this:

> *There is a prolific generation of random coding which is somehow tested for validity, and that most of it is wasted, often very early, as "no good" in some way, though this choice of what is "good" can* never *be infallible.*

Consider the set of comparisons in table 1-A. (Here we will initially treat the shaded part as unknown and mysterious. Later, we can set out to fill in these unknowns with plausible suggestions.)

On the whole, biologists do have a reasonable understanding of genetics-and-evolution (the upper row in table 1-A). Likewise linguists and philosophers have a reasonable understanding of how scientific ideas are built up and formulated in the languages of society (bottom row).

Note that there is a certain formal similarity between these two cases. *Both* knowledge-systems encode using linear "strings" of symbols. *Both* systems are likely to reject formulations which are either (i) inconsistent with other internal formulations already in place — or (ii) damaging to survival chances of that system in the real world outside; (see the last column).

[2] Here we might also include other overview experts of various types, including theologians, *i.e.* those who may offer thought-provoking contributions to the debate, but who do not really suggest any comprehensive explanation through well-defined biological mechanisms.

Both systems allow for massive quantities of such encoding, such that a large wastage through trial-and-error is a viable way for progressing. This is Darwinian survival of the fittest in a deadly contest, a slow but robust strategy.[3]

Much of the present project will be devoted to extending such analogies to the mysterious shaded section, the mind of the individual, and suggesting in some detail what plausible mechanisms could be performing such tasks.

This brings us back to the vexed issue of "scientific method", because any such mechanisms will be difficult or impossible to observe, and hence scarcely acceptable to those trained to believe in the sanctity of experimental testing at every stage.[4] After all, it is easy to agree that "seeing is believing", and then to go one step further by insisting on seeing *before* believing, or at least insisting that some supposedly reliable observer does the seeing for you. This rule does tend to guard against the sort of plausible but fallacious rhetoric often attributed to politicians. Such caution is often commendable, but we can suffer a heavy penalty if we apply the test blindly to every case.

To approach the truth, we could work hard at agreeing on firm definitions and trying to consider all relevant factors: we could • take the "*rationalist*" view and try to apply logic to pre-existing knowledge, seeking supposedly valid internal coherence. Sometimes that is feasible; and sometimes it is not. — Alas, we cannot always tell what really is feasible, thanks to deeply embedded assumptions which we fail to recognize as such.

Another way toward the truth is • the "*empiricist*" path, seeking external coherence. That exhorts us to observe carefully, and learn from the results, assuming we can agree about their future applicability. Such observation does work well in many situations in our workaday world. But so it should: just bear in mind that our powers of observation are biologically based, and they have been honed towards perfection over countless generations. This is an evolutionary adaptation for making sense of that very same *workaday world* — a development which is so successful that we now take our abilities for granted without recognizing their source, their power, or their limitations. And it is the limitations which should concern us most when we venture into study-areas that our ancestors could not have known: atomic theory; brain theory; global politics and economics; continental drift; etc.

Philosophers since Plato have often had grave misgivings about the supposedly rigorous validity of observation; and since Hume (1711–1776), the argument has taken on a more modern form. The point is that there seems to be no way of rigorously checking that any supposed observation is not an illusion in at least some respect.[5] This doubt is enhanced by certain standard effects which *are* optical illusions, and by the finding that blind people who are given their sight in adulthood do not just "see what is there" in the way we might naively suppose. So, whatever tricks we do use to get our (usually valid) observations, these tricks are apparently acquired in some pragmatic way through some combination of species-evolution and personal experience. But in the end, they are just *tricks which usually work*, and they are not the infallible guide we would like them to be.

I suggest that this applies ultimately to any type of knowledge acquisition, so in the end, they must all depend on some fallible test based on checking for self-consistency or *"coherence"* amongst concepts. So in each case, the question is: *"Does this all hang together? Does it all make some sort of sense? And if not, what changes can I make for it to make better sense?"*

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[3] The existence of Darwinian mechanisms need not necessarily rule out their opposites. These "opposites" would be Lamarckian mechanisms in which lessons about the environment are somehow written directly into the coding system, instead of having to wait for the right messages to occur by accident and then selecting them. Clearly this direct recording does happen within society and its science, though not all the time. However I would suggest that society does this by employing *individuals*, and they are "designers" from a different knowledge-system, the mysterious shaded layer, with "mysterious" minds (apparently occult in the society context) which might ultimately be operating by Darwinian mechanisms within their own knowledge-system — though of course that remains to be seen later in the project.
The important point here is, that even if Lamarckian mechanisms do exist, they cannot be relied upon all the time. In particular, they must depend on sophisticated extra devices or designers which must themselves be explained, and which could seldom exist in the early development of a system's methodology. In short, they are a luxury which will probably not help us when we are trying to generalize. In contrast, Darwinian systems are much simpler and therefore much more likely to turn up spontaneously whenever a learning problem arises; so any generalization on these lines is much more likely to be valid.

[4] I personally encountered that training twice. Once in physics, and once in psychology. There *is* some rationale for this over-insistence on experiment,[a] but it has often been applied to inappropriate contexts thanks to an indiscriminate policy.

[5] *Dreams* are the most obvious example. Are they illusions, or simple-reality, or supernatural reality? Today we may think we have a coherent biological account; but Joseph and Pharaoh saw dreams as messages from God (*Genesis* 40-41), a not uncommon view which does have plausibility within many cultural norms.
We could have more trouble over *psychotic illusions*. How do we really know that X's visions or voices are false, even though P and Q fail to experience them? There is no strictly rigorous test (empirical or otherwise), but in practice we can usually appeal to social self-consistency: (i) his supposedly-real dragons or voices do not cohere well with other scientific ideas; also (ii) P, Q and others can together outvote X in a statistically valid way. — Of course, P and Q could occasionally be conspiring to falsify this evidence! In that case X may be made to *appear* psychotic; (Asche, 1956). So once again, can we ever be truly certain about which is real and which is illusory?

It is probably no accident then that the three already understood knowledge systems appear to be based on clearcut digit-like codings. Society, including science, uses *well-defined letters and symbols*, even if the resulting *words* are less clear. Genetics uses the "four-letter alphabet" of the genetic code embodied in long strings of DNA. (Likewise, there is a similar DNA-RNA-protein basis for the immune system, also engaged in knowledge-gathering, though I have avoided mentioning it until now because immunological examples seemed a bit too esoteric for the introductory discussion.)

So, it would not be too surprising if the mind were also based on an "alphabetical written code" with a similar clearcut physical embodiment of some sort,[6] and not just based on the synaptic patterns of nerve junctions, (even though these synaptic patterns clearly do exist as well, and have their own importance).

Indeed there are some strong hints in favour of such an inbuilt digital repertoire for each individual, hints which have long existed within the Genevan body of psychological theory, as we shall see in chapter 2.

1.4 This notion of "coherence" or self-consistency

We have just been considering coherence, or self-consistency, amongst concepts — asking ourselves "*Does it all hang together?*" and so on. That is surely an important property for collections of ideas or theories, and a frequent ingredient in detective novels, or the verdicts of real juries. Whether we recognize it or not, we may sometimes give just as much credence to self-consistency as to the supposedly more respectable direct evidence; and, with certain reservations, I will argue that this division of labour is generally the best course.

The main danger is, perhaps, that self-consistency judgements are more likely to become significantly distorted by parallel issues which should not be relevant — "conflicts of interest" (whether conscious or not), notably ego-involvement, or vested interest.[7]

Concerning terminology. "*Coherence*" has hitherto usually been taken to mean much the same as "*self-consistency*". In this project, there is a slight variation. For reasons which we will come to later on, the perception process within the mind (or experimentation within science) is here seen as *a special case of coherence seeking* — so the notion of coherence has to be extended to cover this "rival" procedure also.

Accordingly I use the term "**internal coherence**" for the self-consistency, and "**external coherence**" for the empirical testing which involves the senses. In fact it seems best to use both, in about equal measure in the long run, and we may call this "**balanced coherence**".

(1). Coherence procedures in the social knowledge-system

As adults we usually have no trouble in seeing the difference between a coherent explanation and an incoherent one — at least in cases where our own interests do not sway us too much, and provided the issues are not too involved, or too unfamiliar. But we tend to take such well-honed abilities for granted — using them on many occasions, but with no clear idea of how such procedures work.

This creates a problem when we want to pass on our findings to our colleagues. If we cannot actually explain clearly why our case is internally coherent, then the best we can do is appeal to others to use *their* own adult skills in the same way. If they do this, they may still have serious doubts, and not without reason because the process is left mysterious and uncontrolled, which essentially means "subjective". Moreover, if their background experience is substantially different, they may not even be able to see the supposed coherence at all. (In principle, special aid could then be provided; but that will surely be difficult to do effectively because we do not properly understand the process ourselves).

Thagard (1992) has made inroads into this problem, offering computerized procedures for evaluating various ensembles of explanatory propositions; and we may note that he includes both types of evidence: empirical *and* self-consistency (external and internal coherence). However, it seems that it is still left to human judgement to decide what factual items tend to explain this-or-that theory. Only then does the computer analysis begin — after the more basic judgements have been listed.

In the context of his own book, that hardly matters. The initial judgements are not particularly contentious as they are mere candidate components for a later major decision. So no-one is likely to challenge the subjective basis for these preliminary judgements.

For instance, his page 48 gives us two candidate explanations for what we now call *oxidation*, or its reverse:
• "metal can be separated into its *calx* (oxide), and *phlogiston*"; or
• "calx can be separated into its *metal* and *oxygen*". On the face of it, either suggestion is plausible, though they cannot both be right in this case. Arguably the main task of science is to weigh systematically all such suggestions plus related evidence, and then tell us which ensembles offer the best fit — a matter discussed further in chapter 5, below. But how do we really know that a suggestion is plausible rather than preposterous?

[6] This basic mental coding would have no direct connection with the linear sentences of ordinary spoken language. These linguistic word entities are a late and complex addition as far as the individual is concerned. True, they *are* the basic underpinnings of *social* knowledge; but that is a different knowledge-system. Failure to appreciate this distinction has led many mind theorists astray.

[7] We could also add *unconscious assumptions* and *tunnel vision distortions*, but then these failings could equally well be biasing the alternative — the supposedly objective observations.

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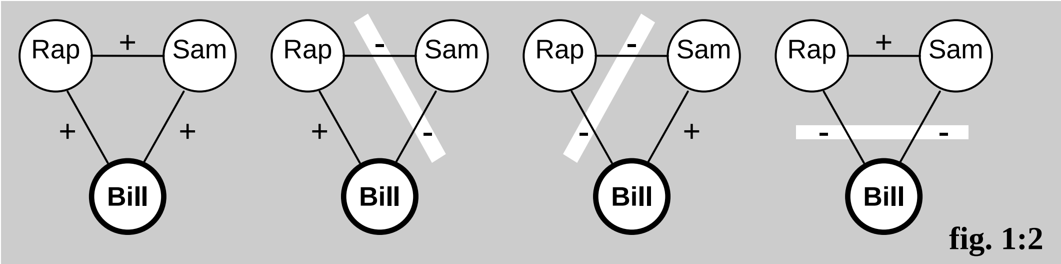

fig. 1:2

The above two conflicting suggestions are based partly on "common sense" *unanalysed judgements* as to what constitutes a plausible explanation of oxidation. For most scientists that subjective element does not really matter (as such judgements of likely relevance seem fairly obvious and uncontentious). But if we are primarily concerned with mind theory or the finer points of any other knowledge-acquisition process, this preliminary conceptualization is just as interesting as Thagard's grand analysis which follows from it.

(2). Cognitive dissonance theory, and the individual mind

How do we form judgements, especially when language is not involved? If our minds use material mechanisms for such tasks, how are the basic elementary concepts encoded? How do they link up with other elements, and what are the dynamics and consequences when such linkages change? Then again, what induces such changes in linkage or affiliation?

No-one yet knows all the answers, so we may take that as a challenge. Later on we will be looking into the likely nature of the basic elements of mind and memory, (a contest between synapses and macromolecules), but we will not pursue that matter right here. Instead let us concentrate on hypothetically possible *linkages* between those elements or their aggregates (whatever they may be); and we may start with the individual's opinion as to the *compatibility* between two such items — a *mental link* between the two concepts.

In the 1960s there was considerable interest in cognitive dissonance theory — an attempt to explain or predict the way opinions would change if faced with internal inconsistencies. After all, if our ideas are mutually inconsistent on some topic, we may find that uncomfortable and try to reformulate our ideas to improve their internal coherence. Even if that means we have to change an opinion or two, that just might be a price we are prepared to pay.

As shown in figure 1:1, the simple basic paradigm for cognitive dissonance is a simple triangle of associations which may be positive or negative. Thus Bill hates Sam, and he also believes that Sam likes Rap music. Will this influence his own attitude to Rap? Well, our own experience of human nature suggests that Bill will indeed be influenced, and tend to dislike Rap music for that very reason.

Alternatively, if Bill were actually very fond of Rap initially, he might tend either to deny Sam's liking for it, or else decide that Sam was not quite so odious as he had thought. These three possible changes were usually expressed as a semi-mathematical rule-of-thumb such as: "*The system will tend to change so that there will be an even number of minus signs*" (i.e. *2 or 0*). That neat and concise recipe may be fine for computers, but it does not seem very illuminating about possible bio-mechanisms.

This becomes rather more meaningful if we interpret the minus signs as a boundary-line, dividing the threesome into two subsets — each coherent in itself, but neatly broken off from the other, see figure 1:2. So this could be seen as just part of a much bigger process of categorizing items into meaningful clusters or "*sets*" whose members embody common attributes. Meanwhile though, these members differ significantly from the members of other sets.[8]

Figure 1:3 gives some idea of how the complexity of the situation might be developed. Here we might expect that the rather unbalanced situation would sort itself out by adjusting one-or-more of these figures until the ensemble either consolidates (with all signs ideally being plus) or else separates cleanly into two or three individual sets, each coherent within itself.

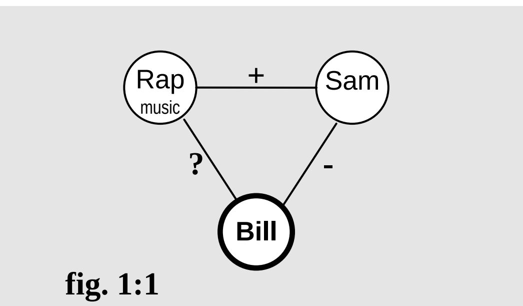

fig. 1:1

[8] We could also see this as a process which translates *descriptions* into *captive lists*; i.e. from definition by *attributes*, into definition by "*putting any found examples safely into a cage*". These are *intensive* and *extensive definitions*, respectively.[a] Probably much of our thought processing would involve re-classifications of this sort, as we adapt concepts for differing uses.

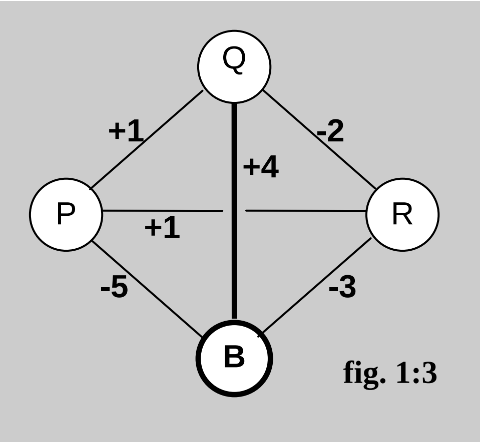

fig. 1:3

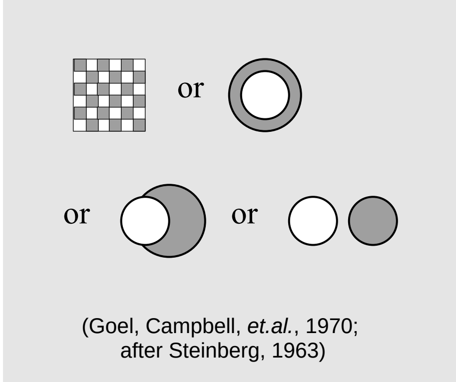

fig. 1:4

I am not concerned here to actually work through such examples.[9] I merely want to pose some of the methodological problems which the self-organizing mind would presumably have to face.

As an outside observer, I have just interpreted the purpose of this activity as *set*-formation; but the basic elementary mechanisms of the mind will not have any such self-insight. (Natural selection will probably have ensured these mechanisms are there, simply because they do help in the survival task, and not because "they have the right objectives"). So if it is actual mind-mechanisms we are seeking, perhaps we should forget the interpretive white lines through the minuses in figure 1:2, and go back to simple rules-of-thumb which a simple mechanism could apply blindly. Actually I don't think the given *sign-rule* is simple enough or biological enough, so it will remain unenlightening. But we may keep it in mind for the moment — until we can offer a better suggestion, perhaps in section 2.4.

(3). Simple link-tactics for the mind?

Simple rules, suitably applied, can produce impressive results — and fractals are perhaps the best known example. Another useful example was offered by N.S.Goel and colleagues, showing (by computer modelling) how units such as cells can form various cluster-types according to the settings of certain simple force-values. Thus (see figure 1:4):

> *More significantly, the immediately following paper considered what happens if the "cells" are anisotropic (effectively having "heads and tails" instead of being just directionless blobs). In this case, the "cells" formed themselves into shapes which look surprisingly like natural anatomical structures.* (Goel and Leith, 1970).

In these cases, the self-organized results were clearly physical structures, with the basic units physically adjacent to each other. In modelling the mind's activity, our problem could be a little different in some of the detail. Probably the main difference is that there is no longer any need for related items to be physically adjacent — a "*telephone connection*" should do instead, or even a "*radio link through empty space*" — provided that the body has the right technology to accomplish these feats. Indeed, as we well know in this era of mobile phones, this adds great flexibility to the system; so organizations tend no longer to be confined to the one physical building or campus.

However that raises the problem of what basic entities are being linked, and the related problem of just how the "telephone or radio links" could be operating within the mind/brain, and even assessing the coherence as well. Further discussion will have to await the analysis of some other technical matters, but we will return to this topic in section 2.4. Meanwhile, some half-answers to ponder until then.

The likely basic entities are of two types, and they may well coexist: (i) the traditional synaptic junctions (and of course they already have an acknowledged "telephone line"); and (ii) molecular entities of some sort. If the latter are to communicate beyond their immediate physical reach, there may be no option but to use some form of photochemistry.

> *This ends our digression into coherence and its ramifications. Let us now return to other preliminary matters.*

1.5 Strategy for explaining a new system to already busy sceptics

Fighting on two fronts must lead to compromise of some sort. The present project covers a wide range of interdisciplinary ideas and their interrelationships, and ideally I should explicate them all in full. On the other hand, who wants to go into masses of fine detail over some newfangled account which *might* (as far as any would-be reader can tell) be leading nowhere? If the fine detail is actually required, it should perhaps come later, after the *prima facie* case has been established.

[9] For further discussion, see the book edited by Professor Martin Fishbein: *Readings in Attitude Theory and Measurement*.

Accordingly, this present work "**BOOK A**" temporarily abandons some rigour in an attempt to offer a more readable account. Nevertheless I believe it addresses the main issues; and if it does fall short, there will be plenty of opportunity to correct matters later within the project. Meanwhile however, I have paid more than usual attention to self-consistency (for reasons which will already be apparent), and this might even compensate somewhat for the other omissions. Indeed we have seen that internal coherence-seeking has value in its own right; and this applies especially when there is some problem about collecting or presenting external evidence.

In the rest of the project, it is already clear that we will be left with some very real logistical problems doing justice to the technical niceties and the ill-organized experimental evidence. Hence, even at an earlier stage, it seemed necessary to divide the subject into two later main books; and those have now became three.

Of these, "**BOOK B**" is needed to describe the underlying **"hardware" mechanisms**, whether known or merely postulated: mechanisms capable of offering the apparently-required digital system and its related support systems.

"BOOK D" will then be free to apply these mechanism concepts — re-writing the psychological **"software" theories** of the Genevan school, and making their hitherto abstract ideas much more concrete.[10]

Meanwhile the need for an intervening **"BOOK C"** arose from an unexpected windfall development relating to embryology. In the scrutiny of technical requirements for *Book B*, and especially the "related support systems" which were needed to cope with newly-suspected signalling requirements, it became obvious that these same newly postulated signalling systems were also theoretically capable of *determining the dimensions of their own signal-channels;* and circumstantial evidence suggested that they might be doing just that. This then offers a bonus — answers to questions within a separate branch of physiology — answers to questions which nobody seems even to have asked before, let alone solved. (You can find the preliminary essentials of this argument in chapter 7 of the present work).

Of course, experimenters have meanwhile made considerable progress regarding *chemical* growth factors; and such chemistry-orientated developments are normal for physiology. The novelty in the present project is the use of *physics* rather than just chemistry. (Both have valid contributions to make, but of the biologists who are conversant with the "hard" sciences, many more of them feel at home with advanced chemistry than with advanced physics, so there has been an inbuilt biased outlook in this field).

Chemistry can explain why such-and-such a growth is allowed to take place, and how materials are transported. Physics, on the other hand, may sometimes be better placed to explain the actual mechanisms, and hence what determines special features like micro-shape, some directional events, and limits to growth which are not due to depletion of nourishment. And of course, physics can ultimately explain the chemistry too — a point which Rutherford delighted in pointing out!

Anyhow, the physics developed for *Book B* did offer this by-product, and I could scarcely ignore it. Apart from being potentially important in its own right (lending further possible insight to embryology etc.), it offers an unexpected *extra coherence* to the mind/brain project's ensemble of theories. Moreover, in so doing, it helps to illustrate the very process of coherence-seeking which (I suggest) all knowledge-systems must ultimately depend upon — for better or for worse.

In short then, I deem it necessary to set forth the whole integrated system of "heretical" ideas in an extended but interrelated trilogy. I can hardly avoid such close attention to rigour when venturing into new arguments, but I also see the need for a somewhat *informal* version as an introduction to the new "heresies". Hence the current *pre*-book:

1.6 The present "Book A"

This book is essentially a prologue, and parts of it are just papers from various conferences and seminars, edited to some extent. As such, it makes no great claims to balance, nor to rigour; though the more exhaustive accounts will appear in due course.

As is now well understood within philosophy, all claims to knowledge are ultimately fallible (to a greater or lesser degree[11]), and remain that way *forever.* Indeed that is a major premise regarding all four of the knowledge-systems considered here. So, of course, the body of theory proposed in this project must also itself be regarded as fallible, and especially at this initial stage. However that is also true for any rival theories. I suggest too that several aspects of the proposed theory do not yet have any rivals. These aspects answer questions which had not been seriously asked nor answered, and which would seem to warrant at least some investigation. Even if the proposals turn out eventually to be wide of the mark, we might reasonably expect that they might have generated some useful debate and investigation in the mean time.

Chapters 2 and 3 offer a brief summary of the project's main overall arguments and assertions relating to the mind: the short "coffee-room account" with minimal evidence or justification, just discussed a page or so earlier. You may

[10] A good analogy for this advance might be found in the conceptual leap within genetics when DNA's role came to be understood. Explanations then progressed from merely using the abstract concept *"inherited trait"*, and developed into the clearcut *DNA account, with a "digital" encoding for genes*.

[11] We do often succeed in establishing some "fact" *beyond all reasonable doubt*; but theoretically, we can still not be absolutely sure because we have no criterion for absolute certainty. And what criterion should we use to decide what is 'reasonable', and why? "Careful observation" cannot solve the problem, because it too is fallible.

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find this the best place to start if you are interested in understanding the overall approach.

Chapter 4 comes from a seemingly mundane departmental seminar of 1994 discussing "four epistemological systems",[12] described as "knowledge-systems". At the time, I attached no great importance to this paper, but I now see it as offering a much more rhetorically persuasive case than my original bases of reasoning. This new argument (already previewed above in table 1-A) draws potentially helpful lessons from comparing[13] four different systems which are faced with the same formal problem: *how to get knowledge*[14] *about the environment when you must have ultimately started with no knowledge, nor tools, nor instructors, nor designers.* I go on to argue that all four systems are probably using the same formal strategy to solve this "impossible" task.

Chapter 5 sets out to discuss theories in general, plus the practical problems for the theories to be tested efficiently, and for them to gain public acceptance. It also discusses how a simple misconception in the basic assumptions behind theories can lead to conclusions which are quite misleading, for the time being, at least. The cases considered include the now-solved debate over continental drift (Le Grand, 1988), and the present *mind* theory, thinly disguised initially as an anonymous *Theory X*. (Thagard's book, *Conceptual Revolutions*, gives an alternative treatment for many of these issues — covering some of the same ground, but in a different way).

Appendix B and *appendix C* are two questions-and-answers from the original live presentation of this paper, plus some afterthoughts: firstly on the modelling of intuition and suchlike; and secondly concerning the possibility of occult influences at the synapse, as proposed by Sir John Eccles.

Chapters 6 and 7 offer an interlude re-examining the nature of subjectivity, its place in natural perception, its oft-overlooked role in supposedly objective investigations, and the special circumstances when it may be of further scientific use (provided we understand its strengths and weaknesses). This discussion centres around a particular set of data which is, in itself, relevant to the project. If this impressionistic evidence is to believed, it suggests a previously unsuspected mechanism for regulating myelin growth. But even if it is quite unreliable, it meanwhile prompts investigation into a promising problem area.

In that case, this rather insubstantial suggestion would perhaps be analogous to a random mutation[15] which just happens to pass the test of *usefulness for survival* (one type of coherence test); and it is more clearly analogous to Kekulé's famous *dream* about a ring structure for benzene — a dream which happened to lead to the right solution to his problem.[16]

A dream is not considered reliable evidence, at least not in contemporary Western society[5], but if it just happens to suggest an idea which coheres with other notions or evidence enough for us to accept it scientifically, who is to complain? Moreover, dreams are presumably based on experience of some sort, and that may be relevant in some way even if that relevance is not apparent; so their success rate may well be better than "purely random guesses" based on no experience at all; if indeed such pure naiveté is possible. And after all, even the lowly random guesses will suffice (collectively) if the circumstances are right.

In this case the idea came, not from a dream, but from a chance observation of a pair of scattergrams which suggested a hitherto unsuspected relationship.[17] This *may* have been a genuine effect, or just an artefact — I do not know yet. But in a sense that does not matter! — The important thing is that it prompted an apparently fruitful idea (just as Kekulé's dream did, and just as staring at cloud shapes might do!).

[12] *Namely* • brains; • the genetic code held on DNA; • the immune system; and • language-based society, including science.

[13] This is *no mere poetic* analogy (though such loose associations might suffice for rhetoric). The four systems can actually be seen as formal models of each other in important respects. So if there are any mathematics or problem solutions which apply to one, they will probably also apply to the others, if only in extreme cases.

[14] In this context, the word "knowledge" is ambiguous, as Thagard (1992) points out. • As used here, (and as used by computer theorists) knowledge is a body of encoded information which purports to represent the truth, but is acknowledged to be fallible. Essentially it means much the same as "belief" when applied to an individual mind-brain.
• Philosophers usually take a more purist view, seeing knowledge as "*justified true belief*" or something similar (Lacey, 1976, page 57); but if that really means an encoding of "*infallible truth*", then such knowledge must be rare indeed, as Lacey seems to suggest. On the other hand, if we were to interpret "*justified*" in terms of well corroborated coherence (in various internal and external 'dimensions', and with no significant contradictions), then we could perhaps claim our belief to be "*true beyond all reasonable doubt*". That is probably what we do in practice, and it serves us reasonably well; though it could still lead us astray occasionally.

[15] Actually it is probably much better than just random. After all our perceptual "subjectivity" or intuition has evolved its present finesse, exactly because this sort of interpretation is usually helpful. Certainly it is fallible, but it would fail rather less often than a random mutation would. (For more on the allusion to Darwinism, see chapter 4)

[16] Oft quoted and re-quoted: e.g. Miller (1987); and W.I.Beveridge (1950) who quotes J.R.Baker — based on G.Schutz's (1890) account in the German journal *Berichte der deutschen chemischen Gesellschaft*. (See "References").

[17] This chance observation is reported in chapter 6 and also discussed in section 7.4, where a possible rationale is offered.

Of course the idea then needs to be tested somehow, if only by internal consistency (now done enough to encourage further work); but empirical tests are also highly desirable if at all possible and affordable. If high cost is involved, no such experiments are likely to happen until the relevant theory has first gained some following. Then we may have to choose between various possible experimental investigations. Some experiments may look likely to be more cost-effective than others, or more likely to get directly to the root of the problem. Re-doing the scattergrams which prompted the idea *might* serve these purposes, though I have some doubts. However there are probably many other suitable lines of empirical investigation, given the will *and* the funds.

Chapter 8 further explores concept structure, drawing on ideas from mathematics and metaphysics, the work of Piaget and his colleagues and more recent work in natural and artificial intelligence. Suggestions are made for understanding some of the functions and malfunctions in the human mind/brain, notably in humour, play and sleep.

Chapter 9 summarizes this preliminary work.

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2. A SUMMARY OF THE NEW "MIND HERESY" — THEORY A

2.1 Software of the mind[18] — some features which may be essential

In the above discussion, we were looking for an explanation for how the mind acquires knowledge. That suggested the need to fill in the shaded part of table 1-A, reproduced here (with only slight changes) as table 2-A:[19]

For the moment, it might be best to forget about external evidence and work instead on the basis of *"what if?"* In other words, let us suppose these ideas just came out of a brainstorming session, and let us assess them collectively to see if they *make sense as an ensemble*. That, of course, is an *internal coherence test*[a,(b)] — a test which I have suggested is crucial both to our own thinking and to any other system which successfully gathers information, including any "other person's mind" which we may be studying.

Coming back to table 2-A: **[a]** *What are the most basic code-entities held within the mind, and used as the basis of intelligent thought?*

Could it be codes for *objects*? And if so, exactly how could the coding system work? (Remember that any such system must have widely general applicability, and be capable of self organization).

No, I suggest that *whole-objects are not good candidates* for basic units within the mind. Admittedly our adult brains may well *contain* templates for objects like "table", but I can see no credible way in which these could be the most basic entities. Surely the lines which we draw in representing them are *more* basic and useful as generalized building-units?[20] — And computer-intelligence people would tend to agree when they build object-templates, *using elementary lines or suchlike* as the basic units.

(There could, perhaps, be special exceptions for particularly important templates in the newborn such as "face-like"; and if they really are exceptions, then so be it. But even then it is worth considering how such ready-made templates would have been inherited. Thus, one economical design would be to insert some simple special organizing-mechanism into the genetic code — a mechanism which would prefabricate this essential template but do so using the same standard building units that would be used for any normally-produced template.

Table 2-A: Mind (details sought), compared with two other learning systems

KNOWLEDGE-SYSTEM	Coding Medium	***What*** is encoded?	Main Validity Tests
GENETICS & EVOLUTION	DNA	recipes for physical traits like: eye-colour, head-size at birth, pelvis size (as mother)	coherence of traits: • among themselves, • with environment.
INDIVIDUAL MIND/BRAIN	**[c] ?**	**[a] ?**	**[b] ?**
SOCIETY, INCLUDING SCIENCE	words & symbols: on paper, or spoken, or subvocal thought etc.	ideas, supposed models of reality	coherence of ideas: • among themselves, • with environment.

[18] *Book D* will deal with this in depth, based on the concepts of Piagetian psychology.

[19] It is also leading towards table 2-B, below — where the blanks will be filled with some tentative answers.

[a,b] All the letter cross-references (a, b, c, …) refer to the endnotes, starting on page 98.

[20] This topic is discussed in more detail in chapter 8. There we will take a more formal look at structure — especially the structures which might exist within the mind/brain — and how they might represent other structures elsewhere.

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This building-mechanism would just *get in early — without waiting for "planning permission" from the individual's own experience.* Nature might well have adopted such a strategy, in which case we could still validly suppose that *all* object-encodings are built up from standard sub-elements. But if not, we can still no doubt allow a few special exceptions.)

Accordingly, instead of taking objects as basic, I choose instead to follow the lead of the late Professor J.Piaget of Geneva[c]. His view was that the basic units for conceptualization are **the encodings for *elementary* actions** (often representable by drawn lines) — and like the elements for the two other layers in table 2-A, I suggest that these encodings are likely to take the form of linear "sentences" of digit-like symbols.

According to this view, we can still arrive at encodings for objects, but these object symbols are now seen as secondary entities: ultimately represented by *ensembles of actions* such as tracing-movements with the hand or eye (or both), or by manipulations such as rotating an object.

Piaget himself kept this idea abstract, using the term *"scheme"* to represent the action-encodement (and, confusingly, also for ensembles of these elementary schemes[21]). Indeed I know of only one or two occasions[27] when he explicitly raised the possibility that we might identify these schemes with physical structures within the brain. This noncommittal abstraction was probably wise at a time when society saw experimental justification as so important — but it meant that this aspect of his theory was left as "barely scientific", and only an adjunct to his clinical work where he *was* able to conduct tangible observations and experiments.

However I see this clinical work as masking his much more fundamental achievement in offering a fundamental bio-mechanism for knowledge-acquisition.[22] On close inspection, this is clearly a Darwinian type of approach, with *schemes* playing a role similar to that of chromosomes. Piaget's theory thus seems to be a worthy candidate to fit into the table. Here it provides a credible entry for the "[a]" cell, even if we are not yet sure what the schemes might be physically.

Returning to the table, let us consider item **[b]**. *What mechanisms-and-procedures could perform the postulated coherence tests?* This would seem to be a task of some sophistication. If we are left with only a traditional neuro-synaptic model, it is difficult to see any way of proceeding further. On the other hand, with a digital-like coding system within the mind, the table suggests we might at least find parallels in society's use of language, or perhaps in the operation of the genetic code.

One pre-requisite would probably be the ability to form "sets" of entities — an important first step towards modelling reality. This could take the form of some sort of egalitarian "cooperative" of the relevant schemes, provided there is some influence to draw them into contact, and keep them in contact. Alternatively such an organization might arise under the influence of some "authoritarian" master-scheme, heading a modest hierarchical organization. Or the arrangement could *start* as a cooperative, and then be taken over by a master-scheme (perhaps a promoted member of its own set) provided that this arrangement had advantages such as decisiveness, or scope for further organization (see chapter 8).

Such control-or-linking might sometimes take the form of a physical glue-like bonding, but it is perhaps more likely to be implemented through some sort of cross-referencing *informational* connection, as if using specific phone-numbers to specify "connections". (This would be much more flexible and would allow such specialities as: (i) coordination amongst multiple redundant copies of the same coding[23], as a security measure; (ii) virtual "structures" which need not be limited to the geometrically possible; (iii) mechanisms for coherence testing, see sections 1.4 and 2.4; … etc).

> *Such abilities may seem a bit far fetched, but then the abilities of the human mind do seem a bit far-fetched when one tries to duplicate them on a computer or some other model. Guided by the analogies in the table, our best bet is probably to opt for some mechanism of this sort — provisionally of course, in case something better turns up later. Meanwhile, I am not aware of any credible alternative, so I would invite you to bear with me in further exploring this possibility.*

The main obstacle may be to account for the rather specialized *communication system* which seems to be needed; but as we shall see later, there are good *independent* grounds for supposing that such a system exists — with signals consistent with the biochemical quantum jumps which are likely to be involved. In fact most of *Books 1 and 2* will be occupied in working through the unexpected consequences of this postulate about a second signal-mode — including the windfall explanations concerning embryology referred to earlier, and previewed here in chapter 7.

[21] It might be helpful if a different word were used for these compound cases. Piaget does offer a variant word '*schema*' (plural '*schemata*'), but unfortunately there is some confusion about its exact meaning. Furth (1969) makes some confident assertions on the subject; but even if we agree with him, there is no guarantee that other writers will do so. Here, for the time being, I choose to dodge the issue altogether, and use "scheme" for *both* the simple (RNA-like?) and the compound cases — relying on adjectives to distinguish the these different cases.

[22] Piaget called himself an *epistemologist*; and epistemology is *the study of knowledge and how it is acquired.*

[23] Each copy might also have *the same* "phone number", and they might then respond in unison.

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I should mention two other interesting consequences of this general scheme-system postulate. Firstly, it seems some schemes specify actions in the external world, while others encode "actions" within their own private-mind realm, thus enabling them to work upon other schemes in some way or another. Thus in some ways the mental distinction between internal and external activity disappears, so any procedure for testing *external* closure or coherence might well be much the same as the procedure for testing *internal* closure or coherence.[24]

Secondly, consider the apparent ability for some schemes to "herd" others into sets, which then form into "compound schemes". It seems that these new compound-schemes can then in their turn be herded (probably in a virtual non-tactile sense) into a higher-level of compound control — and so on recursively. At any rate, that fits in with Piaget's notion of multiple successive levels of development in humans — the basis of his better-known clinical work, as applied to the classroom. (That seems to be what sets humans apart. Other mammals may arguably manage several[25] levels, but they cannot develop the *further-extended mental hierarchy* in the way that humans can).

[c] *What physical digital bio-code could serve as Piaget's "schemes"?* It would seem that the code really does need to be *sentence-like*, with some sort of *digital alphabet*, if it is to have any hope of offering the sophisticated self-organizing structures which apparently underlie the human mind. The familiar neuro-synaptic system is clearly indispensable for some purposes, but there seems to be no way that such a floppy analogue system (with no clearcut linear ordering) could possibly offer the mind-mechanisms postulated above. So where could we find such a coding system?

[24] Of course this diminished distinction within the mind, between internal and external, will also open the possibility of illusion and fantasy, and it raises once more the question of how we actually do tell the difference, usually. However we will not pursue either matter further at this stage.

[25] The actual number of stages is perhaps debatable. Piaget identifies four key levels, typically predominating in humans at the ages indicated, starting with "sensorimotor" as the supposed lowest. Thus: *sensorimotor* (0 to 2 years), *pre-operational* (1½ to 8 years), *concrete operations* (7-11 years), and *formal operations* (11+).

As it happens, I suspect that there should probably be one or two extra simpler levels *below* the sensorimotor, and we will look at this idea in chapter 8 (page 61 and thereabouts); but that complication need not detain us here. (Also see "basement" in the index).

The actual point right now is that there seem to be *at least four* human levels, suggesting multiple recursion of some fundamental set-forming strategy in humans. (Fractals offer a similar example, with multiple successive applications of the same formula, with strangely spectacular results sometimes). Other mammals may have limited recursion, but for some reason they cannot progress much beyond the sensorimotor, and so never acquire language as we know it, nor the powers of mental abstraction so characteristic of humans.

It is hard to see how this could be anything other than one of the several types of linear macromolecule associated with the genetic code: *DNA* itself, or *RNA*, or some of the *protein* built according to the code on RNA — or perhaps it is the more primitive *PNA?*[26] — Or maybe some combination of these?

Note that, in any of these cases, it then becomes easy to explain any *inherited behavioural traits*. We can simply postulate that the relevant scheme-codes are held on the DNA of the genetic code, and then translated (if necessary) into the appropriate form: RNA or whatever.

Given this short list of codable structures, which alternative is the most likely for embodying active Piagetian schemes, if they really exist as postulated? I would suggest that *DNA* is too stable for it to be directly involved. *Protein?* It is excellent for producing specially shaped *physical* structures (because it incorporates various lumps, kinks, and linkages along its linear sequence, and these then fold or "knot" the sequence into reproducibly-shaped blobs or "keys" or "keyholes", etc.). That is fine for physical "buildings", but by the same token it is not very promising if we seek a medium for pure communication. After all we do not find it helpful to have our recording-tape tied up in knots, no matter how impeccable the information on it may be!

That seems to leave us with PNA or RNA, and I shall tentatively opt for the latter. In fact Piaget himself, on one of the rare occasions when he dared to comment on such physical possibilities, did drop some hints that RNA might be the answer.[27] Indeed there is a body of experimental evidence, from such investigators as Hydén (1967), and the ones cited by Piaget, suggesting RNA's possible involvement; though none of this seems entirely convincing on its own.

Moreover RNA would seem to be sufficiently unstable to account for *forgetting* — or at least the forgetting of any scheme-memories *which have not become stabilized* into a meaningful set, whatever that might entail. (Note that it is very important for us to be able to forget meaningless trivia — and especially so if we envisage a "wasteful" Darwinian model for the mind, where there must be masses of hopelessly bad trial-thoughts to dispose of!)

Furthermore it seems that about 80% of the genome cannot be accounted for as producing meaningful protein (and therefore physical structures). Could it be that some of this is actually serving some other function, such as providing RNA *as elementary template-schemes* — and *NOT* for any protein-structural purpose?

So now we are in a position to fill in the shaded area of the table — at least provisionally. See table 2-B.

[26] See, for instance, Böhler *et al.* (17 Aug 1995) in *Nature*.

[27] Piaget (1967) *Biology and Knowledge* — citing, amongst others, Babich *et al.* (1965: Aug & Nov).

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Table 2-B: Mind (details inferred), compared with two other learning systems

KNOWLEDGE-SYSTEM	Coding Medium	***What*** is encoded?	Main Validity Tests
GENETICS & EVOLUTION	DNA	recipes for physical traits like: eye-colour, head-size at birth, pelvis size (as mother)	coherence of traits: • among themselves, • with environment.
INDIVIDUAL MIND/BRAIN	RNA ?	elementary action-schemes & ways of combining these. (J.Piaget)	coherence of action-patterns: • among themselves, • with environment.
SOCIETY, INCLUDING SCIENCE	words & symbols: on paper, or spoken, or subvocal thought etc.	ideas, supposed models of reality	coherence of ideas: • among themselves, • with environment.

That completes the very cursory summary of the proposed physical basis for Piaget's theory of the mind.[28] Let us now take a look at the associated problems of signal-linkages required if the above system is to be credible. This is essentially a question of "bio-hardware" — the basic physics of how molecular sites might be linked to each other and to the orthodox nerve-traffic which communicates with the outside world.[29]

2.2 New communicational links and channels — within the old structure?

For a long time it has seemed to me that there were two things wrong[30] with the traditional account of the nervous system's signalling techniques. Fortunately these two criticisms both point to the same revision to the theory, and we will come to that shortly. But first we had better look briefly at the traditional account.

The main "wires" within a nerve are *axons*: long tube-like "arms" growing out from the main bodies of nerve cells (neurons)[31] — and typically any given axon will have a constant untapered diameter of several *microns* (or "*μm*").[32] These axon tubes come in two main types, according to whether they are insulated or not.

[28] Further details in chapter 8, and in *"BOOK D"*.

[29] Also see *"BOOK B"*.

[30] I suggest the two deficiencies in the present account are, to put it briefly: • The need to add digital mechanisms, see section 2.3, and the start of 2.1[c]; and • A common misunderstanding about how electromagnetic signals are actually carried by their "cables" — see chapter 3.

[31] The root-like *dendrites* are also another type of "wire", but they need not concern us here.

[32] Such a *micron* or *micro-meter* = a thousandth of a *mm* = one millionth of a *metre*.

Thus some are *simply bare tubes of cell-membrane* which transmit signal-blips by a chain-reaction at the surface of the membrane. This transmission involves an upset in the balance of Na^+, K^+, and Cl^- ions, poised ready to discharge through pores in the membrane. This discharge then sets off a further discharge in the adjacent region, and the result is a "domino effect" travelling down the axon as a voltage blip which lasts for about *1 millisecond* at any given point. The membrane then quickly restores its balance ready for another discharge whenever the next cue arrives. This method is typical for lower animals like squids, and for humans at an early developmental stage — or for certain nerves which cater for low-priority or slowly-changing circumstances.

However the axons which concern us here, and which predominate in mammals, have *an extra outer layer of "myelin" around the membrane tube*. Or rather it is a *series* of such coatings, like beads on a string with very narrow gaps between them. Each "bead" extends for about a millimetre or two, as shown here in the schematic diagram (fig. 2:1).

In these myelinated cases, the chain reaction can only occur at the gaps, the Nodes of Ranvier. Meanwhile we have to invoke some other mechanism across the insulated sections; but surprisingly, that is quite easily done. Put simply, the "blip" which is produced through one local chain reaction within one Node, generates enough voltage for it to carry around the insulated section and hence trigger a discharge at the next Node, where the membrane is once again exposed. So we still have a chain reaction, but one which *jumps or "saltates"* from one Node to the next — and in fact produces a *much faster signal-transmission* as a consequence.

Nothing wrong with that so far. It is clearly helpful to have a faster method, and it is encouraging to find that,

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mathematically, we are essentially dealing with the same situation as applied to the early telegraph cables across the Atlantic, carrying morse-code signals between Ireland and the Americas. Indeed neurophysiologists are quite familiar with the "cable equations" used at that time, the 1850s and 60s. We might ask though, *"Isn't there anything further we might learn by looking at any* LATER *developments in cable theory?"* I shall return to that question shortly.

Axons of both types terminate in *synaptic junctions*. In effect these are ultra-small glands which, on receiving a blip-signal, discharge some particular "transmitter substance" into a *synaptic cleft*. That "gland-action" may contribute to activating a relayed signal in another similar neuron cell, or it may help to activate a muscle.

Much has been written about such interface mechanisms, though I have come to doubt their importance for our present topic of *sophisticated* mental activity. Clearly they do serve some *other* vitally important roles, presumably including: fine tuning the system; pattern recognition; relaying the action instructions encoded on schemes, emotion-handling; and relaying sensory inputs. In fact the sophisticated mechanisms must surely depend on these orthodox channels as their only reliable interface to the outside world, (see appendix C, and its table C-A). But indispensable though these activities may be, they are not central to our discussion of *the mind*.

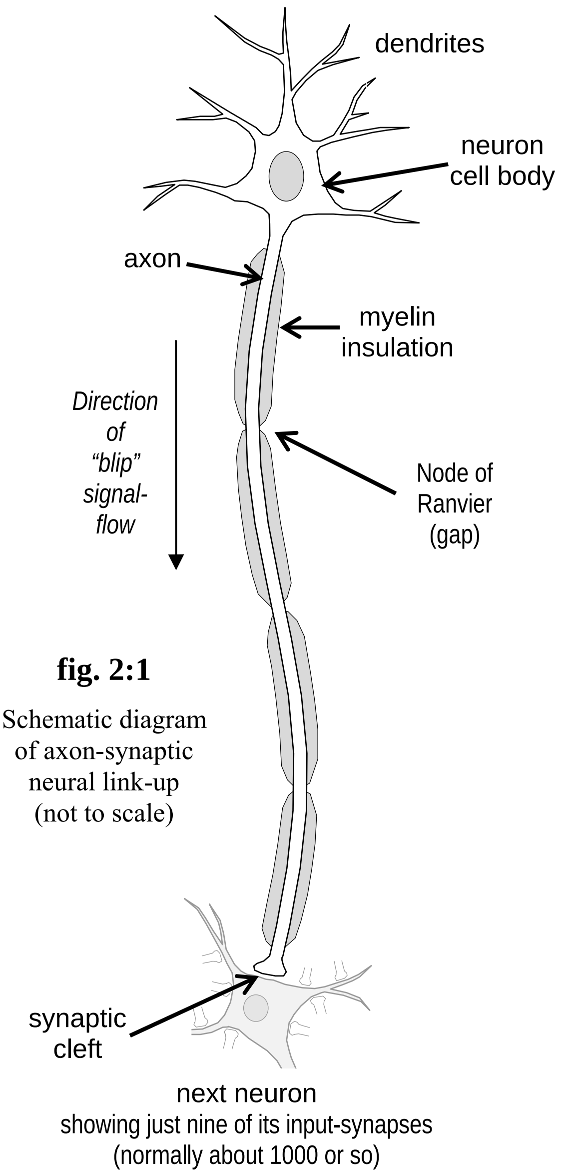

fig. 2:1

Schematic diagram of axon-synaptic neural link-up (not to scale)

2.3 Misgivings over the synaptic system

How does the system fall short? For one thing, the synaptic mechanism seems to be essentially an analogue system whereas we are really looking for some *digital* mechanisms. Then, as we have seen, any relevant digital encoding is likely to be held in linearly-sequenced molecular coding, probably RNA; but just how are such molecules to receive or send meaningful distant-communications using only the traditional millisecond "blips"? Indeed we might think that the resulting "gland discharges", no matter how small and focussed, would probably be a rather clumsy way of handling precise digital coding.

Then again, if we are serious about expecting codings to be mostly arranged in linear sequences (as in sentences or in DNA), it is difficult to see how the synaptic mechanisms could ever achieve this sequential ordering with any adequate degree of reliability.

Other ways of looking at this interface problem seem to lead to the same doubts about its feasibility. Consider this, for instance:

> *"We probably want our voltage blip to act within a pin-point of distance if exact locations are important. But its* time-*length is fixed at about a millisecond, hence it can only have a short* distance-*length if it travels very slowly. So just* how slow *should its progress be if it is to have a physical length comparable to even a largish molecular site of (say) one tenth of a micron?"*

Extremely slow, obviously. —— In fact it would be *0.1 mm/sec*., which is *6 mm per minute* — not quite what is needed for survival in a fast-moving world! This is hardly a conclusive argument as it is not entirely obvious that the distances actually *need* to be comparable; but it does suggest, in everyday terms, some incongruity between the (clumsy) millisecond blips versus (precisely digital) molecular code-sites. — It *looks like* trying to do micro-surgery using fire-tongs and hedge-clippers!

Or perhaps we should look at it from a quantum viewpoint, (Traill, 1988). Consider the energy changes likely to be involved when signals are emitted or received at molecular sites. Any chemical change involved here at an individual site will doubtless be associated with a quantum jump, and its magnitude will be within the normal biochemical range of about 0.5 to 1.3 eV. If we apply Planck's constant to translate these figures into wave-

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lengths[33] for the associated emissions-or-absorptions, we then arrive at wavelengths of *2.5 to 1 μm* — wavelengths in the near infra-red range, with frequencies just above 10^{14} *cycles/sec*, so that each cycle lasts for a mere 10^{-14} *sec* or less. Note that this makes any such cycle[34] *100,000,000,000 times briefer* than the millisecond blip of conventional neuro-synaptic theory. This again raises serious doubts about direct compatibility. It also begins to suggest how any second-system of this type might offer vastly superior performance in certain tasks.

It would thus be very convenient if we could find such a rapid-fire *second* transmission system which could cope with such digitally-oriented signal traffic — but also coexisting alongside the traditional millisecond synaptic system.

As it happens, much of the solution is right there under our noses. *Society* has been revolutionized by advances in telecommunications, moving far beyond the crude telegraphy of the 1850s into the fibre-optic wizardry of today, and (about 1888) inventing radio as a by-product! *But nature too* is highly resourceful, and it is hard to believe that such a powerful technical advance has never come to her attention:

Just what high-performance signalling might be possible within nature's own bio-systems? That is a topic we will explore shortly, in the next chapter. But before we do, let us first return to the question raised in subsection 1.4 (5): the problem of how the mind/brain could *represent coherence* amongst its concepts, and even carry out measurements and comparisons between the resulting ensembles:

2.4 Possible approaches to coherence-testing within the mind

(1). Linkage and coherence

If we are serious about modelling the mind, and if any sort of *coherence* looms large in our explanations, then we surely need a clear idea of how the mind could actually assess this coherence. Perhaps that may not be a problem if we are studying formal reasoning which can be expressed in the *social* medium of words (and that is the sort of case which philosophers will normally choose). Indeed in section 1.4 we encountered some social approaches to the problem, using the rather rule-of-thumb formula of cognitive dissonance theory, and Thagard's computer evaluation of ensembles of uncontroversial intuitive judgements.

But what about *pre-vocal subconscious thought of the individual*, as in learning the concepts of space and time during the sensorimotor stage of development? That could not be readily explained in terms of "+ and –" signs; and if we invoked "judgement" instead (as in the social case), we would simply be begging the question by trying to apply this unanalysed judgement at the level of the individual mind. So now let us look at the problem anew:

What is coherence really? And how could an unguided natural system actually evaluate it? One approach is to see it as alternative logical paths which converge to the same answer, thus forming "loops" between the pathways and hence a stable gridwork of structure (metaphorically speaking). Another clue is to look away from brainlike systems for a moment, and consider instead the coherence of *those real physical systems in the outside world* which brains are trying to model.

Often the coherence of such real systems will depend ultimately on the physical forces holding the parts together; so we get back to the gridwork idea, though now it is a structure quite literally. (We could also consider other sorts of attraction or interaction, such as friendship patterns. But explicitly analysing such metaphorical forces would probably not add much to the present discussion, so let's just keep to traditional forces, and take them as representative). Any such system will doubtless hold together if all the parts attract each other.

That physical coherence will also make the ensemble stable, and hence worthy of note since it is then likely to maintain itself through time — and that also offers the brain one tool for constructing a plausible model, by applying similar attraction patterns to similar parts. (Here "similar" need not imply the same physical causes. After all, the model could be obeying virtual forces programmed into a computer, or onto some comparable bio-device within the brain.)

In short then, there is a case for endowing *scheme* elements with some means for "attracting" others — either a literal attraction, or by some symbolic equivalent. This could be an attraction between *all* component elements, but it is more likely that the parts of a physical system would only be strongly linked to their immediate neighbours; and I hazard a guess that this could be normal for mental models as well. Thus if there were eight parts within a model, it would be a reasonable guess to suppose that each is attached directly to only three others (not seven) — thus forming a *cube-like* structure, with no linkages across any of the diagonals, but only along the twelve edges.

[33] The equation is $E = h\nu = hc/\lambda$ — where *E joule* is the quantum energy (and 1 *joule* = 6.242×10^{18} *eV*); *c* is the speed of light (3×10^{8} *m/sec*); *λ m/cycle* is the wavelength, and *h* is Planck's constant (6.626×10^{-34} *joule-sec*).
The frequency is *ν cycles/sec*, i.e. "*ν Hertz*".
(It is traditional to use this Greek letter *ν* or "*nu*" for frequency, in this quantum context).

[34] or any pulse or "*blip*" which is mainly based on Fourier components of about this frequency. Incidentally, readers with a background in physics will notice a potential difficulty here — the apparent likelihood that any such effect would be swamped by the natural "black body" thermal radiation. I shall be dealing with this in some detail in the next book of the series, "*Book B*".

But note the result: we have a coherent cube-like entity in the real world outside; and this is likely to be modelled by a cube-like link-up (of twelve "radio-phone links" perhaps, plus some disposition to simulate right-angles) all within the mind/brain. Of course we need not confine ourselves to cube-like configurations; but we may leave it at that, on this occasion.

> *Is there any guarantee that we are on the right track? No, of course not — but this does seem to be a plausible line of reasoning. That is perhaps as much as we can expect at this stage. It* is *important to find some plausible bio-solution to these problems, if only to get started. This issue of coherence-evaluation seems to be a key aspect of mind theory which has hitherto had no plausible explication involving self-organization; and without it, by default, we are at the mercy of occult theories. The actual account offered here might well be off the mark, but it does at least suggest that such an explanation may be possible — and discoverable. That in itself would be progress.*

So then, where have we got to? It seems each scheme element may have (i) a 1D sequence of coding for some productive action (external or internal), as argued earlier in this chapter; but also (ii) coding for "bonding" with several other scheme elements of a different type. Moreover let us guess that there will be *at least three* such link-facilities, and perhaps a *maximum of nine* if the two papers by George Miller are of any relevance.[35]

(2). Bio-mechanisms for measuring coherence

We have seen that the linkages within a model could be of at least two types: physical proximity (including possible contact); or else some sort of communicational "radio-phone" link-up, with scant regard for actual physical location.

For the physical proximity models, we can invoke ordinary force-field concepts to explain coherence. We can then go further and see how the stability-or-coherence of this model structure could be assessed, either by observers, or by the bio-system itself. This stability issue is a comparatively well-studied problem of chemistry-type bonding, with few new problems, so there seems little need to say more about it at this stage. (Moreover, such systems could have *other problems* which might tend to make them unviable, and therefore less worthy of study: — problems like how to store-and-manage actual 3D structures, plus questions of dynamic flexibility).

What about the "radio-phone" model with its flow of messages, but no stable proximity? It is tempting here to draw the analogy with social groups (where physical location is likewise largely irrelevant, or at least it might appear so). We experience such problems of coherence within our social groupings, and it comes into the topic of *cognitive dissonance* which we looked at in section 1.4. However this analogy should only be used with caution, thanks to a significant difference in the two cases:

In the social knowledge-system, it is quite legitimate to invoke the special powers of people within the system, (i.e. to add an anthropomorphic touch, because the people-members are indeed anthropomorphic!) But in so doing, we are passing the buck, *from* the social system, *into* the system of the mind/brain of the individual — a clear case of knowledge-system overlap, and we legitimately exploit it. But right now we are considering coherence within the individual mind, and this time we cannot pass the buck back to the mind — we are there already, and the buck must stop just where we are!

This means that, if we want to explain the mind, we now have to look for impersonal mechanisms capable of explaining the mind's intuitive coherence-based judgements; and not just depend on those judgements as a given unquestioned power. But what form might those impersonal coherence-forming mechanisms take, if they are not just physical forces or proximity?

Firstly, there must surely be some way of ensuring **selectivity**. Proximity does achieve that, but of course we are now looking for some other approach. It might be possible to use *focussed signal beams*, though that would probably be somewhat unwieldy, inflexible, and vulnerable; nor is it clear just how this could be used anyhow, though it might perhaps play a secondary supporting role. A more robust alternative would be the use of *dedicated signal-paths*, and of course that is exactly what nerve-fibres are.

But is that selective enough if we have to distinguish between multitudes of molecular sites? Probably not, and indeed we might profit from considering how this problem is dealt with in most computers. They do release messages onto a crudely dedicated line or "bus", but the real selectivity is encoded into part of the signal itself — as *an address code*. It is conceivable that the mind could do this too, especially if its relevant signals are Infra-Red or other high frequency emissions; so let us tentatively postulate this ability, at least until some better evidence or suggestion turns up.

(Note that, for such a system to be workable, there must be a large selection of clearly distinguishable "*address codes*" available for allocation — possibly on a random trial-and-error basis. Significantly perhaps, the immune system does use this sort of approach, though there the coding is in 3D space, as a lock-and-key type of procedure; whereas here we would apparently need *time-based* codes — as in combination locks, phone numbers, and passwords).

[35] He suggests that there is a definite limit to the number of "chunks" of information that we can remember (within a given set, before we find a way to break it up into subsets, and then learn those). According to him, the limit is "*seven, plus-or-minus two*"; (Miller, 1956a,b).

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The human mind does need to have good selectivity — some exact method for addressing specific sites or site-types. Only then is it in a position to make meaningful and reproducible **choices about *set* membership**; and without this ability, we would surely be condemned to wandering around in a bewildering state of misidentification, and mere impressionism in our thinking. (Like snails or squids, we might still muddle through by using the pattern recognition techniques of neural nets; but clarity would be missing, and there would be no feeling of certainty).

In principle then, we now have a plausible method for expressing clear linkages. That is probably vital for the advanced brain capabilities needed in the human mind; but it is still not enough. Any pattern of linkages still has to **have its coherence evaluated**. Moreover, to avoid clutter and misinformation, this evaluation will probably need to be continuous or frequent.[36] But what tests could there be in a procedure which is not intelligent in itself (even though it presumably *leads* to intelligence)?

In regard to direct testing of our ideas of the environment (i.e. **external coherence testing**), the question has already been thoroughly studied within constraints influenced by behaviourism. Typically our test-rats take some initiative which impinges on the environment; and they then take in the feedback information about what happens in what seems to be the result. Effectively they are seen as testing the coherence of their pre-existing *action patterns* with their *desires*, and tending to delete any such ensembles which are unrewarding. And there was no need for any of this to be conscious, nor even insightful — though chapter 8 suggests ways in which such insight could be added.

I contend that internal and external coherence have much in common — that they are both just special cases of *coherence in general*. If that is so, we might expect the bio-tests for internal coherence to be substantially similar to those for external coherence. The most obvious difference is that the feedback loop would now be entirely within the mind/brain, and not appear in any overt action; but it could nevertheless be just as real (though behaviourists would doubtless disagree). Another difference could be that any causal chain is now more subtle and abstract — the causal path of a logical argument rather than a "*bang, you're dead*" sequence of events. Note too, that logical sequences can usually be reversed. That is less common with overt actions, but perhaps mere frequency is of little account here.

Such "abstract" feedback loops figure largely in the study of "mathematical groups". Such a group is a set of *states*, plus *operations* which always transfer us from one state to another without ever leaving the set. It thus inevitably has closure, or coherence, built into it. Significantly certain aspects of our real world fit into this description (notably objects in 3D space). Thus we might half expect an infant's internal thinking about these states and their operations (represented by their internal codes) could eventually "click-onto" a correct coherent solution about 3D space. Anyhow some of Piaget's early work was based on such notions. (Piaget, 1949, 1952).

In summary then, I suggest there is a *prima facie* case for supposing • that natural mind-systems depend on tracing feedback loops to test internal coherence; • that those loops are communication links which usually find their designated destination through coded "callsigns" rather than dedicated lines; and • that these callsigns are highly selective.

And how could the system actually do that *"tracing" of feedback loops?* Consider an analogy: How can we glean some information about a situation when all is dark? Echo-sounding is one answer, and it is used quite accurately by bats-in-flight, and by marine navigators. Within a linked circuit or network, we could interpret this as a reverberation test, thus: • Emit a special[37] test-signal; then evaluate the delay and shape of the resulting ensemble of returning 'echoes' — discarding that whole particular 'subcircuit' if it fails some test (a natural, and supposedly valid reverberation test, but presumably fallible and sometimes capable of producing pathological cases; see section 8.5).

Perhaps I should also add, • that any given effective code will probably occur in multiple copies, all with the same "phone number" or "call-sign", and • this might well entail some extra cross-feed signals to synchronise any crucial timing.

This account may or may not be correct, but it does perhaps show the sort of solution which we might reasonably be seeking to fill in this gap in our understanding of the mind. Of course, some will say that the explanation can only lie in the occult. Maybe time will tell?

[36] Such periodic re-evaluation may be the main role for *sleep*. See section 8.6.

[37] A *special* test-signal would seem to be best, provided it is possible to shut down routine activity occasionally (and that seems to be consistent with our sleep, as we have just seen). However it *might* be possible to do some testing by just monitoring the ongoing signal traffic.

This idea of reverberation is not new, though it used to have more to do with simply *retaining* some signal pattern: *E.g.* memory supposedly stored by recycling it round and round the same axon path in the brain — or (actually) sent round an acoustic path in an early computer.

3. Nerves, Digital Codes, and Fibre-Optics for Theory A

Let us have a look at how our understanding of telegraph cables developed from the early 1800s up to today.

3.1 The simple waterpipe analogy

Electricity somehow "burrows through" metal conductors such as wires. In our first experience of electricity we may find that surprising — but we soon get used to the idea, and most of us come to think of these wires as being like water pipes in some mysterious way.

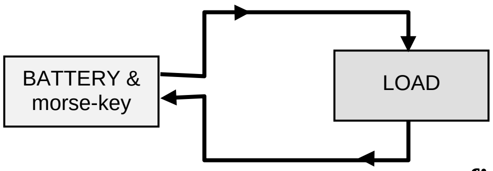
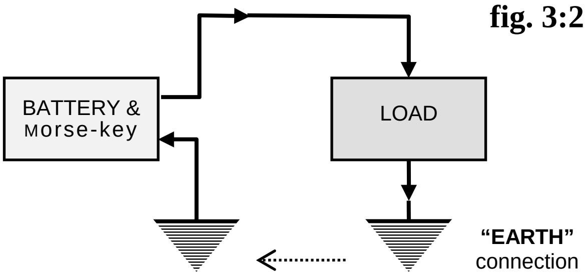


fig. 3:1

Of course we know that a pump will drive water around a loop of pipe. So we apply this knowledge to electrical circuits and so envisage a battery as pumping electricity around a loop of wire. In both cases, at least since 1827,[38] we have come to accept that *resistance-or-friction* will impede the flow somewhat, thus wasting some of the energy. Also we will probably expect to find a *motor or buzzer or light* as a "load" somewhere in the circuit so that it can do useful work.

We will probably also accept a variant on this theme where there is *only one* wire-or-pipe to the buzzer, and the return flow makes its own way through the outside environment as an "earth" connection:

fig. 3:2



Simple theory of this type is quite adequate for setting up short distance telegraph systems across the classroom, or from one station to the next on the early railways (starting 1839). Various coding-methods were used, leading up to the morse code system of 1852.

We could use other mechanical analogies. The closed loop is very like a bicycle chain or the driving belt used in factories of the 1800s. Meanwhile the "single-wire" case can be likened somewhat to a single rigid rod, provided that we allow it to reverse its direction occasionally instead of using the earth-return. In fact we shall see that this "con-rod" analogy will be quite helpful in highlighting some of the more complex electrical issues.

3.2 First complication: "pipes" which are elastic, and perhaps also leaky

Suppose our water-pipes are made of rubber; then to some extent they will act like balloons when we "blow" morse-signals into them — *storing the puff locally* instead of conducting it down the pipe.[39] This is not friction. In principle there is no loss of energy,[40] but some of the signal is simply not getting to the right place. In a long pipe this can be a serious problem because the stored "puff" will spill over into periods where there is supposed to be "no puff" — thus smudging the clarity of the signal, or cancelling it altogether unless it is sent *very* slowly.

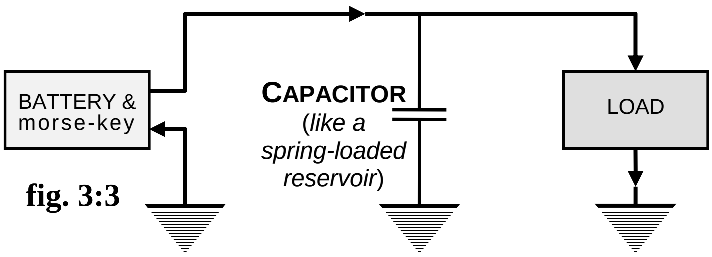


fig. 3:3

The electrical equivalent is ***capacitance*** between the inward and outward flow-paths; (fig. 3:3). Once again any morse-like *"puff" of charge* is partially stored locally, so reducing its effectiveness and clarity. This problem really comes to the fore when the cables have to be laid under water, as this greatly increases the capacitance and hence the apparent need for many more *booster stations* along any long cable.

That was true for the trans-Atlantic cables of the 1860s, and it is just as true for myelinated nerve-fibres[41] when they are functioning in the orthodox *millisecond-pulse* mode (roughly analogous to simple morse transmission). Of course that is why the neurophysiological textbooks call

[38] Ohm's law dates from 1827. (That the *current* is proportional to … the *voltage* ÷ the *resistance*).

[39] Or we could get much the same effect if the water were highly compressible — i.e. *springy* like the air in a bike-pump.

[40] In fact some of it may well return to the sender, or turn up in other counter-productive places In effect the sender is here simply compressing a spring, which stores the energy until it is released.

[41] Here the single "wire" is the column of watery conducting-solution *within the axon-and-its-myelin*, and the "earthed return" is through the watery environment *outside* the cell and its "arms".

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upon the old cable equations of the 1860s — equations which express cable properties (per unit length) in terms of…

(*R*) *Resistance* /length, and (*C*) *Capacitance* /length

In terms of our con-rod analogy, the *R* corresponds to the friction as we move the rod to and fro, but what about the capacitance *C*? Bear in mind that no "rigid" rod is totally rigid. All rods are elastic or springlike to some extent; so when we push-or-pull one end, some of our energy will be stored locally as spring-tension instead of being sent immediately to the other end. In other words, the spring-property has energy-holding Capacity — *C* — just like the reservoirs in a fluid system or the Capacitance across a telegraph cable.

(*L*) *Inductance* /length

Now we come to a debatable point: Should we worry about **mass-and-inertia**? We really should in the case of the con-rod, although there may be some circumstances where we can get away with mere lipservice to "light-weight" rods which will supposedly offer no inertial difficulties. Likewise with waterpipes we can often forget inertia. After all, surely "*water just comes out of the tap when we turn it on, and stops when we turn it off*", with no obvious complications due to momentum. Yet a fire-hose clearly depends on the momentum of its water-jet, and the sudden closing of a valve on a major pipeline will often result in a "hammering" effect which may even burst the pipe.

At first sight electricity seems to be different, with no obvious mass. At second sight though, we discover that this electricity does have a sort of mystical inertia in the form of **magnetic inductance** "*L*" — all bound up with the self-generated magnetic field which threads through any loops in the circuit. In short, if we try to increase or decrease the current, this inductance effect will oppose the change, just like the inertia-effect of a train (or water-column, or con-rod). So this may not be actual mass. Indeed it somehow spreads itself into the surrounding space in a very "*un*masslike" manner — yet it nevertheless produces the same general effect.

Faraday discovered this "*L*" effect during the period 1831–1838, so it was well known to theorists of the 1850s and 1860s; but the consultant[42] advising on trans-Atlantic cables chose to ignore it. Why?

In practical engineering it is important not to get bogged down by trivialities, and in the original morse-type context, "*L*" was justifiably thought to be negligible, as I shall try to explain shortly. Such approximations are fine, and even essential for practical applications, provided we are clear about our rationale for using them — and clear about how much we can legitimately extrapolate from them. The trouble is that when we have had success with our approximation, it is all too easy to forget its origins and then tacitly assume it is universally valid.

In fact though, we might say there are two very different solutions to this signal-problem — a double perspective[43] which applies to all these media with their *R*, *C*, and Mass-or-*L*. When the practical men of the 1850s chose to ignore *L*, they were unwittingly closing the door on one of these two solutions, and it just happened to be the more interesting of the two.

How was this door to be opened again? I can see two possible paths, and we shall mainly look at the neat-and-simple route in section 3.4. However that was too big a jump given the preconceived ideas of the time, and history took the more arduous route via mathematical analysis. I shall deal with that briefly in section 3.3, but the impatient reader might prefer to skip straight to 3.4.

3.3 Curing signal-distortion — an intermediate problem

The pioneering work here was mainly done by Oliver Heaviside (1850–1925), an eccentric partially-deaf recluse who was well in touch with both theory and practice: the maths, *and* the wire-stringing. He had worked for several years as a commercial telegrapher, and he still participated indirectly in such practical problems even after he had left the job, in collaboration with his brother Arthur who remained in that profession.[44]

Now consider what distortionless signalling offers. Firstly it makes telephoning possible over long distances, because voice-sounds depend crucially on the fine-structure of the sound-wave pattern. Secondly if such shapes really do retain every tiniest detail, then each such detail can be used to carry digital data. In the extreme, if we could have perfect shape retention, we could carry an infinitely large stream of signal traffic. Of course that would be expecting too much in this imperfect world; but note that present-day "info-tech" has come rather close to that ideal, and gone a huge way beyond the feeble morse-systems of 1860. In those days, the dots and dashes of even a single slowish message would rapidly lose their sharpness and eventually become indistinguishable — at least when sent through high-capacitance under-water cables.

[42] William Thomson, who was later honoured with the title of *Lord* Kelvin. In fact there are other effects too which he would not have known about at the time, though they would have been even less relevant to his practical brief: The "skin effect" (of about 1886) and the quantum theory (1900+).]

[43] Double solutions are well known in maths, so we should not be too surprised when they turn up in real life. As an obvious example, consider the problem: "Find x, when we know that $x^2 = 49$".
The obvious answer is "$x = 7$". But there is another mathematically valid answer which we could easily overlook if we are not careful: "$x = -7$"

[44] See especially Yavetz (1995), but also Nahin (1988).

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(*K*) *Leakage conductance* /length

So far we have noted three algebraic properties of a telegraph line: *R*, *C*, and *L* (all per unit length). There is also a fourth — the **leakage conductance** between the inward and outward paths-or-wires. (This is often represented by *G*, but here we may as well use *K*, the letter favoured in Heaviside's day).[45] So now we have four parameters: *R*, *C*, *L*, and *K* — of which the last two were ignored by our 1860s consultant[42], for what seemed to be perfectly good reasons: *K* was negligible thanks to good insulation, and *L* also seemed insignificant as long as the in-and-out wires were close together, thus keeping the loop areas to a minimum, as shown in figure 3:4.

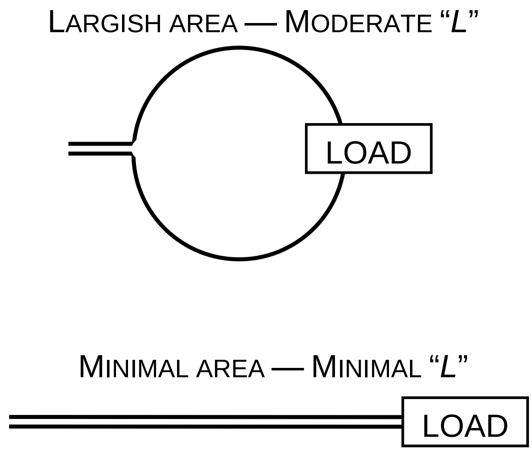

fig 3:4

Extremes of *L*-value for a simple loop. (Can increase much more by • spring-shaped multi-coils, &/or • iron core).

But now consider this practical observation. With Arthur's commercial telephone system in Newcastle-on-Tyne, there was a significant amount of *K* leakage due to the "extra load" of other consumers along the line. This had two effects:

- an "attenuation" or drop in signal strength — no surprise. But also
- an *improvement* in signal clarity!!!

Clearly then, *K* was worth studying.

Moreover if we are considering high frequencies (very rapid changes, and hence the *short wave-lengths* which are inevitably needed in any "high resolution" patterns), then we really must take account of the inertial *L* properties of the circuit. After all, we may be able to wave a conductor's baton rapidly, but could we really do similar things with a supermarket trolley full of bricks, even if it had perfectly frictionless wheels?

In short, we cannot always ignore mass nor its analogue *L*. So if we are after a general circuit-theory solution to the problems of distortion, we must invoke all four parameters. Oliver Heaviside did just that, and arrived at a remarkably simple valid formula which implies *increasing* the *L*. [d] — Unfortunately that idea was difficult to "sell" as it seems counter-intuitive when we think of the trolley-of-bricks analogy. After all: "How on earth could this massive extra encumbrance help us?"

Indeed that was a real "marketing problem" as we would now call it. No matter how impeccable the reasoning seems to be (for those who have the patience to check it), we will not easily be convinced if the result seems to go against common sense — though of course some good practical demonstrations may eventually help us to revise our notions of "common sense".

Historically, it was probably necessary for the ideas to develop in this mathematical way. With the benefit of hindsight though, it might have been better to forget about all that maths (until later perhaps), and benefit instead from a close study of optics and the analogies we encountered earlier in this text. At any rate let us turn to those analogies now.

3.4 Two ways to signal with a rod; or (apparently) with any other medium

Common sense tells us that leaves and other loose objects get blown along with the wind; and yet it has long been known that we can sail *into* the wind! Common sense also tells us that falling objects will hit the Earth's surface; and yet (fortunately) the Moon never does reach us, for reasons which Newton explained. The truth underlying common sense can sometimes mislead us — notably when there are extra real-life complications which the original formulation had not envisaged. But such misleading notions can sometimes be unpicked if we attend to the detail.

When Heaviside suggested increasing the inertia of the signalling system, his critics were *HALF* right in saying that the idea was absurd. We shall see that, in various different transmission media, there are *two different* methods of signalling. Heaviside's critics understood only the more obvious method, in which inertia was indeed a handicap. In fact though, the second method turned out to be much more rewarding. Our interest here is with the electrical signals in neural "micro-cables", and Heaviside was concerned with telegraphic "macro-cables"; but similar *two-method* principles seem to apply in more straight-forward

[45] Any conductance is the reciprocal of a resistance, but here we are dealing with possible leakage *through the insulation*, despite its (high) resistance — quite different from the (low) "*R*" which involves current going down the wire or earth-pathway.
Letter consistency (like *K* versus *G*) is a bit of a problem in such historical studies; and I will not try here to depart any further from modern conventions. As a matter of passing interest though, we may note that Heaviside used "*C*" for current (not "I"), and "*S*" for capacitance alias "permittance".

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mechanical signal methods, so it may help if we explore these analogies first.

Let us look again at the use of rods to communicate. The obvious method is to *push or pull* the rod, like a lever or morse key, and thus transmit morse letters, or operate machine controls and switches. All this is comparatively slow and conventional, and involves moving the rod as a whole as if it were (ideally) infinitely rigid and lightweight — with none of the irritations of a weakish spring soaking up our message-energy (as high Capacitance "*C*") — nor the irritations of a heavy beam which is difficult to start and stop, (with excess mass, analogous to excess "*L*").

But then along come two children who cannot appreciate the niceties of our situation, and they dare to send a message around the playing field by banging acoustically on the heavy railing! They are breaking *our* rules, by not push/pulling the rail at all (at least not in our usual macro sense). So much for our assumptions! Instead they are setting off a chain reaction of micro events within the rail — events which depend on one part of the rail moving relative to the other parts, and which could not occur at all if the rail were really totally rigid nor if the parts had no momentum.

Note that the laws of physics have not changed here, but the mode of usage has. The children are using the same sort of objects, but are now depending on phenomena at a different scale of time and speed, and that affects the practical significance of various parameters.

There is probably no need for me to labour the point further. The main thing is to notice that this will probably also apply in circuitry. Thus *high frequency* phenomena will also now be available to carry messages — using a different mode of operation, and no doubt more suitable for a different form of message.

Of course, in the case of cable-circuitry, any electrical engineer now knows this high-frequency solution to be true. Instead of fairly-slow dots and dashes, commercial signals typically came to be built up using "*Radio-Frequency*" from about the 1890s until perhaps the 1960s. Today such signals are of a much higher frequency still, in the form of *Infra-Red* fibre-optics — which some of us might not even recognize as circuitry at all, and yet the fundamental electromagnetic principles are the same for all three cases: for the "naive" circuitry; for the RF cables; and for the IR of fibre optics.

(Actually these electrical cases have one notable advantage over their rod-or-pipe analogues. As their energy is somehow mysteriously stored *away from the conductors* in the surrounding space, it then has the potential to fling messages off through that space — messages which end up quite independent of the original wire-system. So mankind had the extra bonus of radio or "wireless" from about 1888 onwards.)

Is there any reason to suppose that this dual mode of operation could not apply in that other class of electrical circuitry: the nervous system? That of course is a key question within this current project.

3.5 Waves rule. But we still need levers and rods, as well as optics or sound

If I were blind, how would I find my way round a house which has chairs and suchlike in unexpected places? I would probably use a walking-stick of some sort to *feel* my way round — with the rod/cane/stick allowing me to feel further away than the reach of my unaided hands. This is very similar to the *push-pull* method of signalling with a *whole rigid rod* which we discussed earlier — the analogue of uncomplicated currents of water or electricity in a simple morse-like environment, with no intentional use of vibration.

As it happens I am not blind, and I unthinkingly use the much more versatile strategy of relying on the pattern of light-rays which reach my eyes. But note that *this is NOT direct contact.* Any observer from a universe with different laws of nature might well wonder why we place so much faith in this light — light which only reaches us after an apparently uncertain voyage in which it has *totally ceased*[46] *to touch* the objects we were looking at.

Given the choice, we do opt for vision rather than feel in most navigation tasks, and the key reason is pragmatic: vision is *very much* more rapid and informative. No doubt we can also explain *why* this is so, but perhaps that is of only secondary importance. The important lesson is that: (i) *there exists* a travelling, non-contact signalling mode which happens to depend on *vibrations at the micro scale* of measurement; and (ii) this vibratory mode seems, in practice, to be *very much more powerful* than the more obvious contact mode.

And if we look at the various analogues, we seem to find similar results:

- Ships used to have speaking tubes for communication. A non-vibratory puff would first draw attention as a very simple summoning-message, but the main communication would then take the form of voice vibrations travelling down the pipe as acoustic waves — and *not* as a morse-like message using simple puffs of air.
- Remember the case of the children who sent a message through a fence-rail via an acoustic vibration, thus overcoming the (macro)-immovability of the rail.
- Recall the advances in underwater cables: from single-

[46] The light has apparently "totally ceased to touch the objects" — *as far as one can tell*, though there are some unresolved philosophical issues here!
Incidentally, it seems that the *medieval* view was that this mystical visually-carried evidence was not to be trusted, and that one could only count on touch — the brutally primitive push-pull mode, which doubtless seemed much more understandable.

track distorted morse signals, to the ability to carry Radio-Frequency carrier waves with a signal-rate incomparably faster than had been thought possible (thanks to Heaviside, though Pupin reaped the profit) — and the by-product of free-travelling radio waves (commercialized by Marconi). These radio waves consisted of "light in all but frequency", as the main theorists well knew; and indeed the frequency was then raised still higher up to the Infra-Red range of today's info-tech. In practice then, we can here virtually forget even Heaviside's advanced *circuit* theory and use *optic* theory instead.[47]

So then, what about the brain and nerves that we started with? Are the myelinated nerve-fibres really just the carriers of morse-like "puffs" into their capacitance-loaded pathways, as the textbooks claim? Or are they *also* capable of a high-frequency vibration which can carry a much denser signal traffic, like the other systems we have just considered? — In other words: Do nerve-fibres have the same sort of *dual-mode capability* that other signalling systems seem to have?

As yet, empirical evidence is sparse (which is hardly surprising, for who would have thought of seeking such data systematically?); but a cursory *theoretical* preview does look promising:

• The physics and geometry of nerve-fibres has a lot in common with the underwater cables of the 1850s and later, and as we have seen, these turned out to be much more efficient when their high frequency capabilities were recognized and exploited in the 1890s.

• In both cases, a significant magnetic inductance "*L*" is clearly *available* at high frequencies, and also *needed* to provide the momentum-analogue essential for vibration at the micro level. (This is despite Kelvin's oversimplified cable equation, which is only valid for the non-vibratory "morse-mode").

• Commercial fibre-optic cables are now commonplace, and they usually carry Infra-Red signals. Thus it should not be too difficult to re-interpret segments of myelin as possibly-similar optic pathways (also for Infra-Red as it happens) — with optic signals beamed onto some unspecified sites[48] at each Node of Ranvier. This would at least stop us from having to worry explicitly about *L* or other circuit-concepts as these are subsumed within the optic-theory account — both being alternate versions of Maxwell's theory, as we have already seen.[47]

In short then, many signalling systems operate using high frequency vibrations within their microstructure — vibrations which depend on both a springlike property such as capacitance *C*, and some type of momentum due to *mass-or-L*.

There is no clear empirical evidence that myelinated nerve fibres offer this facility, but **physics theory** suggests that this is feasible, and **analogy with similar systems** also supports the notion. Then again our **knowledge of evolutionary pressures** suggests that any such feasible option which would also be a *strong advantage*, is very likely to be evolved into being — sooner or later.

This all seems to suggest that we should at least take the possibility seriously: that myelin could be clandestinely acting as a fibre-optic channel *in addition to* its accepted role of carrying those traditional millisecond blips, those "action-potentials" which are much more obvious to the lab-based investigator. Mind you, some experimenters have found *some* evidence consistent with Infra-Red signalling (see Traill, 1988). But such evidence could scarcely be anything other than fragmentary and unsystematic as long as these investigators were unaware of Infra-Red's possible significance as a second neuro-communicational system (as fibre-optics). And of course, brain theorists had already found *one* system of neural signals, so they might be forgiven for not seeing the need to look for a second system — even though their first system has left a lot of things unexplained.

However, lest we get carried away by the idea of a second system, we should also be quite clear about the importance of the first. Touch is still vitally important (including the blind person's white cane) even if it is less spectacular than vision using the mysterious wave-properties of light. Levers, con-rods, and cogwheels are likewise still important even in this era of digital electronics. And so on.

In general: solid push-pull rods and probes, which "ideally" should minimize their distortion and weight, are still an important part of our everyday world; and the relatively unsophisticated morse-like[49] signals fit into this approach. But why should we not enjoy the benefits of wave-based communications as well? As long as they can both coexist, surely we should have the best of both worlds? Indeed we might suspect that natural selection has done just that within its own speciality of "designing" bodily function!

[47] Maxwell's electromagnetic theory (in its most general form) underlies all these various electrical-or-optic approaches. In practical engineering though, it is helpful to make different types of approximation, and use different calculation-methods for various different frequency ranges.

[48] Such molecular sites *could* be within the traditional nerve cells, but there is no special reason to suppose that they are, and indeed that seems a trifle unlikely. Note however that the signals would be cast loose from the myelin at this stage (though they are likely to be absorbed wastefully within about 20 microns if they do not reach a useful target by then, *i.e.* within 1/50 of a mm). That means that other sites are quite feasible as targets and/or emitters. For instance *glial cells* were long thought to play a fairly humdrum role, but maybe they have hidden talents in this regard.

[49] supposedly non-vibratory — "ideally"!

4. FOUR LEARNING-SYSTEM TYPES (EPISTEMOLOGIES): WITH A COMMON BASIC STRATEGY?[50]

4.1 In praise of 'analogy' between epistemological systems

(1) Some hidden mysteries about the learning process

At a casual glance, learning looks easy and straightforward.

> "Obviously you just observe reality,
> read books, or listen to your teachers".

But of course we now know that this confidence is naive, and that any in-depth understanding of the knowledge-acquisition process raises a host of difficulties — issues which have raged from time to time ever since Hume or earlier[51], and which have not yet been fully resolved.

What are the obstacles to further progress in understanding how knowledge is captured? Here are two suggestions.

Firstly I shall suggest that we are hampered by confusing the features of the *individual learner* with those of *society*. Consider this distinction:
(A) knowledge-acquisition in *individual brains* is a process which does NOT initially depend on words or language; and
(B) knowledge-acquisition in *society-as-a-whole* is a process which DOES depend on words and language; and arguably often follows a 'logic' of its own, somewhat at variance with what individual citizens might decide.

It seems to me that many theorists, especially philosophers, run foul of this distinction — especially if they assume that words underlie all thought, when clearly this cannot be plausible for the newborn, nor for any other animals which display signs of thought.

My second suggestion is that we have overlooked an important and revealing parallel between four very different types of system. Despite their differences, these are all engaged in an essentially similar task: The task of capturing knowledge from a non-cooperative environment, and with no benign teacher initially.

The four systems identified here are:
- • Brains themselves
- ••• The genetic code, held on DNA
- ••• The immune system
- • Language-based society, including science.

The middle two may come as a bit of a surprise, but consider this:
• The genetic code is indeed the result of a multigenerational effort to increase *knowledge about what helps survival*; and
• Your own private immune system amounts to *knowledge about how to protect your body against dangers existing in your actual environment.*

Both these bodies of knowledge have to be acquired somehow, and such processes might have at least some analogical significance elsewhere. Moreover these two system-types are now reasonably well understood, and that could help considerably in making sense of the other two.
Accordingly I shall spend some time looking more deeply into these two well-understood cases, before coming back to a general comparison of all four cases. But first let us clarify some of the underlying ideas.

(2) Key concepts (or 'pseudo-definitions')

Knowledge — Any 'map' or model of the environment which enables the possessor to cope better with that environment. (It is assumed that this map/model will be encoded in some sort of *physical structure* associated with the relevant brainlike system, or constituting an integral part of it).

Epistemology — Study of the nature of knowledge, how it is *captured* into any 'useable form' for any lifelike system, and how it is stored and accessed in actual use.

Epistemological System — Any *'brainlike'* system: *ie.* any system which can capture and process knowledge, and which originally initiated this process by fortuitous trial-and-error, without any external purpose-driven designer or programmer.

> *(If a designer is involved, then he/she/it must be included as part of the system, and be explained along with it. Likewise, any genetic forbears must be included. So, while achievements can be inherited, we must still explain how they arose* originally.
> *This leaves some ambiguity as to whether I am talking about one particular brain (say), or about all brains. However the main issue is one of* knowledge-capture strategies*, and we may plausibly claim a common overall strategy for all members of the same class.)*

[50] Seminar paper, Department of History and Philosophy of Science, Melbourne University, (1994). This perhaps offers a useful alternative introduction to the mysteries of knowledge acquisition (epistemology).

[51] Hume (1748); but also see Descartes; and Plato's "cave shadows" analogy in *The Republic*.

(3) The problem of pump-priming this process from nothing

Knowledge-capture seems to need a *pre*-existing structure, yet this structure is itself encoded knowledge — a chicken-and-egg dilemma! So, is there any way we could escape from this apparently-endless causal loop?[52]

It seems to me that there is only one way such a knowledge-capture process could *ever* get going initially if unaided, and that is through the chance use of whatever physical 'junk' the system happens to find on-site. Such junk, with its own inbuilt structure, could be mere random configurations thrown up by chemistry or other inanimate processes, or it could be the discarded by-products of other unrelated bio-activity.

Note the analogy with the work of artists like Marcel Duchamp who assimilate ready-made commodities into a new context, supposedly unrelated to the original 'purpose' of these articles.

Note also their use of the term *objet trouvé* for any such object. I have elected to extend this term to cover the initial fortuitous structure which happens to seed an epistemological system. This lucky chance 'seeding' would thus provide the system with a simple mechanism which happens to be capable of capturing *more* knowledge. That means that its 'capital' of competent structure can increase, *as if* by its own design. Nevertheless there is actually no intention nor design at this stage, even though the system might eventually get round to belatedly evolving these capabilities for itself, (unintentionally!).

(4) Kant's attempted solution (1781) for the mind/brain system

Kant proposed that space, time, ethics and causality concepts should be taken as inherent and 'transcendental' — present in some God-given way from the beginning, or *'a-priori'* to use the accepted term for such supposedly unquestionable intuitions.

Of course this formulation does not actually solve the problem, as many of Kant's contemporaries were keen to point out. But how exactly does it fail? In terms of the last section, we might perhaps say this about the Kantian 'a-priori' concepts such as space: "Space and time concepts are still much too sophisticated to be representable *in one step* by randomly generated mental substructure, no matter how careful the subsequent selection process may have been during that one step." [53]

With the benefit of hindsight however, we can see some useful transitional ideas in this approach. For one thing, it does tend to 'buy time' in the controversy over problems of immediate perception, by shifting the problem further away from the immediate battle between extremists.[54]

As it turns out, this does still happen to offer significant potential-progress. If 'space' and 'time' are not actually as basic as Kant believed, they are nevertheless valid idea-organizing concepts which do offer models of reality, though the crucial question remains as to how the brain is able to construct these concepts. That leaves us then with a *two-stage* problem, but by the same token, *each stage* is now a simpler problem which thus becomes much more amenable to plausible solutions, as we shall see.

In short, Kant's approach opens the way for a modular or 'stage' approach which might be expected to work like this:

The more fundamental epistemological process fortuitously generates the concepts of space and time after a great deal of evolutionary trial-and-error. The process must presumably start with an unlikely-looking initial chance structure of DNA fragments or whatever — *les objets trouvés* for this original stage.

Then, having achieved such concepts as space and time, the physical encodings of these concepts (whatever these may be) will now themselves be available as new *objets trouvés* for pump-priming the next stage of self-learning, even if these space/time concepts are not truly a-priori in the strict sense.

(5) The essential task — find at least one self-learning technique

The essential task is to find at least one generalizable technique simple enough to generate knowledge using only whatever structure is already available as undesigned environmental flotsam — the *objet trouvé* approach.

(6) This is actually a very exacting constraint

This is an exacting constraint which is not likely to allow us many suitable solutions. Yet clearly knowledge does actually exist, so we do know there must be at least one solution, against all the odds. Nevertheless that solution must have been oddly fortuitous. This does *seem* to be a task which is impossible unless we invoke occult forces (supernatural or vitalistic). So if we are committed to

[52] Another way of viewing this paradox is expressed as "*lifting oneself by one's own bootstraps*" — hence the term "*bootstrapping*" or just "*booting*" — getting a computer's basic operating system going, starting from a very simple starting point. So here we may choose to speak of "*epistemological bootstrapping*".

[53] Moreover Kant himself would perhaps have been appalled at such a non-theistic approach.

[54] a tactic not unknown in politics. In this case the battle was between theists and mechanists.

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natural explanations alone, there seems then to be no great likelihood of multiple solution-strategies. We could be lucky to find just one solution, but a multiple "abundance of opportunity" would seem to be expecting too much.

After all, many real and important problems have no solution at all, despite our wishful thinking. — Precise sets of quantum measurement, for instance; or Absolute Utopia. Meanwhile we should maybe just count ourselves lucky for this one single fortunate solution.

If indeed there is only one such effective epistemological strategy, then we can at least draw the following useful conclusion:
The four different knowledge-capture systems *must all be using the same formal strategy* — regardless of their history or their physical 'hardware' substrate, since there is only one such strategy available.

But suppose we do allow for two such possible strategies? That is still only two amongst the four systems, so some must still share a common strategy. Only if there are *four or more* different viable knowledge-capture strategies can it be possible for the four systems to differ radically from each other; and I have suggested that this degree of plurality is unlikely, due to the complex difficulty of the task demanded.

I conclude then that all-or-most of the four systems will be using essentially the same strategy for capturing knowledge; and that therefore any similarities will usually be more than mere analogies. In particular, if we need to fill in gaps in our understanding of *System A*, we might tentatively expect to achieve this by looking at *Systems B, C, and D*. Such a methodology could well be a powerful tool if we do accept it as potentially legitimate.

So then, what do we currently know about the knowledge-capture tactics of these four systems?

4.2 The four successful types of epistemological system and their possible formal similarities

(1) Genetic knowledge

This is mostly encoded in nuclear DNA. It features:

(a) Stringlike coding, with simple discrete gene elements which may be viewed as '*objets trouvés*'.

(b) Knowledge gained through trial-and-error as 'Natural Selection' rather than through design (so no need to invoke the supernatural, nor to call it vitalism).

(c) Cooperation between elements is both possible and necessary.
This may be seen as a criterion of *symbiosis or coherence or closure*, a test which determines survival of the so-called 'fittest', and this will probably mean *the system which is most coherent in its collective activity;* (see sections 1.4 and 2.4).

(d) Operations are ultimately mechanical; though the systems defy full prediction, in practice. This unpredictability arises because minute variations can ultimately lead to large variations in particular cases, even though the system may still be *statistically* predictable. (This, of course, is the now-famous 'butterfly' principle from Chaos Theory).

(2) The immune system — operating through a vast repertoire of 'keys' ready to fit any unexpected 'lock'

Its features include:

(a) Stringlike coding, with simple discrete gene elements — protein shapes determined by preset DNA-sequences *plus extra arbitrary 'switch-settings'* allowed for in the coding sequence.

(b) Again knowledge is gained through trial-and-error rather than design; but now the dice are thrown at two-or-more stages:
- Genetic component which affects the whole individual, as above.
- Local 'switching' mutation for each lymphocyte cell (which is then committed to producing a single particular antigen or 'key', usually just kept in stock as a reference-sample ready for mass-production if that ever becomes appropriate).

(c) Cooperation between elements is both possible and necessary, as before; and once again this is interpretable as a test for some sort of *coherence or closure*.

(d) As before, operations are still seen as ultimately mechanical, though now full prediction is even less feasible.

(3a) The brain — according to the current orthodox synaptic view

(a) Coding is *not* seen as stringlike coding, but rather a neural network with synaptic connections which used to be seen as logic gates, though it is now increasingly apparent that there are baffling non-digital complications to this picture.

(b) Knowledge gained is believed to be encoded as re-adjustments to the pattern of synaptic connections caused as a result of their actual usage, and such processes have been computer-modelled with limited success. There is little doubt that this synaptic activity occurs, but we are yet to hear how this could account for *non-trivial* mental abilities, even in principle.

(c) Cooperation between elements?
Certainly, though the details seem to lack any coherent overall pattern.

(d) Any mechanical self-organizing explanation?
For the above trivial re-adjustments — "Yes, perhaps" (though it is less clear how the connections were set up in

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the first place). But what about the non-trivial thought processes? This issue seems to have been largely ignored as inconvenient. Where it has been faced at all, science has apparently fallen back on implied or explicit occultism — mainly a sort of tacit vitalism, though Eccles has taken a supernaturalist stance, attributing synaptic wisdom to divine intervention.[55]

This nerve-net model has been around for a long time. Much was expected from this concept, but personally I feel that its explanatory power has turned out to be disappointing, and that it will remain disappointing unless we look for new (perhaps unseen) features, inside or outside this network system. Actually I do believe it plays several important-though-*subsidiary* roles even as we now see it, and I shall shortly outline these roles; but as a prime-mover for *sophisticated* brain activity, I suspect it has been a time-wasting red herring.

But even if it is subsidiary, it is nevertheless essential to the life and mental activity of higher animals (though clearly single-celled animals cannot possibly have such a nerve net). So what would its roles be?

Firstly this axon-synaptic system must be fulfilling its obvious role of relaying signals even if it is only doing it *passively*.[56]

Secondly it undoubtedly plays a major role in mediating emotions and subjective feelings — very important aspects of our humanity, though I will say no more about such aspects here.

Thirdly, it is well known that the 2D patterns of nerve-endings and other sensory input are often re-mapped in more-or-less the same pattern within the cell organization of the brain itself thanks to the tidy organization of the 'parallel wiring' of the bundles of axons. (This sort of activity is rather more macro than the postulated digital-IR signalling which supposedly operates primarily at molecular level. This scale difference probably allows scope for them to operate *either* independently, *or* in collaboration — according to local requirements).

Fourthly we should note the recent success in using artificial neural nets in such tasks as character recognition. This entails arbitrary-but-reproducible reshuffles of image-patterns or signal-patterns — *something which neural-nets are very good at*. The multiple-reshuffle means that sooner or later one is likely to find a re-formulation which gives a reasonably good 'Yes/No' test for some feature of the original image, (eg. its "T-ness") despite confusing pre-shuffle variations on how the letter "T" might be presented.

[55] See section 5.8 below — and appendix C.

[56] Appendix C offers one useful way of looking at this relay role. We have the problem of finding a reliable interface between the outside environment [E], and a postulated deep micro-mechanism [R], probably molecular. There seems to be no plausible way these domains could interact *directly* (except in single-celled animals), but our conventional neural network of axon connections [A] does seem well suited to act as a workable intermediary.

This is a valuable 'skill' and accords with the spirit of trial-and-error which is certainly a feature of other successful epistemological systems.

But essential though these four-or-more roles may be, they are not enough on their own to explain non-trivial thought; and I need to be persuaded that vague, slow, and 'floppy' mechanisms like synaptic modification can ever do any better than this unless they can also call on some other mechanism or trick.

Something else must be there. Something which is difficult to pick up experimentally, but what? Perhaps a supernatural interface on Neo-Cartesian lines as implied by the ideas promoted by Eccles? Or perhaps we should tacitly accept that such things '*just follow their own nature like electrons moving in a magnetic field*' (a form of vitalism)?

Alternatively we can look for less obvious mechanisms which may be operating in collaboration with the neural net — most likely something which (i) is on a smaller scale, (ii) offers more precision and speed, and (iii) offers a credible way for storing *sequential* coding of events. The most obvious candidates are at the molecular level, and particularly stringlike molecules such as DNA, RNA, and perhaps protein molecules derived from them.

As it happens, there is quite a body of circumstantial evidence to suggest that the really interesting activity is indeed going on at the molecular level; so let us now quickly re-examine the brain-as-an-epistemological-system from this alternative viewpoint.

(3b) The brain — the alternative view, molecule-based

(a) Coding *is* stringlike, seen clinically as a preset inherited *sequence of activity* (the 'scheme'), capable of alteration, selection, and compounding (early Piaget). Physically this could plausibly be encoded on RNA molecules (Hydén; and late Piaget) and used either individually, or else in coordinated clones. Note the analogy with normal morphological genetics, and with the immune system. Inherited behaviour traits would now be very easily explained.

(b) Knowledge is gained through spontaneously emitted behaviour *from within*, which is then experienced as being accompanied by satisfying or painful feelings. This is clearly a trial-and-error procedure analogous to the two previous systems, and indeed it is perhaps part of a single grand system along with them. Clinically this is well known to educationalists who realize that the child has to learn *through its own initiatives*.

A rather more radical application, which I offer for comment, is the suggestion concerning: — *How do I understand what you are saying when you talk to me?* A mere tape-recorder analogy would get us nowhere. Instead, could it be that I understand you only because I am constantly making a host of micro-hypotheses about what words or concepts you might utter next? Of course most of these micro-hypotheses will be wrong, but I will usually be left with the correct ones, as intended by you. Yet, in a sense, they will actually end up being *my own* words-or-concepts too!

(c) Cooperation between elements? Yes certainly, and especially as the child develops. In mammals there are persuasive signs that (as Piaget suggested), some scheme-codings come to control *other schemes internally* instead of operating muscular action directed at the outside world. Here is the basis for introspection, fantasy, and meta-linguistic abilities. It is also the basis for clustering elementary action-schemes into *mathematical groups* (Piaget 1949), and this then delivers the abstract concept of 'object', and hence the concept of *space*, which Kant wrongly considered to be irreducibly fundamental.

Mathematical groups are, in a sense, ideally self-consistent ensembles, with perfect coherence. Many human motivations can be explained in terms of a search for greater coherence in this-or-that perceptual area (especially relating to one's own self-concept within some environment). Thus this might be seen as an extension of the same drive which leads us to master the more material concepts of object and space. This attraction to self-consistency is also analogous to the coherence-seeking criterion which is now seen as important *socially* in the evaluation of scientific hypotheses and theories; as discussed in the following section.

(d) Such a system will be ultimately mechanical, though only in the quantum molecular sense, and not in same class as a 'cogwheel-and-lever' mechanism.

(4-i) Science and other social knowledge

In some ways society can be thought of as a live-creature and an epistemological-system in its own right. At any rate it does make some sense to say that a mob has 'a mind of its own' and is thus capable of making collective 'decisions' which the individuals in it would never make alone; and this can also apply to some extent in other more benign groups like committees.

So what is actually going on? I am not privy to any recent research on this matter, but it seems reasonable to suppose that there will always be a mass of minor communicational signs, words, and body-language between the participants — serving generally to adjust each person's status into a more consistent affiliation with the other participants. (Incidentally, this picture of population dynamics might well shed some light on how our brains function, seeing that they too constitute populations of individual cell-or-molecule activity).

But to return to the dynamics of society: We might say that there is a sort of hermeneutic adjustment of ideas, and this will tend to gravitate towards some sort of maximized coherence of concepts *within the mob as a whole*, and with rather less-than-usual weight being given to the coherence criteria that each individual would normally apply when in less emotionally charged situations.

(4-ii) Features of scientific-and-social epistemology

(a) A stringlike coding called 'Language'
— with simple adequately discrete elements — words, phonemes, alphabet, symbols, etc. (*objets trouvés* from a *social* viewpoint, though also a non-trivial product of individual brains!).

(b) Scientific Knowledge gained through trial-and-error rather than design?
This could be a major debating point! Perhaps one can safely say that it is *partly* true. (Just 'how true' one believes it to be will rather dependent on one's metaphysical view of the individual within society, but we had better leave that for another time). Let it suffice to say that there is at least something in the notion that ideas *from individuals* are often little more than arbitrary 'objets trouvés' in the eyes of society-as-a-whole; and that it then goes on to judge the ideas according to its own idiosyncratic 'logic' which has more to do with maintaining a self-consistency within its own bizarrely defined world, than in serving 'truth' as normally understood!

However my point is that there is probably some validity to the analogy with other trial-and-error based epistemological systems, despite the also-plausible view that having *thinking people* within the system alters everything because it introduces a genuine inescapable vitalistic element into the *social* system. After all, *surely you and I can genuinely design things in a pseudo-supernatural way, even if nothing else in the universe can!?*

I believe both these views can be reconciled, with honour both ways, but I had better not digress into that now!

(c) Cooperation between elements — both possible and necessary.
Despite the doctrines of modernism and extreme-empiricism, there is more to knowledge-capture than mere evidence-hunting, important though that may be. Philosophers at least, are now well aware that the strategies of coherence-seeking and hermeneutics[57] are ultimately more important — and that even our perception processes (used to assimilate evidence) are subject to these new criteria.

(d) Operations are yet again ultimately mechanical, but the systems defy full prediction in practice — and here especially. It may sound strange (and 'politically incorrect') to even suggest that society is based, even ultimately, in blind mechanism. The danger in such a view (even if it

[57] *Hermeneutics*: the search for mutually consistent sets of ideas, via the interchange and reshuffling of ideas through debate.

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is correct) is that we shall be tempted to run political and economic systems as if they were mere machines with no real people in them. Unfortunately that mistake has been made many times during the twentieth century. The point is that the mechanism is so remote from the manifest phenomena that there is never any discernible trace from one to the other in any real particular case — and any arrogant claim to have squared this circle is likely to end in disaster or absurdity.

But there is still a case for facing up to such esoteric connections, as long as we maintain a proper perspective on our limitations. Countries and economies do have to be managed in some form, and knowledge about the ultramicro underpinnings can help to understand the constraints within the macro, if only we have wit enough to see the theoretical connections.

4.3 Some tentative conclusions on the four types of learning-system

1 : The *trial-and-error* or "natural selection" strategy is widespread in its potential applications, and not confined to traditional Darwinian contexts.

2 : It seems likely that it **is** ultimately the only workable epistemological strategy,[58] (though complicating factors will often disguise this ubiquity).

3 : If so, it follows that insights in any one of the four epistemological systems will often be applicable to the other three.

4 : That could clear the way for new progress in brain-studies.

5 : This also sheds light on the process of scientific knowledge-capture.

[58] Note Jerne's similar conclusions within a somewhat narrower field which included further Darwinian variations. (His comments appeared in the same year that Piaget published his *Biology and Knowledge*):
"Looking back into the history of biology, it appears that wherever a phenomenon resembles learning, an *instructive* theory was first proposed to account for the underlying mechanisms. In every case, this was later replaced by a *selective* theory.
Thus … species… until Darwin…
Resistance of bacteria… until Luria and Delbrück…
Adaptive enzymes… Monod and his school…
Finally, antibody formation…"
— the actual topic of his 1967 paper. [My *italics*].
(This book effectively lumps the first three of these together as *all* being Darwinian. But perhaps we should be more discriminating — in which case there would be *six* systems to consider in this chapter, and not just four.)

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5. ASSESSMENT OF THEORIES, IN GENERAL[59]

5.1 *An "anonymous" theory — as a symbol for* every *theory*

There is a particular body of theory which has been around since the 1920s, waiting all this time to be accorded the recognition I feel that it deserves. For the moment I shall enigmatically refer to this long-running "heresy" as *Theory X* — this being just another of those theories which is gradually developing within itself, and awaiting some magic formula for gaining public approval, especially if it happens to be correct.

My own contribution to *Theory X* has been to arrive belatedly at the problem as an interdisciplinary outsider, and as someone with enough knowledge of physics and info-technology to see through the technical weaknesses of its rivals.[60]

Today I do not really want to talk about *Theory X* itself even though that will be unavoidable; but my immediate interest will be to talk about the political and rhetorical issues raised in trying to get such a theory off-the-ground and properly understood.

Of course, after 70 years there has to be a sizeable body of literature already, but its rhetorical power is virtually nil. The related formulations *have* had some following from pragmatists looking for new quick-fixes, but in my view this has done nothing to further understanding of the underlying theory. Quite the reverse in fact, especially when those particular quick-fixes then go out of fashion. Moreover this *Theory X* has hitherto had no credible physical basis which would allow readers to picture the processes in any material way; hence the explanations have had to be abstract, and pure abstractions do not make for best-sellers!

There have been further problems too, but it is interesting that these have also been shared by that well-documented theory in geology, the now-successful theory of Continental Drift. Both had to endure the period of 1930s–1960s when positivism[61] and overzealous empiricism reigned supreme (at least in the Anglo-American world), but as both theories were somewhat dependent on theoretical arguments and undersupplied with convincing experimental evidence, their place was somewhat tenuous. In both cases, well targeted expensive experimental studies might have settled the matter earlier on, but who is going to fund such a project on a still-heterodox idea? — *"Catch 22 !"*

Let us look at one generalized agenda for developing and "selling" such innovative ideas, i.e. the agenda which seems to have applied in the Continental Drift case. We may then be in a position to try applying it to the more complex and emotive case of *Theory X*.

5.2 *A framework-procedure for handling theories in general*

What procedures do we follow when we assess theories, alone or in competition? It should be helpful to spell out explicitly what actually goes on; and we need to be clearly aware of the theory-conceptualization environment and its constituents:

It seems we have to posit *some structure somewhere* (even if it is in some supernatural dimension). In particular we seem to need some idea of basic building-blocks, basic code-entities, or 'elements' of mind, some set of indivisible stable "atoms" for the system, and we also need some formulation of the ways in which these atoms interact. Call them "causal laws" if you like.

Here is the sequence of theory-development events which might apply in general; but at any rate it seems to apply to the events leading up to the acceptance of Continental Drift, and it also seems likely to apply to *Theory X:*

Let us say that the theories we are interested in are all claims about

(i) the basic elements of each theory,

(ii) possible entities outside the system but which affect it in some way,

(iii) causal connections between them, and

(iv) how the system behaves in these circumstances.

Thus, in figure 5:1 —

[59] Based on a paper delivered to an AAHPSSS Conference at the HPS Dept, Melbourne University, (30 June 1996).

[60] As a contrast, Professor H.J.Furth was attracted to this same body of theory because it seemed to be the only one which offered a coherent account of the *problems and abilities of deaf people*. So he too was in a position "to see through the technical weaknesses" of the rival theories, but starting from rather different premises. (Personal communication).

[61] See, for instance, *Logical Positivism* by Hanfling (1981).

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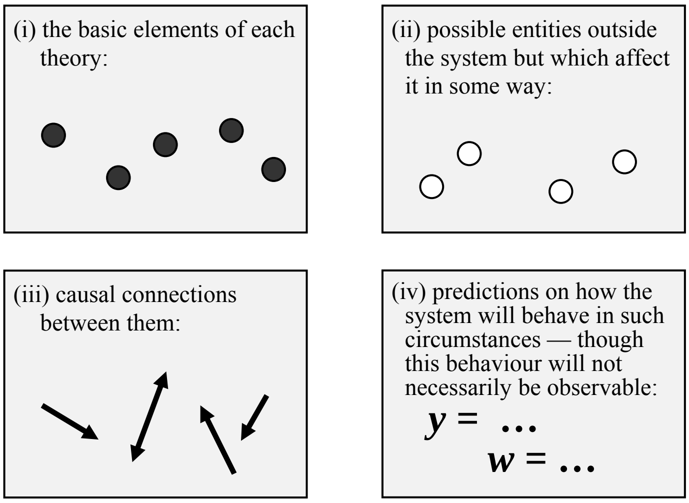

fig. 5:1

We might say that any given theory must make some sort of claim,

• firstly about which of the possible (i)-(iv) items exist and are *relevant*, and then

• how they are supposed to be interacting.

Let us partially copy the way algebra would express these claims, and write a typical postulated-relationship (symbolically) as in figure 5:2.

Note that I have not made any attempt here to set these elements inside the "(…)" into any sort of explicit order. That is the task for each theorist to tackle: In effect, he or she must turn the unspecified algebraic "*f*" into some sort of postulated structure, which may or may not be right as a model of reality. Meanwhile some other theorist might make a different claim: $y = g\,(\ldots)$.

And what is the *real* state of affairs? Strictly speaking, no-one can ever know *for certain*. We can represent it algebraically any way we like — $y = \boldsymbol{F}\,(\ldots)$ perhaps. But of course that leaves out the secret hidden details about "***F***"; so then we have to *assess* what its true nature might be, choosing as best we can between: *f*, *g*, *h* … — or whatever.

In practice though, we do sometimes decide what ***F*** must be, and take this decision as being "beyond all reasonable doubt".

Thus we now say with confidence that: *The Earth* <u>*is*</u> *ball-like, and not flat*; and even: *Continents* <u>*do*</u> *drift, and the Atlantic is a gap left by such a drift.* (We will look at the history of the

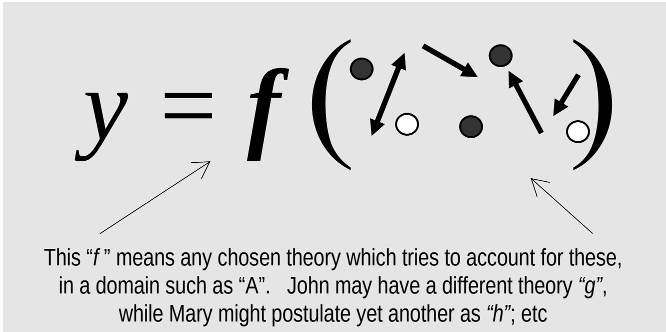

fig. 5:2

Continental Drift theory in the next section).

We shall deal with assessment and testing within a paragraph or two; but right now we are concerned with the underlying fundamentals.

First note that each claim/postulate (like *f*) needs to be made reasonably specific. So let us note down an algebraic noncommital checklist of assumed *elements and forces* (dots and arrows) — followed by a list of *rival theories* about them (*f*, *g*, …). We can also add predictions arising from these theories ($y =$, $w =$, …) whether these forecast

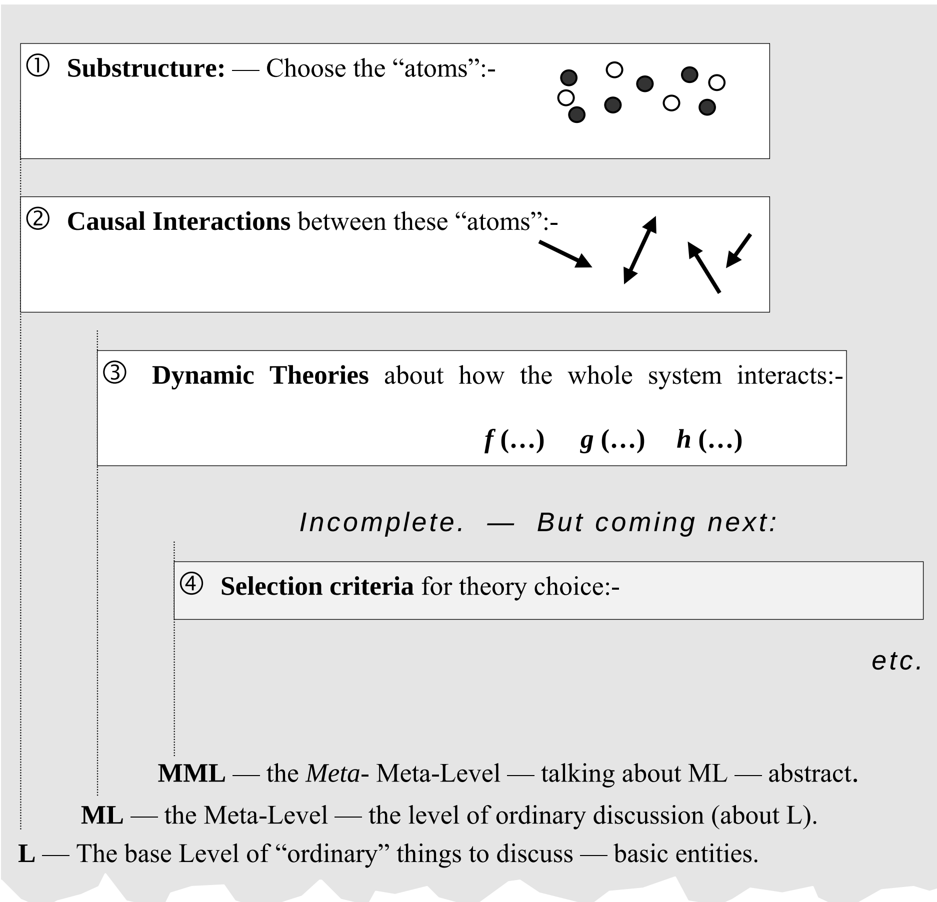

fig. 5:3a

One way of processing theories — (part 1) events be observable or not. — See figure 5:3a —

Now we can turn to testing (④+⑤+⑥), whether that be • balanced testing (allowing both external and internal coherence assessment), or • unbalanced like the Popperian insistence on experimentation exclusively (external coherence alone); or indeed • unbalanced the other way, using pure internal coherence.

But what about • *common sense and other "tricks which usually work" even though they do not pass normal standards of scientific validity?*
This topic was raised in chapter 1, and there is no need here to debate it further; but we should notice a few points directly relevant to practical theory-processing:

(a) These intuitive skills are indispensable in the real world which can seldom wait for full rigour, and their decisions are often right. The trouble is this:

(b) We seldom understand *why* these intuitive skills usually work, so it is difficult to guard against our expecting too much of them; and in our ignorance, we are likely to cast our bans much too wide "just in case" — like the many bizarre measures taken to ward off disease before Pasteur made his discoveries about bacteria.

(c) If we did understand our intuitive skills properly, I suspect they would all ultimately reduce down to coherence-analyses rather like the present one. In that case, our present in-depth analysis would possibly cover them too (though they might well categorize some of the elements differently, and they would certainly tend to operate at a more subconscious level).

(d) Whenever we do not understand our intuition, or when it is clearly suspect as a mere dream or ink-blot association, we should treat any conclusions as tentative only, and seek alternative confirmation (or disconfirmation) through respectable processes which we *do* understand.

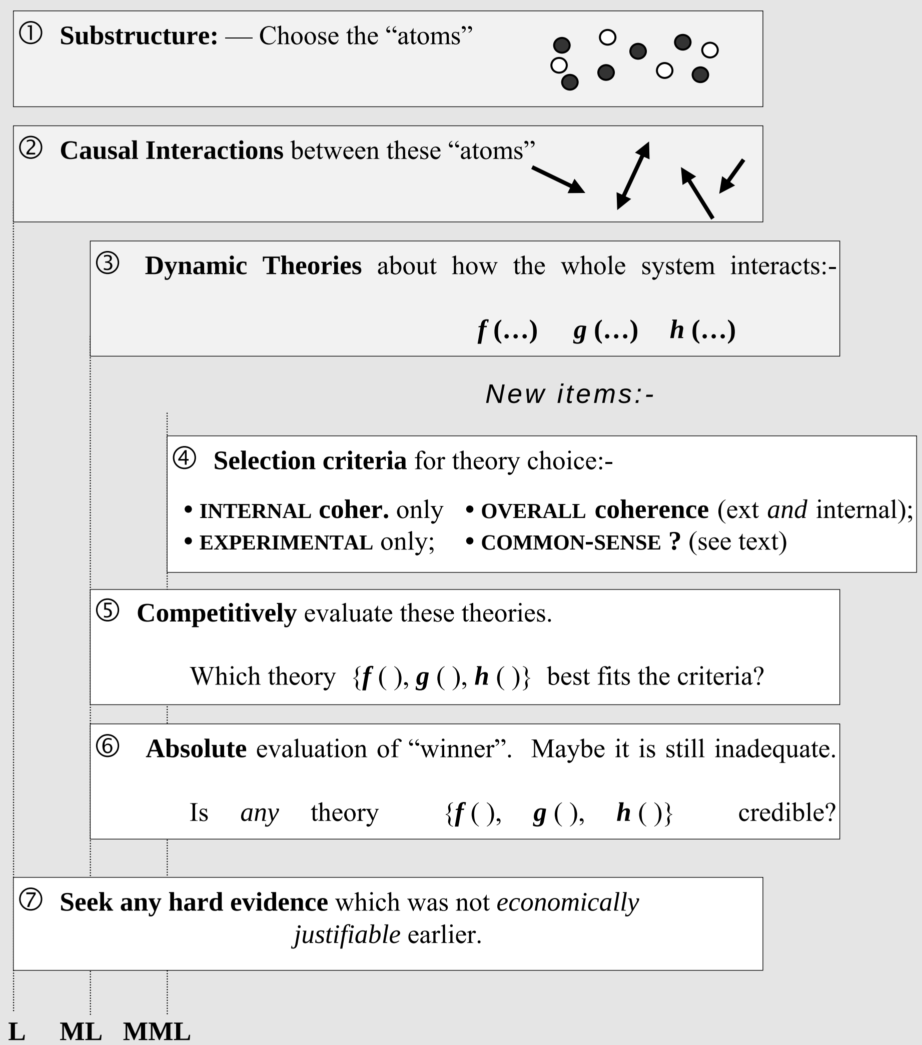

fig. 5:3b

One way of processing theories (completed chart)

So, despite some ambivalence on this last point, let us now complete the chart of theory processing, giving us figure 5:3b.

— Or to summarize it all, more compactly:

① **Substructure:** — Choose the "atoms"

② **Causal Interactions** between these "atoms", hence:

③ **Their combinations as *theories*.**

④ **Selection criteria** for theory choice

⑤ **Competitively** evaluate these theories, using the criteria.

⑥ **Self-consistency** evaluation of "winner". Maybe it is still inadequate.

⑦ **Seek any hard evidence** which was not *economically justifiable* earlier.

↑L ↑ML ↑MML

This may be a little *ad hoc*, and not above criticism[62], but perhaps it will do for our present two cases. Anyhow there are four things I would like to point out about it:

Firstly, the whole sequence is a rather shaky house-of-cards, which could collapse (or partially collapse) in the light of new evidence or a new conceptualization at any level. — Call this a "paradigm shift" if you will.

Secondly, coherence-testing[63] plays a part in decision making at every level, though this is often hidden from our attention. (The levels are suggested here by degree of indentation, and labelled "ML" for Meta-Level, etc. — though that too may be debatable in its detail).

Thirdly, any really "critical" experiments will often be very expensive, and are therefore not likely to get going until there is already a persuasive coherence-based case. That obviously makes good sense to budget-watchers who like to pick winners, though we might like to debate its wisdom overall.

Fourthly and finally, note the progress-blocking effect of this sequence whenever a rigorously empiricist-positivist policy is in place at step ④: No theory is officially allowed to pass the tests at steps ⑤ and ⑥ unless they have solid experimental backing — and that is something that can not be granted to them until they reach step ⑦! The common result will thus be an impasse, or at any rate, a very prolonged campaign.

Could this be deliberate policy, like the political strategy of referring matters to a Royal Commission? Probably not usually. Such things can quite easily happen unconsciously, and if the purse-holders find nothing wrong with the present situation, they will see no reason to question current procedures. No actual conspiracy then in that case, but it would be naive to believe that this is always so, especially if there are powerful commercial interests involved.

5.3 Geological theories — Do continents drift? [64]

Let us apply the above chart to geological theories in the decades before the death of Wegener, the original proponent of the idea:

[62] On this occasion my objective is pragmatic, only concerned with "generalization" as a guide to a narrow range of cases; so while this chart *just might* turn out to be universally applicable, that is not my prime objective right now. And in any case:

> In the social sciences, complexity and constant-change ensure that we can *never* find infallible laws; and socially-based "scientific method" is no exception. We may legitimately aspire to "reasonably-reliable laws", but woe betide us if we take such guidelines as infallible!

[63] *I.e.* evaluating a theory along with its set of postulates — according to how self-consistent they are, rather than appealing directly to observation as such. *E.g.* see Thagard (1992).

[64] This account is substantially based on the account by LeGrand (1988). *Drifting Continents and Shifting Theories.*

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Pre-1930 (year of Wegener's death)

① **Substructure:** "Atoms" = Stable continents
"floating" in denser *solid* rock (*isostasy*).

② **Known forces :** Centrifugal force;
Tidal; Earth's contraction due to cooling.

③ **Theories**: Permanentism — Contractionism (Suess)
— Drift (Wegener)

④ **Selection-criteria bias:** • Fieldwork (Anglo-American);
• Internal Coherence (Europe).

⑤ **Competitively:** Contractionism best — *theoretically best*,
(calculated: Energy & Forces)

⑥ **Self-consistency Evaluation:** — None adequate!

⑦ **Hard evidence:** — None; but inaccurate misleading calculations for
Greenland suggesting that it was drifting rapidly!

If I may digress for a moment. — Please note the *perhaps-constructive* role of "dodgy data" like the supposed rapid drift for Greenland, which was eventually shown to be empirically wrong, but which meanwhile helped to keep the more-correct theoretical approach alive.

In *chapter 6* we will look at similarly unreliable (but possibly correct) evidence which I came upon unexpectedly. Even if these unplanned observations turn out to be misleading, we will see that they have nevertheless prompted a potentially profitable side-line of inquiry in the *Theory X* project, as discussed immediately afterwards in *chapter 7*.

POST-WAR (1945-)

① **Substructure:** ———— no change ————

② **Causal,** ***NEW ITEM:*** Earth self-warming due to Radioactivity
— so *Convection possible!*

③ **List of theories:**: ———— no change ————

④ ***SHIFT*** **in criteria:** "Kuhnian revolution" *1960s* —
Opens way for • *Internal Coherence*.

⑤ **Competitively:** Drift is best *theoretically*,
but damned while Positivism rules.

⑥ **Self-consistency Evaluation:** Drift theory: very good
— (*Overall coherence* evaluation).

⑦ **Hard evidence:** *Expensive* submarine geology, etc.
— ***ACCEPTED AS "PROOF"***.

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5.4 From geology towards "Theory X"

In retrospect it turns out that the geological problem was actually comparatively simple. Its "atoms" were fairly straightforward, and the final solution can quite easily be explained to the layperson. If I may draw an analogy, its solution is like a single-span bridge (like the Sydney Harbour bridge) with the macro-problem on one side of the waterway, and the "atom-based" solution on the other — but the waterway is narrow enough so that a single span will suffice.

But some waterways are wider than that, which means that they need two or more spans to bridge the gap, like the railway bridge across the Firth of Forth. Likewise we now come to a different problem area which is decidedly *more complex* than Wegener's continents, and no-one has yet got near to bridging it with a single span of theory.

From the context of this book it must be obvious that my supposedly anonymous *Theory X* is involved in the age-old problem of understanding the mind/brain. Of course Descartes saw this as (in effect) a two-span problem as long ago as the 1640s, but with one of the spans as being impossible to build. While the physical bodily brain component (A) was in principle open to human explanation, the mind (B) definitely was not. Indeed the mind was relegated to a supernatural domain[e] beyond our ken, and outside our space-and-time — effectively putting this aspect of the problem into the "too hard basket".[65] (See figure 5:4).

Of course Descartes was then stuck with another problem. He had to explain the *interface* between these two incompatible domains (A) and (B). We may not now think much of his suggestion that the pineal gland might serve this role, but we should ourselves take heed that interfacing is indeed a vital problem if we are to envisage mixed domains; and of course the sense-organs and muscles serve this role in our physical brain's dealings with that foreign domain called "the outside world"! — (We shall return to this question of interfaces from time to time.)

These days we can offer other *alternative approaches to explaining that Mind component* which Descartes considered ineffable; see items (C) and (D)[66] in figure 5:5.

The psychology item is reasonably self-explanatory, but the "word" item perhaps warrants some preliminary comment.

Philosophers like Bertrand Russell and the earlier Wittgenstein (of his *Tractatus* period) understandably assumed that *words* (C) were basic to thought. Admittedly that word-basis may well underlie the *advanced thinking* that philosophers so happily indulge in. But can words really underlie *our more elementary and fundamental thought processes*? (Surely these were in place long before our species evolved any language ability?) We will return to this question shortly.

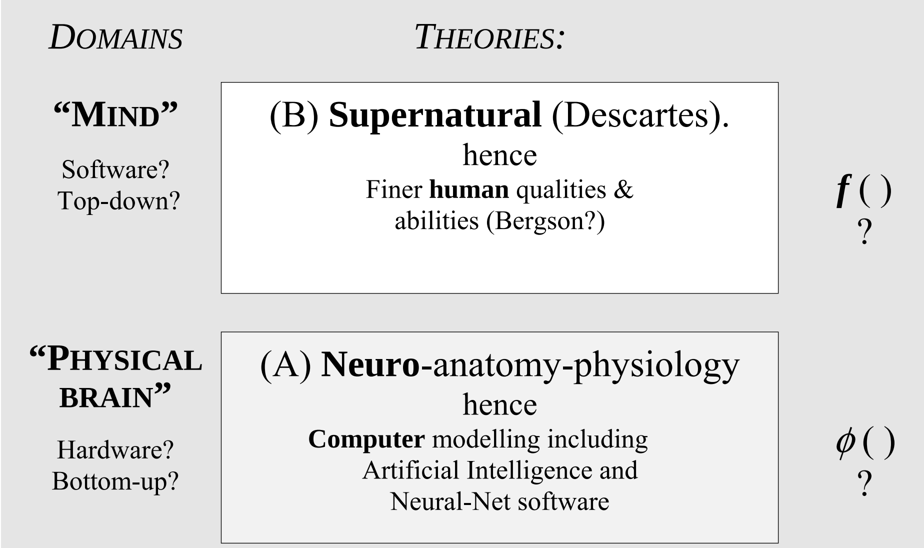

fig. 5:4

[65] Later in the same century, Boyle also had to admit mechanistic defeat in a similar way, in trying to account for the activity of particles or "corpuscles"; (Chalmers, 1996).

[66] Here "A, B, C, D," refer to supposed *mental domains*, each built up from its own collection of "atoms" and causal connections listed under ①+②+③, above. For each domain there may be various theories as to how the elements interact; or there *may* be only one theory for each, as depicted here.
Later (especially in appendix C), the relevant domains are taken to be slightly different from this set, and the labelling [E,A,R,S] is also changed. Here are the equivalents, where applicable: **(A)→[A]** "Axon-neuron-synaptic" domain; **(B)→[S]** "Supernatural" domain; **(C)** discarded as belonging to the social system, and *not* primarily to the individual mind; and **(D: somewhat developed)→[R]** "RNA-like" domain. To these is added **[E]**, the "External Environment" domain.

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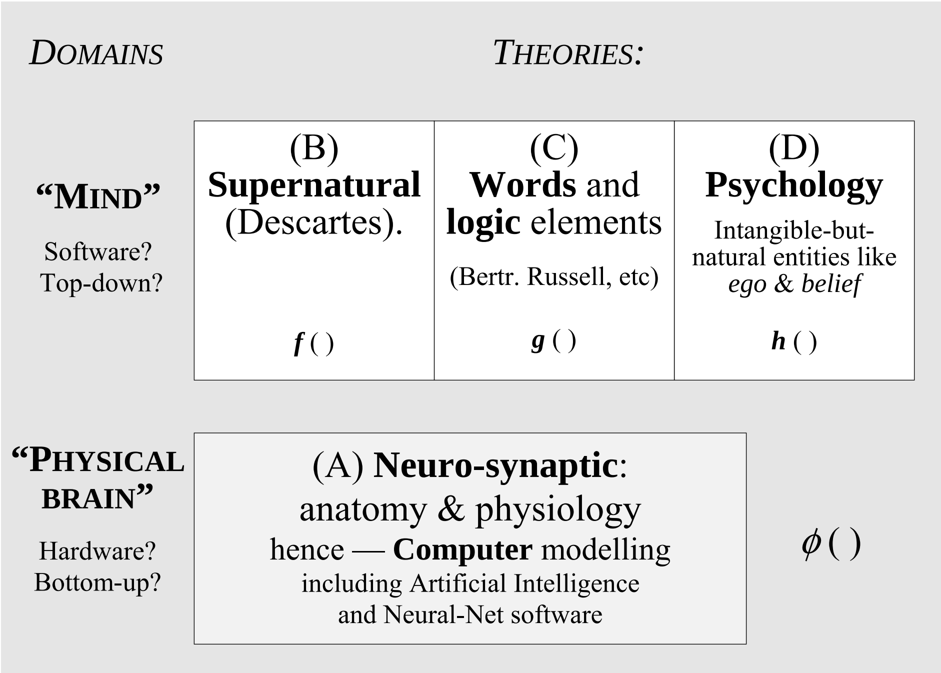

fig. 5:5

"action potential" signals in the nervous-system (A) to interface with the psychologist's version of mind (D). See the next version of the chart, figure 5:6 —

So what about (C), that questionable idea that all thought is word-based? Paradoxically I suggest that this is both wrong, and yet still an important clue to the truth. Taken literally, it cannot be right. Infants in their first year cannot use language, but surely they are not devoid of all thought? And what about your pet dog? Then there are also rather more esoteric problems about how and where any totally word-based process could possibly start, beginning from scratch — questions involving Gödel's theorem, and Wittgenstein's repudiation of his own *Tractatus*.

I suggest that there is a natural confusion here between the thought processes of the individual, and what might be loosely described as "social thought" which does indeed use words as its basic units.

One might, or might not like to think of society *en masse* as having a sort of Gaia-brain which does use its words as its basic "atoms" of thought. But be that as it may, herein lies a clue since words and sentences are *one-dimensional coding sequences*, and that fact seems to accord *formally* with the RNA postulate. Thus:

If words	are	the "one-D mental atoms for mind-work" **within society**, then	
RNA sequences	may be	the "one-D mental atoms for mind-work" **within the individual**.	

However if there is going to be molecular encoding within the mind/brain, must this encoding necessarily be one-dimensional? Why not 2D pictures, 3D models, or zero-dimensional disorganized "jottings scattered around the room"? Surely there are great logistical advantages to be gained from one-dimensionality in one's coding system, usually a neat compromise between storabilitity and accessibility; and of course one can still use maps or models for special purposes if needed.

Perhaps then, that is what was missing from the neuroscience model (A) — some sort of one-dimensional *sentence-like* or *word-like* coding system. (These could not plausibly be actual speech-type words; but a linear coding system such as DNA or RNA would be much more feasible, and so maybe that is what we should be looking for as an adjunct to the recognized neuro-synaptic system?)

5.5 Mind-brain theories

Descartes promoted a dualism of Mind-versus-Matter (with a problematic interface between them). His idea of mind was essentially *supernatural*: (B) in the above chart, figure 5:5. Bergson took a similar attitude to Descartes some 250 years later, (around 1900), and the late Sir John Eccles was still promoting the idea in recent years (1986, 1990). However there are now at least two other models of the mind as such, making three in all (B, C, and D). Given this extra scope, I see the task of Mind Science as looking for *at least one* of these mind systems which has a technically credible interface to the "axon-synaptic" structures known to neurophysiologists. I would then expect that this chosen mind-system should then be extensively explicable in ultimately material terms.

In short, what we need is the missing interface-span from the centre of a three-span bridge.

Piaget seems to have undertaken this task, and yet he stopped short when he was apparently within sight of his goal. It is not clear why, but given the still-existing preference for empirical work, he may well have thought that further developments were beyond anyone's experimental competence. He did postulate an abstract unit of action (or perhaps rather a unit of action *encoding*), and hinted very tentatively in 1967 that it *might* be RNA. But then he seems to have left it at that.

If we do take up the suggestion, we arrive at quite an interesting set of likely theoretical consequences which Piaget himself never seems to have considered. To start with, it does give us a credible basis for the well-studied

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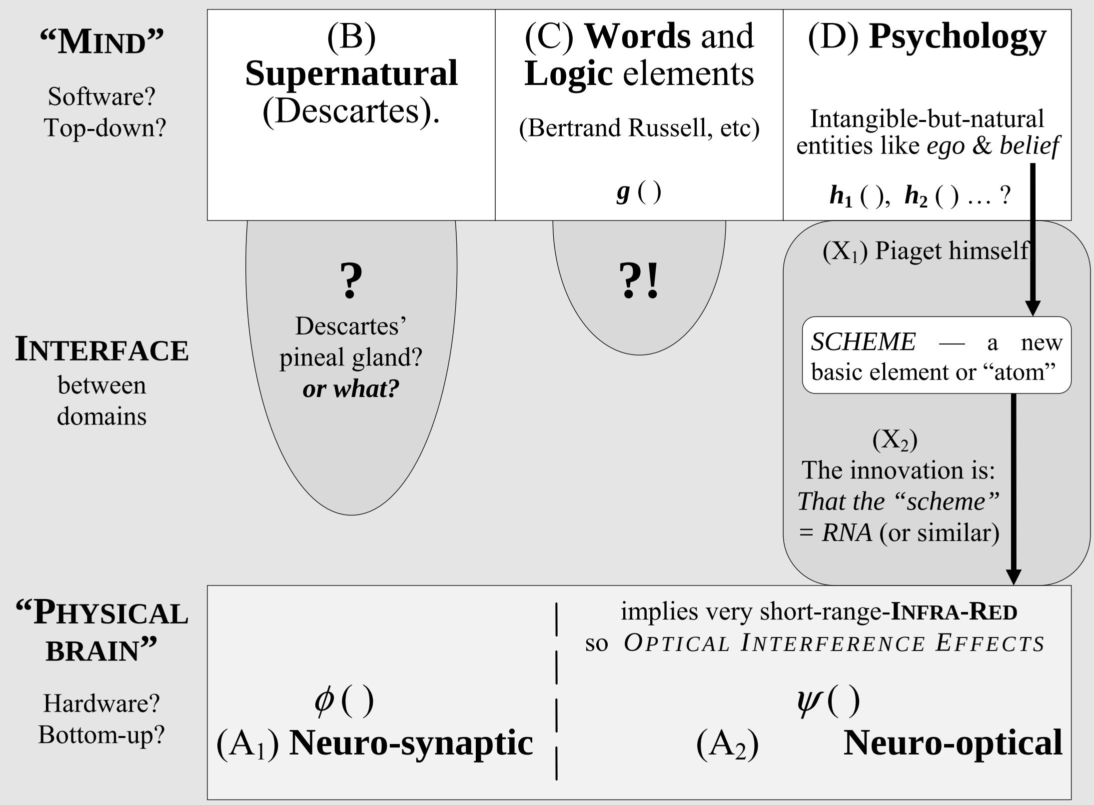

fig. 5:6

Anyhow it is helpful to look at the way ideas have developed about the workings of the mind, with animism and supernaturalism being probably the "*1st Attempt*" to explain the-mind-and-everything-else. Then we may see Descartes' effort to explain the mind as a *"2nd Attempt"*.]

Likewise we may look on recent orthodoxy as the *"3rd Attempt"*:

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3rd Round on Theories of the Mind — Mainstream 1880s-1960s

Domain →	**(A) Neuro**	**(C) Word/Logic**	**(D) Psych (mainstream)**	**(B) Supernatural**
① **Structure/Atoms**	Synapses etc; do not → *mind*	High structure but limited value	Rigid method, vague ideas!	Vague, disputed, or denied, etc.?
② **Causal Intraction**	DC-electricity + Chemistry	Rules of logic and Maths	Statistical etc., but vague detail	Vague, but some "common sense"
③ **Mind-Theories**	• (vague)	• (vague)	• (vague)	• (vague)

④ **Selection criteria:** Group rivalry? Unbalanced Coherence: Empiricism OR Internal (*only*)

⑤ **Comparison**: None convincing; but (B) still closest to everyday life, so **tacit lay approval!**

⑥ **Overall coherence**?? Poor in each case. — Something missing?

⑦ **Hard evidence**?? None regarding details of overall mental operation

Note that over the decades, the natural-science approach has promised much. Its achievements in applied technology might or might not have been good enough, but when we come to fundamental explanations of mental phenomena the results really might be seen as being a bit disappointing. Of course many arts-orientated people and humanists never really believed that science could ever properly explain such special things as mind or soul, so they will not have been surprised at the non-turn of events.

However some rather more helpful basic ideas have actually been hatching over much of the same period; though it was not prudent to advertise their radical and less-than-fully-empirical nature during the pre-Kuhnian era[67] — so mainstream science has failed to recognize this trend for what it is. Thus (4th round, top of next page):

Piaget was usually very reticent about suggesting any physical embodiment for his abstract concepts like the *scheme*-code; so at first sight this seems just as vague as (say) Freud's *superego* concept. Nevertheless a linear structure is implicit in many of his writings; and if we are looking for physical linear encodings within the body, then RNA and DNA are obvious candidates. Moreover any such system would immediately go a long way towards explaining the often-faithful inheritance of behavioural traits and mannerisms. In any case, Piaget actually lets us know that he *does* have RNA in mind as a candidate mechanism, though he scarcely does much to promote this idea. (See his book *Biology and Knowledge*, 1967).

However if we do take this idea seriously and investigate its micro-physical implications, we end up with a minor chain-reaction of plausible suggestions. Something like the following "5th Round" in fact. But as we go through this chart, I invite you to watch yourself for signs of overload on your attention-span, a serious problem when one tries to explain an extended system like this — (see 5th round, bottom of next page).

5.6 Informal summary about theories in general

First let us look at one more example, a simple one to outline: In the period 1846–1896 there was concern to calculate the age of the Earth reliably using the then knowledge of geology and physics.[68] The basic elements (or "atoms" ①) underlying the theory included those initially listed above for continental drift, plus the orthodox physics of the day; *but no-one then knew anything about radioactivity, so there was a vital element missing.*

[67] The best-known landmark of postmodernism within Scientific Method, is the book by T.S.Kuhn (1962/1970) *The Structure of Scientific Revolutions*.

[68] This is discussed in some detail in a chapter of Nahin's (1988) book. We meet again two scientists who figured above in section 3.3 in a different context: Here we see Lord Kelvin as the main theorist, and Oliver Heaviside who was called upon for his mathematical expertise.

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4th Round — Piaget, and Cyberneticians like Ashby (1952) —. 1920s-1970s

Domain →	(A) Neuro	(C) Word/Logic	(D_2) PIAGET'S Psych (+old)	(B) Supernatural
① **Structure/Atoms**	Synapses etc; + new detail	High structure; + new detail	"*scheme*" as a unit of action	Vague, disputed, or denied, etc.?
② **Causal Intraction**	DC-electricity + chemistry	Rules of logic and Maths	still vague, but much less so	Vague, but some "common sense"
③ **Mind-Theories**	• (vague)	• (vague)	• (*less vague*)	• (vague)

④ **Selection criteria:** Still the same rivalry and Empiricism? + *Internal-only* fundamentalisms?

⑤ **Comparison**: Piaget's basic notions win *some* converts (in D_2 domain); but still no consensus.

⑥ **Overall coherence**. Quite good if the *whole* Piagetian epistemological system is adopted, but lacks explanations for accompanying physiological development.

⑦ **Hard evidence** None!

5th Round — Piaget + Physical mechanism

	(A) Neuro	(C) Words+	(D_3) PIAGET'S PSYCHOLOGY + compatible micromechanisms	(B) Super-natural
① **"Atoms"**	Synaptic	Structure; but...	"*scheme*" as RNA-like, = a language-like code for units of action	Vague
② **Causal**	DC-phys + chem.	Rules of logic	Laws of chem & advanced physics: Info-tech including fibre-optics! Optical interference?	Vague
③ **Theories**	• (vague)	• (vague)	• Old Piagetian + *New Piagetian* ***with-physics of high-frequency effects.***	• (vague)

④ **Selection criteria?** Seek *balanced coherence*: External (experimental) + Internal

⑤ **Comparison**: The *New* version is much more specific, removing many "somehow"s.

⑥ **Overall coherence**. Incorporates whole Piagetian system + the current neurosynaptic system (in a secondary role) — and it offers *unexpected explanations* for the accompanying physiological development and shape-maintenance.

⑦ **Hard evidence** — Fragmentary and retrospective — details in later publications. Thorough tests are probably feasible, but they would be very expensive to do properly (like deep-ocean geology to test for "Drift"). Chapter 7 mentions a set of *long-shot* observations which are clearly unreliable except as a catalyst to further work (*cf.* the erroneous "large drift-rate" for Greenland mentioned on page 32). These myelin-dimension measurements could be re-done, though their relevance is a bit tenuous anyhow.

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Lord Kelvin argued that, given the laws of cooling, the Earth could only be some thousands of years old (more-or-less in line with the biblical-sources account), and *not* the many millions of years which accorded with astronomy and Darwinism. Note that his argument was perfectly valid given his basic assumptions. We now know that natural radioactivity keeps the interior of the Earth at a high temperature. But without that, our terrestrial climate would have become very frosty indeed, long ago!

Lessons from this debate?
(a) If some vital ingredient is missing, then our conclusions can be drastically wrong.
(b) There may be no obvious sign to warn us that such a vital item may be missing — and that lesson might be applicable to our problems in solving the mind/brain riddle.
(c) There was nevertheless a sign here that something was wrong, and this was a failure of overall coherence, notably a failure for the model to cohere *internally* with the models of other sciences.

Likewise in the case of continental drift. Here almost-the-same vital element was missing, but with less excuse. Radioactivity had been discovered in 1896, thus soon explaining Kelvin's Earth-cooling dilemma. It was thus no huge extra step to infer that mid-Earth temperatures were high enough *for continents to be actually floating on a fluid substrate which allowed convection*; and yet that conclusion took a long time to become effective. Of course, the distraction of two intervening world wars did not help; but neither did the policy of rigorous experimental work at all costs, along with a reluctance to meet "all costs". So:
(d) The evidence may be there after all, and it may be worth looking for it.
(e) balanced coherence would have been a worthy explicit goal here too.
(f) Crucial experiments (part of external coherence-testing) are often very expensive; so depending on them alone may well block progress in a *Catch 22* situation. It might be more effective, and cheaper, to pay more respect to properly conducted searches for internal coherence.

In our current topic, *the mind*, it is obviously still too early to draw definitive conclusions, but it seems possible that the above advice will be useful. Also it looks as though the following suggestions could be applicable:

(g) For really complex problems, it may help to break it up into two or more layers of complexity and deal with each separately. — Descartes did this in 1620 giving us *mind + body + pineal-gland interface*, though he (or his censorious culture) gave up too early on the *mind* aspect, and today we might not think much of his other details. So:
(h) Even if we get these layers right, it *might* take a long time to get much further.
(i) There may be more layers of complexity than we bargained for, and
(j) Some of these layers may be unobservable, so we may be forced to depend on internal coherence if we are to make progress.
(k) Internal coherence is a risky procedure if left on its own for too long. This is especially true unless we can find a rigidly defined set of basic elements (like an *alphabet* or set of *"atoms"*). However *if ever we do find such a plausible digital substrate*, it gives us the best chance for building plausible models from the bottom up.
(l) It is conceivable that nature itself was only able to proceed reliably in the first place by following this sort of "building-block" procedure.

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6. The Dilemma Over Striking-But-Elusive Data

6.1 Impressionism used on scattergrams, (of Boyd and Kalu)

Consider these two scattergrams (Boyd and Kalu, 1973). Never mind what they actually signify, but look only at the patterning at this stage. To the original authors, the important issue was the gross distribution of these points, as two or three amorphous clusters. But I happened to notice an additional *different* suggestive trend amongst the fine-structure of their distribution, especially in the bottom left-hand corner near the origin. Before reading any further, you might like to study the distributions yourself, and see if you hit upon the same statistical trend?

Did you notice anything — any surprising regularity? — What struck me was the tendency for the points to lie on straight lines radiating from the origin. So, did that have any real significance? Was it a just a random effect? Or was it perhaps some artefact of the experimental set-up?

Alas I did not know then — and even now, well over a decade later, I still don't really know. (Professor Boyd kindly sent me some of the original micrographs and tables of the actual measurements; but he made no comment about likely artefacts, and perhaps indeed there was no evidence that there were any). I also made my own measurements with whatever material I could lay my hands on; and while this gave slight encouragement, the results were hardly acceptable statistically. Nor were other publications with similar data much help. For one thing, such measurements were becoming automated using pixel imaging. This technique was quite appropriate for the gross-trends sought by the experimenters themselves, but it completely sabotaged the fine-resolution which I was seeking. (Kalu had presumably done the measurements by

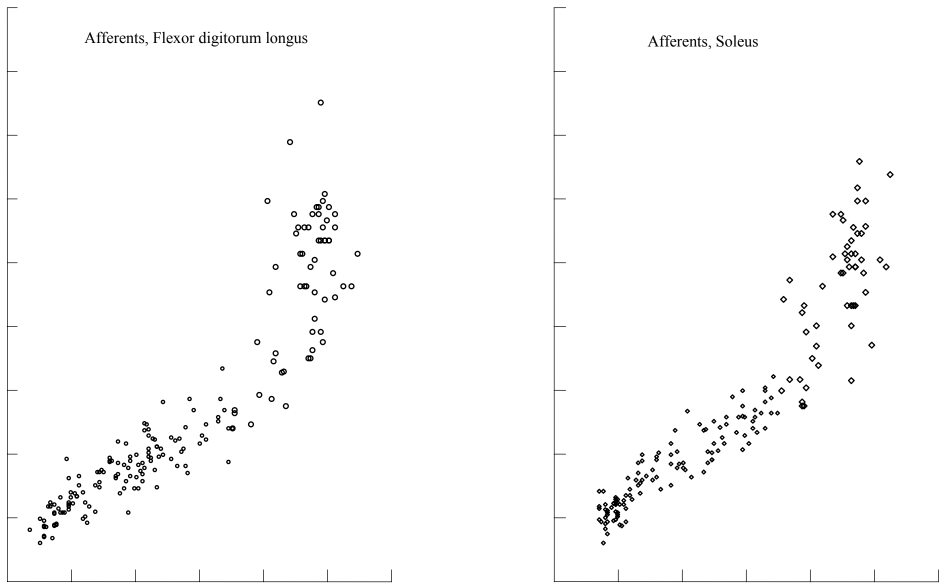

fig. 6:1

Scattergrams from the paper by Boyd and Kalu (1973) — in further detail: next page.

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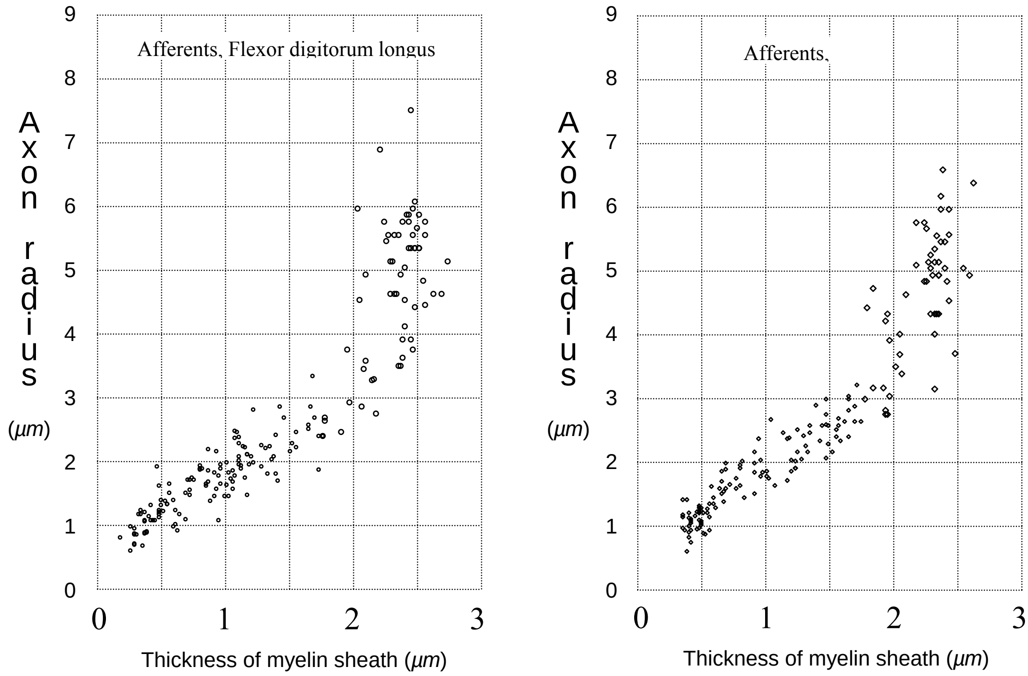

fig. 6:2

The same two scattergrams (Boyd and Kalu, 1973) with labelling added — re-scaled numerically so as to show the axon radius and the myelin thickness in the same units — *microns* — "*µm*". (My calculation of the myelin thickness assumed a certain standard lamella thickness, and that seems to differ slightly from the original; however that does not affect the present *ratio* argument). The "radius" is somewhat putative given the dubious circularity of many of the sections, but it is calculated from the original "circumference" in the usual way: ($\div 2\pi$).

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hand, as part of his thesis work).

6.2 *Suppose, for the sake of argument, that this radial effect* is *genuine*

How could we then explain it? In fact, thanks to the RNA-interpretation of Piaget's scheme, I already had grounds for suspecting the presence of infra-red signals within myelin (which is why I was looking at this sort of publication anyhow, though I had not thought of looking for this particular effect). So it did not take much prompting to:

• interpret those "lines" on the graph in terms of *optical interference nodes* due to this postulated infra-red signalling; and

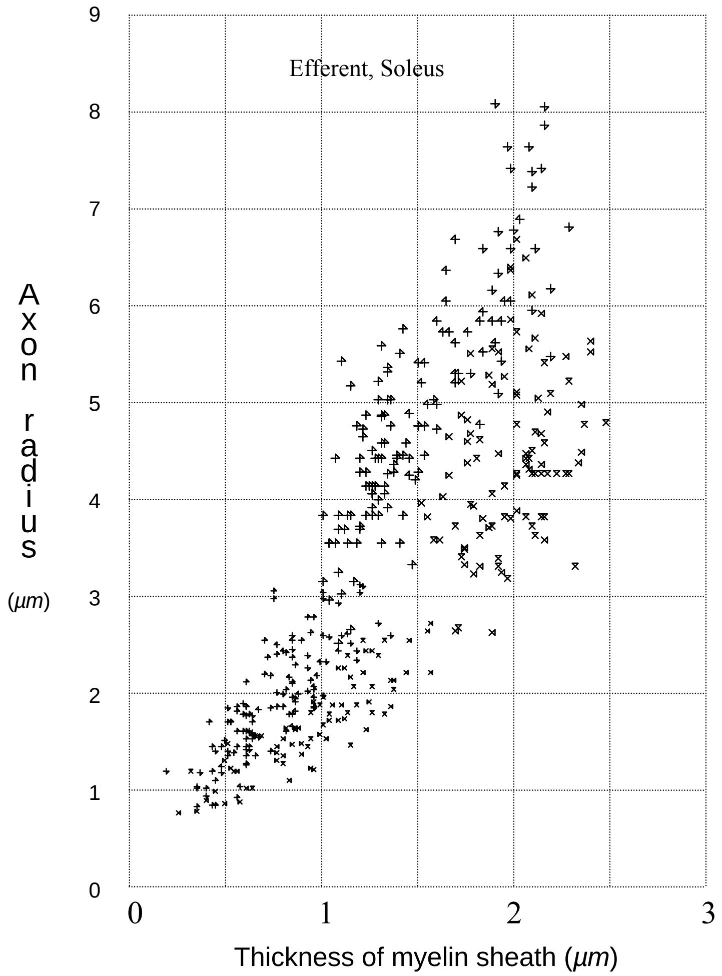
• see that these effects could neatly answer some *unasked* questions about self-adaptive growth-control — an area outside my own investigative brief, but surely a very important one. (There are some details in the next chapter).

The result then is a whole ensemble of interrelated hypotheses, with very little direct *experimental* justification, but offering a highly persuasive case due to their *collective self-consistency or "internal coherence"*. Note that, taken individually, these hypotheses are quite unconvincing.[69] Their power depends mostly on the holistic picture they are able to offer *collectively*.

6.3 *An unexpected cross-check, from Boyd and Kalu themselves*

I had publicly delivered this material two or three times, and done the investigations summarized in the next chapter, and I still had not realized that important further evidence was at hand. Professor Boyd had sent me a copy of the

[69] I do not know anyone who would dare to even try publishing an account of this impressionistic effect based on the Boyd and Kalu data *on its own*; but placed in its proper context (as here), some useful lessons can come from it.



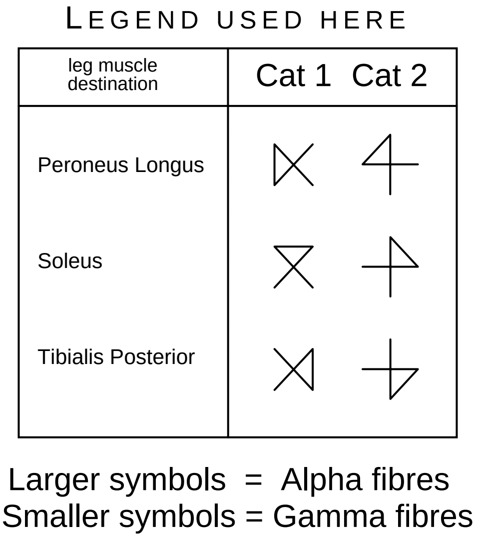


fig. 6:3

Plot of further data (apparently unpublished), kindly supplied by the late Professor Ian A. Boyd.

These geometrical details refer to *output* nerve-fibres, whereas the previous plots were for *input* signal-channels

data long ago, and of course that is what the above re-plots are based on; but I had not really looked carefully at this data and how it was categorized. Only recently did I realize that the data went beyond the two published diagram-categories, and offered a *third* diagram. Then as this had not influenced my original impression, it did provide some minor degree of "objective control" in a retrospective sort of way! Anyhow the plot from the long-lost data is given in figure 6:3; so you may wish to judge for yourself.

Several points of interest:

• The original published plots were of *"afferent"* nerve fibres — (that is to say *input* or *sensory* channels). But in contrast, the additional data related to *"efferent"* (or *motor* or *output*) channels, sending signals to muscle cells. That is a significant difference, so the comparison is likely to be interesting.

• What impression does the new scattergram offer? Arguably it offers a *better* impression of a straight line through (0,0) than the two published figures.

• *The new main gradient is different* from the main slopes in the old afferent cases. As we shall see in the next chapter, that is consistent with there being different optical modes associated with the two directions of signal-travel, (output versus input).

Of course we are still in the realm of speculation here, but it does help the case in favour of further investigation.

6.4 Subjective "Freudian inkblots"? — Or are they objective "spectrum-lines"?

If I stare at the clouds, or gaze at a log fire, or look at a Freudian inkblot in a Rorschach test — what do I see? In the absence of genuine meaningful structure in the image, I will of course furnish the structure from my own imaginings. I will be "*like a spider, spinning cobwebs out of my own substance*" (Bacon, 1620)[70] — though steered fortuitously by whatever chance-configuration the *cloud/fire/ink* might come up with.

However if there is a trace of externally-meaningful structure in the image, there is a fair chance that I will detect it, at least tentatively. As I have already mentioned, that is no mere coincidence. Our perceptual abilities have

[70] In the same passage Bacon also even-handedly criticises the pure experimentalists as being "like the ant, they only collect and use". Instead he then advocates what amounts to a balanced coherence strategy: "*But the bee takes a middle course: it gathers its material from the flowers … but transforms and digests it by a power of its own*". — (Aphorism XCV).
Thagard (1992, page 251) makes the same threefold distinction, respectively: "*rationalism*", "*empiricism*", and "*explanationism*".

evolved to serve that very purpose, and our survival in a competitive world depends on it. True we will sometimes come to the wrong conclusion; but that is probably the best we can do, and usually it will be impossible for our peer-competitors[71] to do much better, except by luck. (That is the very nature of the epistemological learning process, see chapter 4).

So then, if we think we see structure out there, we may well ask whether that structure really exists *"out there"*, or whether it is really only *"in here"* in our minds. What should we decide?

Perhaps the best insurance is *to be aware of the problem* — to recognize one's own ego-involvement, and not let that sway one unduly. (This is an example of the use of meta-levels, those "ML and MML" indentations used in chapter 5, and characteristic of human intelligence). This allows us some detachment from misleading influences; or at least we hope so.

Secondly, and in collaboration with the last point, we should use procedures like *repetition* to ensure that the effect is stable and not just a transitory random display. (Of course that assumes that we are looking for reasonably stable phenomena, as here; but if we are actually concerned with one-off events, like some historical happening, then we will have to make do with other strategies).

In the present case, the fortuitous re-discovery of the third set of data does offer some such check, though it might be argued that all three sets of data may be tainted by the same systematic biases arising from some peculiarity of the equipment used. More on that point in the next section.

Thirdly we may strive to use "*objective*" procedures. In effect that means trying to remove any decision-making aid whose operation we do not understand, including our own mind processes. (Actually we are inconsistent here because we leave untouched those processes we understand so little that we do not even recognize their contribution and ultimate fallibility: notably our perceptual processes).[72]

Anyhow this is a bit like not allowing any strangers into your shop for fear they might be robbers. It *might* make your shop a safer place; but it might also send you bankrupt! In some branches of psychology, for instance, too rigorous a policy of objectivity will leave us with little to investigate, so the enterprise can descend into mere banality. Better surely to accept certain findings tentatively, with conscious misgivings, and then evaluate them for coherence in some balanced way? Indeed the lesson of chapter 4 seemed to be that we can actually do no better than that, much as we would wish to — though some of the hard sciences manage to keep hidden this awful secret of fallibility (because their subjective tests look as though they are objective, and because their patterning of events is relatively clear-cut).

This raises another point. Note that the present axon-data case is arguably microscopic enough for us to *expect* clear-patterning to start to appear — patterning due to discrete-sized molecules and/or wave phenomena of some available wavelength. Note too that, in the past, the secrets of atomic shells (and hence of chemical bonds) were largely revealed through the study of the discrete spectral patterns from the various elements, and then simple compounds. These were unforseen patterns which eventually told us about the substructure which caused them.

Nor is that just a mere analogy. The mathematical setup is likely to be quite similar in the two cases. The theory of the Bohr atom (Pauling and Wilson, 1935) depends on the interference pattern of waves.[73] These are waves operating within a sphere-centred 3D space so that some of the *sine*-or-*cos* waves shapes have to be re-formulated in a modified mathematical form, here known as *Legendre functions* (or sphere functions). Clearly that has much in common with the theory outlined in the next chapter, where electro-magnetic waves (IR) are considered as pattern-formers within a 2D space, using the modified *sine*-or-*cos* waves appropriate to 2D — the so-called *Bessel functions* (or cylinder functions).

Waves are powerful shapers and measurers; (ask any modern surveyor, spectroscopist, navigator or astronomer). Such waves deserve a fair hearing as candidates for the more esoteric aspects of growth-control, and of the mind too, of course.

6.5 Using statistics — potentially the best of both worlds?

Subjective methods may be powerful, but we do not really understand them. That means that we cannot trust them to go unchaperoned into virgin territory; and we try to devise objective watchdogs to keep an eye on them.

Statistical methods are a step in this direction. Let us look at their main properties:

• Obviously they are designed to cope with partly-corrupted data.

• We are able, *in principle*, to explain exactly how they do it; and see for ourselves that no seriously ego-involved subjective decision-processes are used. (We may have to accept a trade-off here: The designed procedures, while "safer", may often be less sensitive than our natural perceptual abilities.)

[71] *I.e*. competitors with similar background experiences.

[72] This whole attitude seems to be the mark of *modernism*. Postmodernism has justifiably rebelled against it, but I am not convinced that its main proponents properly understand the points made here; and it is doubtful whether these postmodernists can suggest any *coherent-and-balanced replacement policy*.

[73] Schrödinger's ψ waves in that case.

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• With a little ingenuity we can improve our statistical methods without losing control in any serious way. Image-enhancing used on satellite pictures is one example, and curve-fitting for graphs is another. Note however that we may be re-introducing some subjective elements here, through the back door. After all, we may now be making *subjective* decisions about several things: — which class of curves are worthy as candidates for fit-testing — what to do about "outlier" points which are seriously out of step with main trends — and what confidence-limit thresholds to accept; etc.

One safeguard is to agree social conventions on these matters so that, hopefully, any residual ego-involvement or inappropriate bias[74] is removed from individual projects and "set at arms-length". For that sort of reason, it would not be ultimately proper to try to read too much into the Boyd and Kalu data retrospectively. It has already served its new-found purpose in alerting us to new possibilities. If we are really serious about this type of investigation, then we should be seeking to *re-do* their experiments under relevant control conditions, whatever we may now deem these to be[75], and bearing in mind that the original authors were actually looking for different features.

Meanwhile it does not hurt to see what tentative information we can squeeze out of the B&K data, as long as we are clear about its limitations and accept the desirability of data-replication if we want to take the matter further.

Let us now look at the statistical agenda from another viewpoint.
Any scattergram plot will suggest something to us about the overall system. If the dot-distribution is bizarre, then it suggests something bizarre is going on: or if the distribution is "messy", then …; and so on. Points on a scattergram don't just come from nowhere, and some cause or causes must have determined the position of each point. In other words, the position of each dot *must be caused by something* (with one slight reservation about "random" fluctuation which we will come to in footnote 77). So any pattern will be *caused*; but that does not say whether it is caused by the effect we happen to be interested in.

It is probably fair to consider four categories of cause:
(i) Various aspects of the phenomenon *which interests us*. Ideal lists would stop here!
(ii) Other recognized phenomena in the system proper, but ones which are irrelevant for our present purposes; *e.g.* in the present case, perhaps the gross clusters which B&K were studying, though I suspect they could be brought back into the discussion at a later date;
(iii) Systematic errors caused by unhelpful quirks of the apparatus — or unhelpful biases in the behaviour of the experimenters.[76] Such errors will have their effect in the resulting graph, and we may even be able to explain fully the various pattern-features in these terms.
(iv) "Pure random" error which is likely to corrupt each and every point to some degree in a way which is consistent overall and beyond our control.[77]
If this error is smallish, we can estimate it and then use it as a benchmark when trying to make sense of the other plot features. But if this random error is large, it will swamp everything and we won't get any other useful information from the plot.

In the case of the B&K data, we have already looked in some detail at the supposedly relevant fine structure (i). But there are clearly other trends and patterns, apparently common to both of the two original published plots.

Those "other" patterns which keep appearing will probably be caused by bio-mechanisms (ii) which are not directly relevant to the current focus of interest. These include the *unspecified causes*[78] of the clustering studied by B&K, which are probably somewhat incidental to whatever causes the supposed lines through the origin.

Unfortunately it is not always easy to distinguish these various (i)-(iv) categories, and subjective judgement will doubtless be needed here too. Take two examples from the fine structure of the B&K scattergrams. • Inspection shows an occasional local horizontal line. These are almost certainly due to a natural observational bias (iii), probabaly rounding approximations[76].

• Rather more mystifying is a strange trend towards local ring-shaped patterns, best seen when the B&K data is plotted in a different way[79] (not shown here). These rings

[74] Some biases will actually be *needed* or we will digress endlessly. It may well be sensible to try to fit a curve to the formula for a straight line, but not to a complicated polynomial unless we had some cogent reason for expecting to make progress that way. That too is a matter of judgement — necessarily subjective and biased in the end, even if we try to formularize that as well.

[75] Indeed some would say that I should have done that already myself. There are however problems in doing bio lab-work if one inhabits a philosophy-orientated department, and especially on the basis of a theory which has not yet been fully explicated.

[76] approximations such as estimating distances as being "40% of the gap between markers" when it is actually closer to 42.4%, etc. — a *rounding* up-or-down. That is one likely explanation for trends towards horizontal lines in the B&K scattergrams; in fact this may be regarded as obvious and scarcely worth commenting on. However I became interested in the B&K data *because this effect is so low here* — in contrast to many other sets of comparable data where no-one cared about the fine detail, and used mechanized measuring techniques which allowed obvious local rows and columns due to rounding. These fine-detail disruptions did not matter to the original researchers, concerned with more macro effects; but of course they *do* matter here.

[77] There are some theoretical difficulties with the concept of randomness. There is some difference of opinion as to whether "genuinely random" effects are caused or completely *uncaused*, whatever that may mean. Fortunately though, this quibble need not detain us here.

[78] Maybe it is some wave-or-chemical phenomenon based on unmyelinated axons *before* any insulation gets added to them.

[79] Plot of the (myelin thickness/axon radius) *ratio* against axon radius.

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could be random effects (iv), though that seems unlikely when several such trends appear on the same plot. More likely they are due to some sort of taboo on certain graph-points, 'pushing' any would-be dots onto the adjacent locations for some unknown reason — and that reason could be a genuine bio-effect (ii), or a hidden systematic bias-taboo in the lab (iii), akin to rounding but now in 2D. Who knows which! — (ii), (iii), or (iv)? One could probably find out; but of course we need also to decide whether that side-issue is worth the effort.

6.6 Summing up

The chance observations discussed here prompted the theorizing of the next chapter, theorizing which was probably worth doing even if it turns out to be wrong, and certainly worthwhile if it happens to be right. Can we decide which? Almost certainly, though that could turn out to be an expensive exercise, and it is unlikely that anyone would take the trouble or expense to follow up such lines of lab-investigation unless a theoretical airing of the issues (like the present one) is made public.

Even if a theory is wrong, as long as it has enough coherence to generate new approaches it will usually be beneficial in the long run, if only indirectly. Wegener and his data suggested that Greenland was rapidly drifting west In fact his data-information was quite misleading, but it was a useful catalyst in a process which was really driven (successfully) by coherence considerations.

Our very methodology too deserves careful review from time to time, and we should not be afraid to change it where it is found wanting. The more we understand the scientific epistemological process, the better we are placed to use fancy techniques knowingly, without having to take them on trust. But where we do not yet understand our abilities fully (as in our naturally evolved powers of perception), we should not be afraid to use them *tentatively* — recognizing the danger of misapplication, and the circumstances that can lead to it.

7. WHAT CONTROLS THE SHAPE OF CELLS WHICH HAVE IMPERMEABLE BARRIERS? — *"THEORY B"*

7.1 Self-shaping[80] if chemistry cannot cope on its own

Just how do bodily structures come to be the way they are? I have tentatively come to see this as a twofold problem, mainly involving *chemistry* on the one hand, and *physics* on the other, though we may perhaps allow some overlap in many cases.

Biochemistry goes a long way towards explaining most of the phenomena of growth-and-maintenance:
• the *DNA-RNA-protein* processes;
• the *feedback* and cross-feed mechanisms which control them; • the consequent production and suppression of *growth factors*; • the generation of *antibody molecules* for the immune system — protein molecules which curl up[81] into "tangles" in ways which are highly reproducible for any given code sequence, and hence these tangles can serve as "lock-and-key mechanisms;"
• some other "navigational aids" such as concentration gradients. And so on.

In short, in many circumstances at least, chemistry can explain *what* substances are constructed or deconstructed, and *when*. It also offers some navigational tools. But is that enough? I can see at least four problems with this *chemistry only* system:

(i) *The reach of a molecule's influence is limited*, usually to its immediate vicinity (within the effective reach of its *bonds* or any other such influence). Of course if such molecules occur in large populations, this obstacle may often be overcome by the presence of many "outposts" — and chemical gradients are an example of this partial solution.

(ii) The trouble with the "outposts" concept is that there will usually have to be some sort of *framework or scaffold to govern the distribution* of those outpost molecules; and if that framework is at all complex, or extended in size, we are left with the question of how *it* came to have its present geometry. So perhaps this only shifts the problem.

(iii) Chemical effects seem *ill-equipped to impose shape* on any structures much bigger than the molecules concerned. Mere growth-rate at a particular point does not guarantee any particular chosen gross shape in what emerges from the manufacturing site (as if from a long-running mincing-machine or grease-gun). We might think of this growth as a sort of *scalar* effect whereas it is often a *vector-governed* cell-structure that we require.

As we have seen, molecules are quite good at shaping *themselves*, and we usually call that activity "chemistry" even if it is also physics, as already noted[81]. But such robust shape-control does not just happen even here within the molecules. It seems to require some sort of fast internal-coordination "signalling" system with reliable laws of behaviour.[f] In this molecular case, that fast system seems to be embodied in the orbital motion of the molecule's electrons.[82]

What about the shaping of cells and their traditional sub-elements like mitochondria, microtubules; and in the case of nerve cells: dendrites and axons? Could their shape and proportions be fine-tuned by traditional biochemical means alone? My guess would be "*Yes sometimes — though probably not always*". Once again this would seem to require some sort of coordinating signal system, but whether this could be accomplished (and fast enough) by chemical diffusion[83] is perhaps an open question. Nature might dodge the issue by using giant molecules including crystals; though some might call that physics anyhow as we saw earlier.[81] But even if these ploys are feasible, I suspect that some fast pure-physics signalling would serve the coordination cause much better — and we might, of course, have *both* sometimes.

[80] As explained earlier, this *shaping* question was not part of my original inquiry; but I could hardly help noticing the possibilities suggested by the material which had came to my attention. In a sense then, it is a side-issue and my main topics do not fully depend on it, and probably that is just as well since it arguably rests on shakier ground. For further details see "*Book C*". (This is *Book A*.)

[81] This is actually one of those overlap areas involving both chemistry *and* physics, as we shall soon see. The *effect* is classified as chemical, but the *deeper explanation of its causes* lies in quantum physics: *ie.* in the Bohr explanation for the molecular orbitals and how they affect the chemical bonds, as explained in such books as Pauling and Wilson (1935) or Pauling (1960).
(In fact that physics-of-bonding explanation is ultimately true for *all* chemistry — but it is rather more obvious in this present case).

[82] We now have excellent mathematical models for this (at least in the simplest cases), but we are still not quite clear about what exactly the electrons are doing, nor even what precisely we mean when we talk about electrons. However that seldom bothers physicists, and it need not bother us here.

[83] Diffusion of two or more chemicals can account for patterns in zebras and butterfly-wings; though note that there is no need for any hurry in such cases. (There is also the *framework or scaffold problem* (ii) to consider here. Presumably there is already some established tissue to diffuse into, but that scaffolding did not just appear out of nowhere, so it too needs explaining.)
See Turing (1952) (he of "Turing Machine" fame, though this present topic is a separate issue); also Brenner *et al.* (1981), and Meinhardt (1982).

Case 1: A pattern that won't keep still!

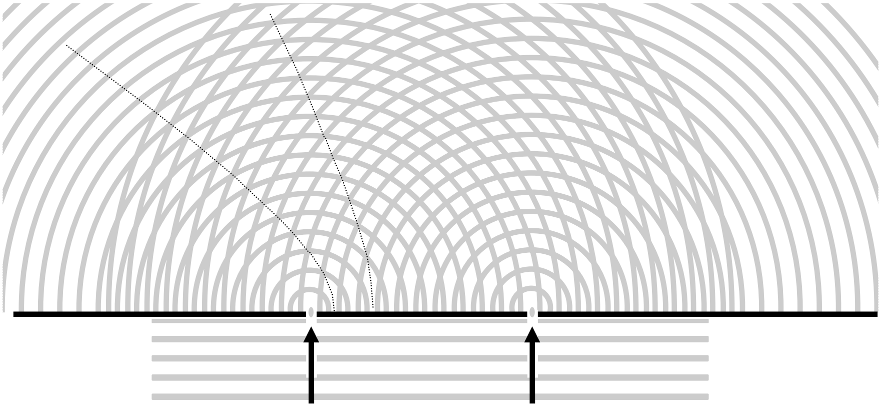

fig. 7:1

The incoming wave is split into two "new sources", and the result is then a cross-hatching of wave "peaks and valleys".

That pattern is moving too fast to be of any *direct* use, but it *is* possible to detect constant "flow paths" (dotted lines).

(iv) *Coping with an impermeable barrier*. A physical barrier can disrupt chemical effects since they depend on contact; but electrical vibrations such as light or radio-waves do not need contact, and insulators like glass or myelin *do* always transmit some of these electromagnetic signals, provided that suitable frequencies are offered.

If growth-control is entirely chemical, how does a growing myelin sheath "know" when to stop? Is there some chemical *borderline marker*? And if so, how does it know it is still the right distance from the unreachable *far boundary* on the other side of the newly forming layer of myelin?[g]

A human designer might propose some "overly-clever" technique involving arithmetic — something like:
• Let there be a *limited ration of myelin material* for each segment so that the process stops when the supply ceases; or even
• *that the axon can somehow count(!)* how many times the sheath has rotated around it. Or
• That some *measure of curvature* (in relation to axon size) will trigger a stop-signal.[84] —
The trouble is that these suggestions would then themselves have to be explained plausibly in chemical terms; and we might have doubts that this can be done without the guidance of human intelligence at each site. — Isn't that just shifting the problem?

Moreover such a dead-reckoning system (with apparently no relevant feedback) would probably be unusually sensitive to error. Indeed any harmful mutations would tend to make the system unworkable, and it is hard to see how benign mutations could have helped much to create such an unguided system in the first place. Nevertheless we are not yet in a position to rule out all such ideas dogmatically, so we might still keep them in mind in case nothing better turns up.

[84] As the cross-sectional shape is seldom reliably circular (see footnote 95 on page 51), this explanation would be difficult to justify anyhow; though presumably one could concentrate on occasions when the axon was supposed to be 'fully inflated'.

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7.2 Physics — optical and other electromagnetic opportunities

Optical methods seem free from the four objections, (i)-(iv), raised against chemical candidate-mechanisms. Light-beams and other electromagnetic transmissions can certainly reach much further if the conditions are right. Moreover, if we are looking for some means of drawing boundaries for shaping and limiting growth, there are at least three ways in which such waves could be used — thanks to their ability to form interference patterns, no matter whether they are travelling *or* standing still as "stationary waves". However it is not enough for these patterns to exist, we also need to envisage some means by which growing bio-tissue can feel the actual effect of these patterns. Let us look at the more obvious possibilities:

Case 1 (fig. 7:1) is the well-known "double-slit" experiment from optical physics. It clearly does form a regular pattern, but it is not clear that biological growth could make use of it as a navigational tool, and I won't say much about it here apart from pointing it out as a logical possibility.

However we should at least note that radio technologists *do indeed use this approach for aircraft navigation*, with synchronized aerials playing the part of the two slits. Such usage can vary considerably in complexity. One could simply select which dotted line (hyperbola) is the path one is interested in, and then follow that path. *Maybe* biomechanisms do just that, or something similar.

(Actually air-navigators usually use the system in a more sophisticated way. They keep track of *two* such patterns simultaneously so that they can locate a actual *point* an the map, and not just the crude information that *"We are somewhere on path So-and-so, but I don't quite know where!"*. In effect then, one system offers something like the *x-coordinates* of a graph, and the other provides the "*y-coordinates*"[85] — even if they are a bit bent by normal standards.)

Maybe all such versions are too complicated for the simple biosystems found at cell level; in which case, so be it. However let us not forget that this complexity is still much simpler than that other triumph of bio-processing of high frequency waves: the skill we call "vision". Of course individual cells could hardly have sight as we know it; and quite likely the hyperbola-tracking mentioned here is also beyond them, even if it is simpler.

Case 2 (fig. 7:2) is probably a more feasible solution for bio-systems. The standing waves of a guitar-string have many analogues in nature and technology, and the "constant-zero" nodes in such vibrations do at least look like the boundaries we seem to need. Their main drawback seems to be that these nodes are all embedded well *within* the system[86], whereas we should be looking for a system which can set up boundaries *outside*, as "boundary fences" which can curb expansion at some suitable range.

Case 2: HARMONIC PATTERNS ON A GUITAR-STRING *DO* PERSIST, DESPITE THE VIBRATION

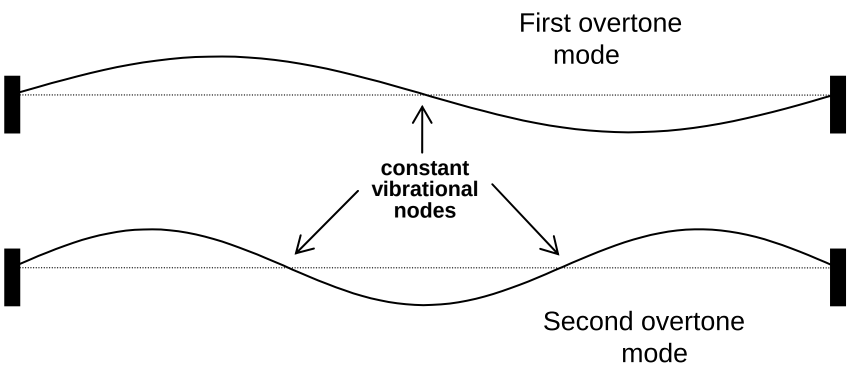
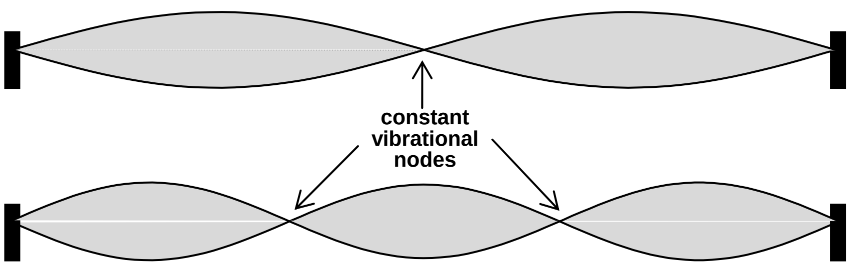


fig. 7:2 — *a* and *b*

Such single-line drawings of the string show it as a **"snap-shot"** — a moment of time which freezes its up-and-down motion (movement occurring at all points apart from the the nodes).

However what we usually see in real life, is a sort of **vibrational blur** due to that very same rapid motion, which is too fast for us to dissect visually. But this view is actually *better* if we are looking for the nodes. These stand out as the *non-blurred points* along the string:



[85] Grid-pattern systems like this were devised during World-War-II as secret navigational aids for when vision was not enough; and have now long been established commercially in a much improved form. See, for instance, Crowther and Whiddington (1947). The "*x*" lines are a family of hyperbolic curves, and the "*y*" lines are another such set, but the two sets still cross each other to form a grid.

[86] *I.e.* the pre-existing system acts as a *framework or scaffold* — see problem (ii) near the start of this chapter. The question now seems to be: Can we operate outside this frame whilst still using it?

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Standing waves occur thanks to reflection. A rapidly travelling wave reaches the end of its guitar-string (or other optical or acoustical track). There it encounters something which stops its progress, but returns most of its energy so that it is able to travel *back* along the same route. The mixture of these to-and-fro fast-waves all just adds up to a *non-moving*[87] *pattern* of (locally-moving) vibrations.

Vibrational nodes as "fences or moats"? Here is one feasible scenario of what we may call **the moat postulate**:

Our growing tissue may certainly need certain chemical aids such as nutrients or growth factors. But suppose it also needs energy supplied at a certain high frequency if it is to grow properly, and that this *light-or-IR* happens to be playing some other useful role so it is present in abundance overall. Let us further suppose it is also reflected to-and-fro causing standing waves, and that this leaves some *node-areas* which are starved of the necessary energy boost. Surely then, the tissue would grow unhindered in the region *until it got near to the waste-land of the first node boundary*? — And of course it would then have to stop for want of its energy boost.

The main remaining question though is *whether such "moats" would be useful* if they are located only internally (as in this guitar-string case) rather than externally.

Case (3): Standing waves *beyond* the "guitar-string" vibrator.
Any guitar which kept its standing wave entirely intact locally on perfectly-reflecting strings *would be of no practical use!* It is meant to leak some of its energy away as music, firstly as a *secondary standing wave* in the body of the instrument, and then as a travelling wave through the air. (I am, of course, talking about *acoustic* guitars).

Let us look at a simpler version of the same sort of thing. Instead of an orthodox guitar-body, let us say that any leaked vibration continues on *into another string* beyond the fixed end of the main string. Of course some such leakage will occur at *both ends*; but if the local conditions are different for these two ends, we will expect the results to differ also — if only in magnitude.

(See figure 7:3, on page 50).

The diagram illustrates that most of the main internal standing-wave is reflected at the two dark grey end-stops; but some of the energy leaks out at either end, as a forced secondary vibration with the same frequency. What happens next will depend on various things:

- the properties of the external string;[88]
- how much its vibration is damped;[89] and (*especially*)…
- whether this external route is capable of any effective back-reflection, thus converting the external travelling wave into a *supplementary standing wave*.

On the left of the diagrams we see travelling waves which do not get converted into standing waves, either because there is nothing to reflect them, or because they are absorbed before they can ever reach the mirror in enough force to be effective.

On the right we do see effective reflectors in place; and hence the resulting external standing-waves, along with their nodes. Note that such reflectors need not necessarily be an organized part of the system. It might be enough just to have a population of reflective-objects moving around arbitrarily in the vicinity: Sometimes some of them will be near enough, and correctly placed[90], for them to allow a resonant response; and it is such resonance which builds up the energy-levels within the standing waves. According to the moat postulate (previous column), it is *only then* that certain types of myelin-like growth will occur; and even when these favourable conditions exist, the growth will usually be stopped by the first node.

If this is true, or partly true, then we might expect to find the outgrowth reaching out until it gets near ***A***[91] — or at least that would apply in the case of the "fundamental frequency", as shown in the top row. If the prevailing frequency is actually an octave higher (the "first overtone"), then we might expect the first node to be at point ***P*** instead (with ***Q*** as its fallback position).[92]

---

87 — unlike Case (1), in which the waves *and* most features of their interference pattern were much too agile, leaving little more than the dotted line "tyre-marks" of where the energy is escaping to.

88 notably its *tension-and-stiffness* (analogous to 1/capacitance "C", as in section 2.3 (2) above); and its *mass-per-unit-length* (analogous to the magnetic inductance "*L*" in that same section),

89 *Damping* (absorption into the local transmission-environment) is of course analogous to the electrical energy-loss caused by resistance "*R*"; see section 2.3.

90 at one of the potential node-positions, as depicted in figure 7:3.

91 or ***B*** if it somehow gets jogged past the ***A*** barrier. Just how close it would get to ***A*** or ***B*** is uncertain; that depends on how low a threshold might apply. Presumably the growth process would require some not-yet-known minimal intensity of signal strength — if the theory is correct.

92 Note that, in this simple linear-string case, ***Q*** and ***A*** both fall at exactly the same position; but in more complex analogous situations, this correspondence between different modes will not necessarily be true.

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CASE 3: STATIC PATTERNS FORCED UPON THE LOCAL *EXTERNAL* ENVIRONMENT?

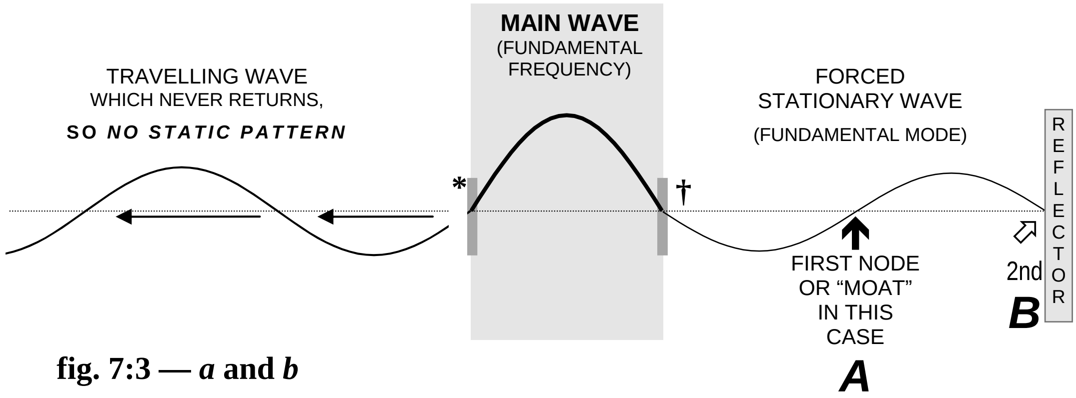
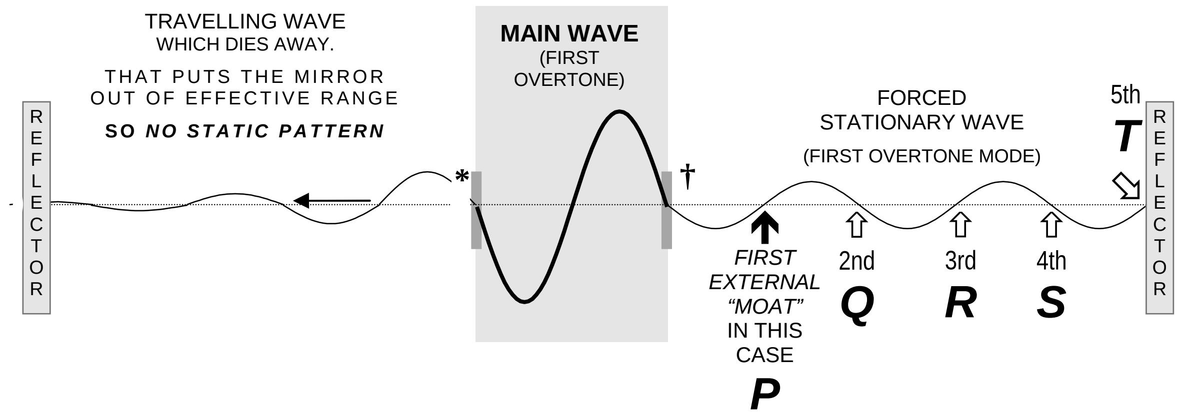


fig. 7:3 — *a* and *b*



* The leaked wave may appear to be "out of time" (out of phase) with the original string — typically by 90º. However that need not concern us here.

† Even when we have standing-waves on *both* sides of the "end-stop", there may still be a phase-lag, since one is driving the other. That may affect some precise calculations we might wish to make, but it does not alter the general principles about nodes as "moats".

To summarize then. We were looking for a mechanism whereby nature might be controlling the shape of bio-structures significantly larger than the relevant molecules, and up to about cell size. Chemistry does not seem adequate on its own, and the above account attempts to invoke realistic capabilities offered by physics. This proposal does perhaps have some claim to offer a coherent account; but so far we have considered only the simplified case of a one-dimensional "guitar string" system.

Accordingly we may now turn briefly to look at the myelin-growth situation as a problem involving growth around a cylinder; and in effect that means dealing with a *two-dimensional* system[93] — the cross-sectional slice through that cylinder:

[93] As mentioned above near the end of section 6.4 — Pauling and Wilson (1935) invoke a similar-but-spherical *three-dimensional* situation to account for the peculiarities of the Bohr atom, and do so using a different sort of wave; though that is not of direct relevance here.

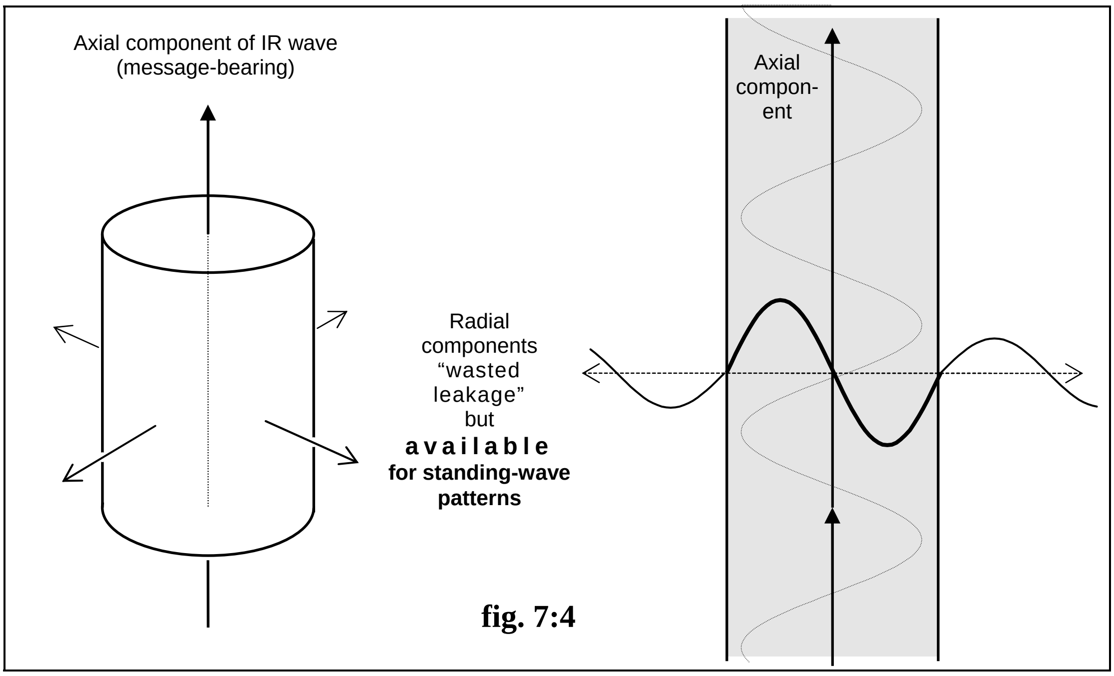


fig. 7:4

7.3 *Myelin self-shaped from actual usage — not just inherited plans?*

We have so far been looking at guitar-strings and suchlike — one-dimensional systems. For an axon and its myelin sheath, we may concentrate on any one[94] of the two-dimensional cross-sections; and any such slice will ideally give us at least two concentric circles:[95] the axon-membrane itself, and the outer perimeter of the myelin sheath.

Myelin is actually wound on like a bandage,[96] and the active site of its overall latest progress is at its current *outer* cylinder boundary, the surface most remote from the axon itself. Any natural *monitoring to limit the insulation growth* could therefore entail measuring the myelin thickness — the distance from the axon proper to the outer perimeter, *measured along some radius*.

If the partially myelinated nerve-fibre is indeed carrying Infra-Red signals (along with traditional millisecond "spikes"), then most of the IR will presumably travel parallel to the axis, but some will inevitably go in other directions. We may tentatively assume then that there will be a radial component of the postulated IR; and it is this component which we will be considering here (fig. 7:4). The analogy with the guitar-string example is then reasonably straightforward:

The main quantitative difference is that here we cannot accurately use sine or cosine graphs to represent the radial waves. The reason is that the outward waves are ever-expanding their wavefronts, thus spreading themselves thinner and thinner; and the graphs of their wave-heights must reflect this diminution. (This is not to be confused with the exponential decay of amplitude when a wave is absorbed wastefully. In our present radial-flow case, all the energy is (ideally) retained — it just gets more spread out. And if it were all reflected back in an orderly manner, it would *all* converge back to the centre, *reversing* the effect).

For many purposes, that is all one needs to know, and we can still use sine-and-cosine as a rough guide, as long as we recognize the approximation and its limitations.[97]

Figures 7:5 and 7:6 show what the cylinder-based wave-patterns look like when they are plotted in perspective after correcting for the spread effect. First the *cosine-like* case:

---

[94] All these cross-sections are presumed to be equivalent.

[95] Some cross-sections are far from circular. Maybe many of them are circular at some times and deflated at others. That would fit in nicely with the present proposals which envisage growth as often only happening at intermittent times anyhow; but such convenience is no guarantee of truth. However we have to start somewhere, and after all, many cross-sections are reasonably circular. Moreover even the ones with non-circular shapes may later be amenable to similar analysis, though doubtless the analysis would be more complicated.

[96] This myelin is supplied as the outgrowth from a neighbouring cell. It first wraps around the axon, and continues wrapping in a tight spiral of "wrapping paper" which is fed from the outside cell. However this does depend on the right substrate being present (Carey *et al*., 1986), and it might feasibly depend on suitable irradiation energy as well.

[97] The corrected functions are known mathematically as *Bessel functions* or *Zylinderfunktionen* — $J_0(x)$ instead of $\cos(x)$, and $J_1(x)$ instead of $\sin(x)$. Of course their graphs all look like waves.

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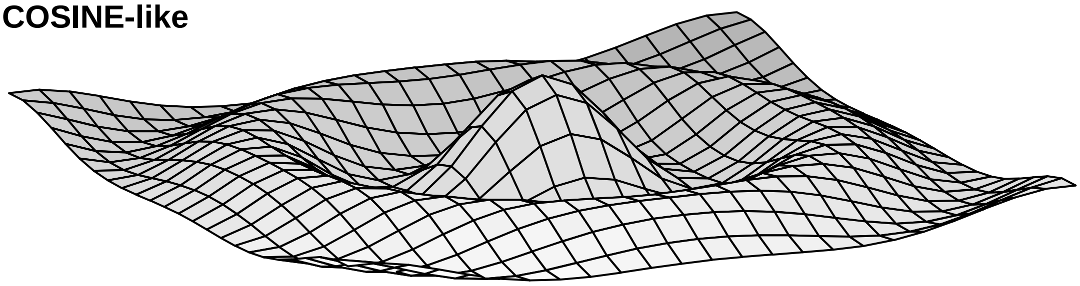
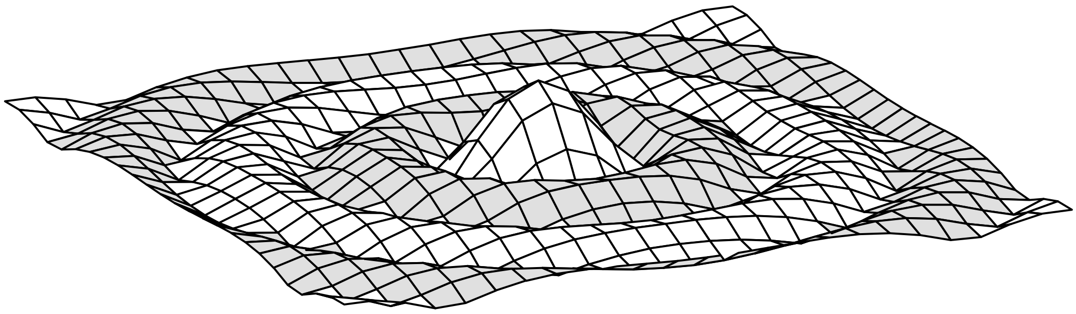
COSINE-like



Here we have a **"snap-shot"** view of the cosine-like cylindrical wave. However it is difficult to see where the node-lines will be. Of course they must be at the zero-contours, *half way between* the hills and the valleys — but these are somewhat difficult to identify. (Likewise, fast snap-shots of guitar strings do not clearly indicate the nodes either, as we would see in the diagrams on page 48 if the dotted line were removed).

fig. 7:5 — *a* and *b*

So here next is a **vibrational blur** picture of the same thing — the blur we actually see if it is vibrating rapidly (upper loops only). Now we have a series of *vault-arches* along any radius, each standing on a sharp edge resting on the zero-plane; and of course these sharp edges are the node-lines or "moats" which may be serving to bar further growth — and clearly they form a series of concentric circles:



The light-coloured vaults correspond to the hills in the top diagram, and the grey vault-rings correspond to its valleys. But of course, the whole system is vibrating rapidly, so hills and valleys change places at a great rate — too quickly for us to see, (maybe even in the case of slowish water-ripples).

Unfortunately this tile-drawing technique does not always show the *sharp* node edges to best effect, but at least we can now see where they are.

Such a pattern might well anchor itself to a cylindrical structure such as a nerve-cell axon (whether myelinated, partly myelinated, or neither), provided that the radial component of the wavelength fitted the available cylinder size. In that case, the first nodal ring would then probably end up sitting on the axon membrane itself, and the other nodes would then form a set of concentric rings around it. The first of these would presumably be the effective moat in most cases.

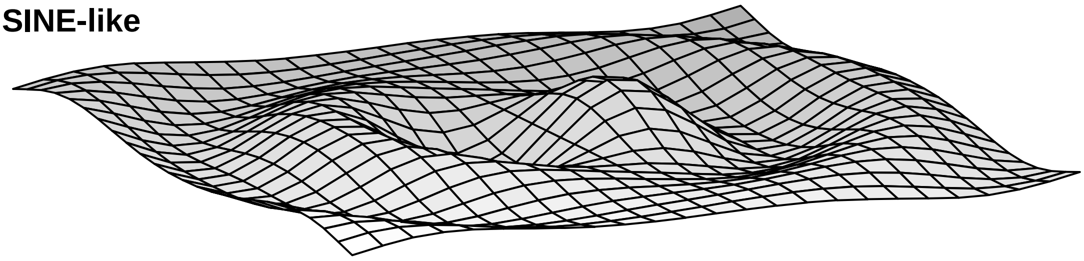
Other arrangements are possible, but all point to a limited repertoire of radius-ratios for the concentric rings, and hence a limited repertoire for the *stable myelin thicknesses* *ratios* — *per micron of the axon radius*. (Meanwhile we should remember, of course, that this is all conditional on the moat postulate being correct[98] — and the presence of a relevant wavelength.)

The sine-like cases (figure 7:6) add some further possibilities to the repertoire, but they do not materially affect this conclusion about a limited repertoire of concentric moat-distances for any given axon size:

But now notice the potential economy and efficiency of this *moat-barrier* system. We might suppose that a given nerve fibre does not necessarily "know" what frequency-range it will be mainly transmitting. But then, in practice, it keeps encountering *frequency x*. Now of course it has no capacity to think about this at all, but how convenient if the

[98] For the *moat postulate*, see page 49. Also note that the predicted limited repertoire of values is for the *ratio*: (*myelin thickness* / *axon radius*) — and NOT for the myelin thickness as such.

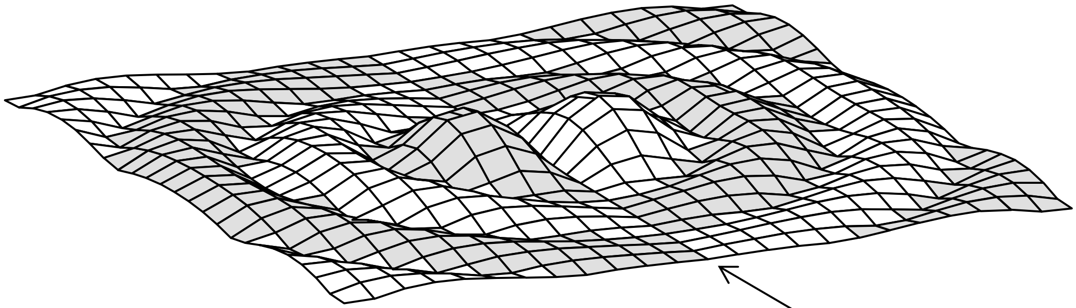
SINE-like



Once more there is a problem of identifying the node-lines in the **snap-shot** drawing, though we can see the sine-like assymetry of the hills-and-valleys.

fig. 7:6 — *a* and *b*

But with the **vibrational blur** drawing, we can clearly see the new set of nodal rings even though there is a further complication. This new feature is an extra node-or-moat right across the diameter. In principle, this inconvenient internal moat *could* stop myelination prematurely. However I doubt whether it could have more than transitory effects, if only because the whole pattern could quite plausibly rotate to and fro, allowing the myelin-wrap to continue whenever the diameter is elsewhere.



very presence of frequency *x* automatically served to guide the myelin growth into some geometrical form which happened to favour the conduction of frequency *x* itself. This is not the place to explore further whether that happy outcome does actually take place; but the potential is there, and it might explain a lot of things. It is the sort of cunning trick that nature sometimes comes up with; and so it should, after several million years of systematized learning!

7.4 Where the 'moat-limit' idea comes from; hints versus evidence

The preceding discussion in sections 7.1 and 7.3 argued the case theoretically
(*a*) that axon myelination might well be controlled by Infra-Red reverberation around the pre-existing structure, and

(*b*) that the resulting cable-geometry might thus be "tailor-made" for the IR that happened to be present. Also the earlier discussion had suggested:
(*c*) that particular types of IR would be present for neural-communication purposes.

The growth-control ideas (*a* and *b*) do seem to make coherent sense as a logical argument on the basis of what we know about the system, and what we might expect its further secret ideas must be. This is hardly conclusive, but it is perhaps a promising start. Indeed I find some encouragement that this may be on the right track because • the account does seem to explain rather more than we might expect from mere *ad hoc* hypotheses, and • as yet, there seems to be no rival explanation for some of the suggested solutions. In other words, they seem to pass an internal coherence test reasonably well, at least provisionally.

However that was not the chain of reasoning that initially prompted this (*a* and *b*) notion about tissue-shaping . As I have explained already, the idea was prompted by a chance observation — by serendipity — and I have given some details of this observation in chapter 6. But first let us look again at the conclusions from the previous section, (7.3), in this present chapter:

The retrospective "prediction" was that the ratio (*myelin thickness* / *axon radius*) would tend to have only a limited

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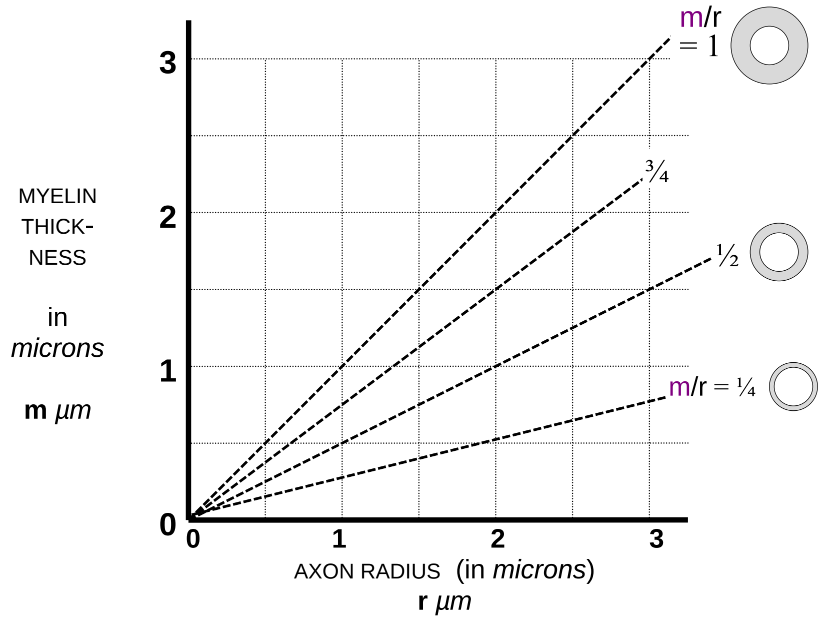

fig. 7:7

Grid for plotting the geometry of cross-sections through myelinated axons.

The *moat hypothesis* plus the subsequent fallible reasoning together predict that the *m/r* ratio will mostly take on a small repertoire of values.

Each such value is represented by a straight line through the origin — here shown as dashed lines, using fictitious values.

After swapping the *x* and *y* axes, this may be compared with Boyd & Kalu's experimental data re-reported in chapter 6 — the data which originally *prompted* this present digressive sub-inquiry. (Of course that observation could just have been due to an artefact or random effect — but it has raised some interesting questions anyhow.)

range of constant values, for mature[99] myelin sheaths; *e.g.* let us guess the values to be (say) *¼, ½, ¾* and *1*. Taking these fictitious values[100] then, we would expect an experimental survey of myelin cross-sections to plot onto a scattergram in a certain restricted way — like this figure 7:7 in fact, with the plots expected to fall on-or-near the dashed lines:

But why should we bother with this speculative idea which is not immediately relevant to our main topic, the mind? Should I apologise for wasting your time on a wild goose chase, or does this digression have something significant to offer?

I can offer five reasons for pursuing and reporting this sub-issue. Two of these reasons apply *no matter whether the "moat theory" is correct or not*:

(1) *It offers a useful case-study of the knowledge-acquisition process* — the workings of epistemological mechanisms when that taboo-word "intuition" is involved.
So even if we were merely looking at (say) how judges try to intuit true knowledge on some quite unrelated topic, and even if their decisions were quite erroneous, nevertheless their decision-process would be of legitimate interest to the epistemologist, and hence relevant to our present discussion.

Even Popper, a pundit of the "Scientific Method", did not object to postulates coming from intuition *or anywhere else*, (so long as they were then tested experimentally[101]); but in this he was perhaps too lax and indifferent. It surely does matter somewhat where most of our postulates come from, since "good intuition" can surely save us vast amounts of time and effort, even if those intuitions are unavoidably fallible.

"Intuition" implies genetically evolved strategies for unconscious problem solving. Its status is discussed in chapters 1 and 6; but the main points are these:
• Intuitive non-rigorous processes are actually inescapable, and even their severest critics are using them unconsciously, *e.g.* by assuming observation is infallible, without really understanding that process.

[99] We may have to treat this term "mature" with some caution. Of course, according to the moat hypothesis of page 49, the *m/r* ratio would be fairly meaningless experimentally as long as rapid growth was still continuing, especially during the early stages of myelination. The process would then presumably grind to a halt as a node/moat is reached, and in that sense the myelin would be mature. However it is less clear what other disturbing influences might arise in the longer term when the myelin is somewhat *more* mature, so we might prefer to take "mature" to refer to the earlier intermediate condition, with less danger of the later complications.

[100] In principle we could try to predict actual values, given that we know how to correct the cos-or-sine graphs for these divergent-wavefront conditions. However there are other complicating factors involving: the differing optical properties of the two media; questions about phase change at boundaries; and threshold levels for "cut-out" near the node-lines. It would thus be premature to speculate on these rather more messy issues here, except to assume that they will probably be more-or-less *constant within a given environment* — so we can then expect some sort of constant node-pattern, even if we cannot yet predict the actual ratio-values.

[101] Popper was, of course, a typical scientific-modernist who favoured external testing above all else (Popper, 1934/1972). This approach is discussed in section 1.3 (page 2) and later in *endnote "a"* (page 98 — associated with chapter 2, page 10),

• Untested intuition can certainly be dangerous and misleading, especially in science; so this calls for planned extra testing whenever practicable if the issue is important enough.
• Testing can be through external coherence (experimentation), or through internal coherence, or preferably *both in balance*. Modernism has unduly favoured the external, and distrusted the internal testing, to its cost.
• The present discussion, starting at section 7.1, offers an internal-coherence test; and it might now be appropriate to consider seeking support for some corresponding external tests.[102]

(2) Even if this "moat-theory" turns out to be quite wrong; it has nevertheless raised some interesting questions, including some problems which do not seem to have been faced before now.

And if the "moat theory" happens to be correct:

(3) It will surely have very important implications for embryology and surgery, etc. — especially *reconstructive techniques*.

(4) If the moat-causing interference patterns do exist, and if they are indeed "tailor-made" to adapt the myelin to IR signals appropriate to that axon; then that will surely do much to help us understand *self-organizing systems*. In other words, it would be an interesting comment on "structure and function".

(5) It would tend to corroborate the RNA-and-IR mind theory.

IF • the *moat-theory* is correct, AND IF • *IR-signals do offer a second signal system* for myelinated axons, then these two theories will together form a strong internal-coherence system. Each tends to support the other, and my interest in the "moat" idea stems partly from its possible corroboration of the other, more mind-related theory.

Yet ultimately these are two separate theories, which do not necessarily stand-or-fall together. IR signals *could* traverse the myelin without having anything to do with myelin growth; and moats *could* perhaps be formed from reverberations from unrelated ambient thermal IR waves. However both of those *one-only* scenarios look rather like cases where nature has surely missed an opportunity. So if one of the two theories does turn out to be well founded, it would be rather surprising to find that the other is quite baseless.

[102] There is a brief discussion in chapter 5 on how proper funding may well only come belatedly, after an against-the-odds development of the theory. That is understandable, but often frustrating.

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8. CONCEPT STRUCTURE — TO SIMULATE STRUCTURE IN THE OUTSIDE WORLD

8.1 The Study of Structure — inside and outside the mind

(1). Coping with the many arcane hints from Piaget and his colleagues

Although his writing is often less lucid than one might have wished, Piaget did offer a promising new way of looking at how our mind's acquire knowledge, and he expressed these ideas in a sort of *semi*-mechanistic form. He used *fairly* precise terms like "assimilation, accommodation, and scheme" to give a fairly specific account of his postulates — specific enough to yield some testable hypotheses about overt behaviour (as the modernist culture demanded) but with little suggestion as to what might really be going on at the micro scale.

Of course that is not unusual. Freud had made comparable semi-specific pronouncements a generation earlier, and even today we still have no clear notion of what physiological entities could be the bearers of his "*id, ego, superego,* or *cathectic processes*". Perhaps some day his vague system will be *rigorously known* to us. Perhaps!

But such vagueness and semi-mechanism applies even more validly in the social sciences like politics, sociology and economics, where there is little alternative. Here we had better resign ourselves to the eternal use of discursive hermeneutic methods, for some tasks at least. After all, we can never *fully* understand the impact of any ultimate substructure the system might have.

In short, such a system can never be "*rigorously known*" here, though there is surely still considerable room for improvement.

In contrast chemistry *is* fairly rigorously known, precisely because of great advances made in understanding what molecules and atoms are, and how they interact. Without that basic enlightenment we would still be tinkering with alchemical glassware, making slow sporadic progress during some misguided master-quest for "*the philosopher's stone*", or suchlike.

Perhaps we would also be having learnéd hermeneutic debates about practicalities based on vague general concepts — debates which might well be useful in the absence of anything better, but very naive by the standards of chemistry as we now know it.

This present project has clearly aimed at casting the Piagetian model into something like the chemical mould. Obviously that was the purpose behind trying to identify what "the scheme" might be in physical terms, since that appears to be the basic building-block, analogous to the atoms in chemistry. Having found a plausible class of candidates, we are now in a position to explore how these "bricks" might actually generate the "palaces" which inhabit the mind, and whether the ensuing behaviour-predictions have any similarity to the actual behaviour or feelings of real life.

Sometimes it will be useful to try to fit these postulated physical entities back into the extended Piagetian theory, in all its wordy hermeneutic splendour. At other times, if the substructural basis holds up to scrutiny, we might be better off starting anew seeking external checks independently of the existing Piagetian canon — but there need be no hurry to rush into that.

In this chapter, I shall concentrate on some of the technicalities of building a mind system from the bottom-up, and mention likely behavioural consequences only as a secondary issue — mainly as (i) Piagetian *stages*, and (ii) Non-Piagetian *psychotic and sleep symptoms*. That curtailment into only two treatments is something of a compromise. Neither account goes deeply into detail here; though such detail might be appropriate in a later phase of this project, after explaining the possible digital and switching capabilities of "RNA-like" schemes.

Right now though, I suspect that it is best not to get side-tracked onto anything but the most fundamental consideration of the overall task of *structure building*. In this book the basic unit is taken to be the "simple uncompounded scheme" — but we would surely need a similar discussion on substructure for any other basic entity which we might propose. After all, *the capabilities of the human mind are truly astonishing by all other standards* — so there must be some very fancy organizational strategies to achieve its power economically no matter what the basic units may be. In the end it is probably these *strategies* which are the secret of the whole operation, and it is then comparatively unimportant just what mechanisms actually finish up fulfilling these roles. So let us bear in mind what these key strategies could be, or perhaps *must* be:

• In chapter 4 we looked at *the Darwinian trial-and-error strategy* as probably applicable to the mind (*and* to any other systems facing a similar task[103]). That discussion led to support for the Piagetian notion of the scheme, and to the idea of its ultimate embodiment as an RNA-like coding-strip.

• The human mind is obviously able to handle very complex organizational structure, so it must presumably have some way of encoding such things or patterns. Also it

[103] a point also made by Jerne (1967), see footnote 58 on page 28.

must be able to do this encoding flexibly and with reasonable economy. We will see below that this points to a particular structural pattern of the basic elements and their standard mode of assembly. This pattern is *the recursion-based hierarchy* — a simulating structure which could be applicable even when it is modelling a *non*-hierarchy.

Such a powerful and flexible strategy should surely be seriously considered even if the available observational evidence were against it? Conveniently though, it does actually seem to be consistent with Piaget's notion of developmental stages.

The point is that theory, carefully applied in a situation like this, will probably either yield *just one* such robust hypothetical solution, or else no coherent solution at all. In short we may well expect *a single theoretical answer* (though this might well be implementable in various different hardware guises, which may initially *seem* quite different).

Note that there must surely be *some sort* of mechanism to achieve the structure-modelling role no matter whether we can identify that mechanism or not. If we can envisage only one possible candidate, then we had better keep tentatively working on that candidate until such time as it is shown to be quite untenable, or a better candidate comes to light. Meanwhile we might change our minds several times concerning how this strategy could be physically embodied. And note that our doubt about this "hardware" need not condemn the underlying strategy itself.

So now let us look at the issues of how the mind might handle structural knowledge.

In this, we should not allow ourselves to be too distracted yet by exact interpretations of hierarchy-levels etc.; nor by any reservations about the separate matter of actual physical embodiment of coding, dealt with earlier.

(2). Structure in the mind[104] — an oblique reflection of structure outside

Organizable *structure* is surely a necessary ingredient for knowledge and hence for mind, so structure has been a recurring theme throughout this book. Mostly the concern has been with two aspects of the active mind and its environment:

(a) How might concepts be encoded methodically as *material physical structures* within the brain? (This should include the encoding of *complex* concepts). And hence, indirectly:

(b) What are the *structural patterns* in the real outside world — patterns which the mind can somehow detect and cope with?

This now obviously raises the question: "What connection might there be between the structure in these two realms of *mind* and *environment*?" One naive answer might be to postulate a one-to-one correspondence — with a real dog *Fido* represented in the mind by a model dog with Fido-like features, and then another dog *Max* represented by a completely separate model — and likewise for mapping all other aspects of one's environment, with no economization through generalization or compacting techniques.

That all seems unlikely (i) because of its profligate waste of memory-space,
(ii) because of the implausibility of maintaining *dog/chair/comet/devil/cloud-like* model-objects (as such) within the brain — especially (iii) given the early observations of Lashley and others that memory seems to be widely dispersed throughout the brain.

And anyhow (iv) it is difficult to envisage any mechanism or process whereby such models could be constructed step-by-step without passing through other (*non* one-to-one) formats; and if we are to allow those other formats at all, why do we really need to insist on *the* one-to-one format? Such attention to detail-copying might be fine if we are consciously building a one-to-one scaled-down model railway; but nature is unlikely to have given us minds which do such building within our skulls, except perhaps occasionally on a limited scale.

Moreover (v) even if this system did apply, we would still have to find a further explanation on how we can do such activities as *generalize* — as when we recognize Fido and Max as both being dogs — i.e. members of the abstractly conceived *"class of dogs"*.

(3). Structural types, which need not all be available in both realms

But if we do now agree that the correspondence is something other than strictly one-to-one, we need to consider what structures can offer us symbolic substitutes for the original (in some useful encoded form). It must mean that a real object-or-phenomenon with a structure type of *X*, may sometimes have to be depicted within the mind by structures of type *Z* (say), instead of *X*. — Why so? — Because the mind-system either contains no elements with the physical properties of *X*; or else it has no means for getting the necessary coding onto that sort of item, so it has to give up, and use *Z* items instead.

For instance think of the concept of a "*continuum*" either in general, or as a specific case such as an electric field. In nature itself, that seems to be a fairly straightforward entity. (Even if we allow for its magnetic complications, it is still much simpler in its basic "real" laws than many social situations which we deal with daily). But our minds

[104] *I.e.* the supposed pre-existing structure of the Piagetian "scheme" element-of-thought, and how it might be compounded to generate the structure for other concepts derived from it within the mind/brain — as discussed in chapters 2 to 5.
Chapters 6 and 7 dealt with structures of a different sort, which do not immediately concern us here. (These were, respectively: • How we perceive structure, even though based on poorly structured evidence, and • How sub-cellular anatomy might have its structural size-and-shape determined.)

presumably cannot encode such a continuum-reality *reliably* onto their own continuum elements, nor make proper use of any such coding it might have. Maybe they can do it *approximately and unreliably*, perhaps via the non-digital placing of synaptic mechanisms, but surely we often need something better than that. To get around this obstacle, we have to resort to some very round-about intermediate modelling via symbolism and abstraction such as Maxwell's equations using discrete algebraic symbols — something which nature itself does not need to do because it participates in the continuum directly.

In the Piagetian theory discussed in section 4.1 (4), we have already seen another example; though some people may find it harder to accept. The common (Kantian) view is that *object*-concepts are basic to our thinking. But what objects might there be within the mind? And how might they relate to objects in the outside world?

According to early Piagetian theory, the basic mind-elements are those abstract entities called "schemes" (of the simplest type) which are effectively encodings for various simple types of *action*.[105] Going further: In the revised Piagetian theory, these schemes are identified as RNA-like and so clearly *objects* in a strictly physical sense — and yet they are not seen as individually capable of depicting other objects — at least not until they form a collective. According to this theory then, we have objects within the mind/brain which *contribute to* our mind-models of "object", but which cannot themselves represent any such object.

So, to return to the general comment, a structure of type *X* in the real world, may well be depicted mentally by brain-structures of *other physical types* like *Z* (or even occult types like *Ω*, say) — and not necessarily by any *X*-type structures, if indeed there are any *X*s within the brain.

(4). Examples of structure-types — hierarchy, action-subroutine, etc.

What sort of structures are we talking about? What are these *X*, *Z* and *Ω* types of entity? I personally have no suggestions about any occult types, like *Ω*. (I leave that for others to speculate about, if they feel moved to do so). But here is a list of likely *physical* structure-types such as *X* and *Z* — though this is by no means an exhaustive inventory:

- **Hierarchy**
- **Action**
- **Encoding for action (Subroutine)**
- **Object**
- .. Extensive set, several types —
  (• Tethered set + • Bounded set
  + • Range-bounded set + • Linked set)[h]
- Intensive set
- Property reference
- Destination reference

and we will be mainly concerned here with the first four of the eleven listed. Arguably *all* of these types exist within the environment we are trying to model, our accessible region of nature. If we agree[i] that mind/brains are also a part of physical nature, then we might expect most of the same structure types to be present there too, though some of these structures may be functionally ineffective.

This book is just an introductory text so we need not go too deeply into the possibilities, and anyhow we have already briefly considered these structure types: *Object* — *Encoding for action* — and perhaps even *Action itself*. However I would like now to concentrate on the first-listed of the structural types, the one which most seems to be of especial importance: **the Hierarchy**.

This is a comparatively elaborate configuration, so modelling it would not ever be trivial; but of course any worthwhile mind-brain will need the flexibility to cope with various types of natural hierarchy in its environment, and maybe also the concept of *hierarchy in general*.

8.2 Hierarchy — an especially interesting structure-type

(1). Hierarchy in various guises — and likely sources of confusion

Hierarchies are not always what they seem. In a government or company, the hierarchy-chart on the wall may differ considerably from the real actual power structure, especially if bribery, blackmail, or sexual intrigue are major factors. In this case then, we can usefully consider two different hierarchical charts which interpenetrate each other, but which we may sometimes be able to deal with separately: the *ceremonial wall-chart* version, and the *actual clandestine* situation.

Nor is that the end of the complications. As well as this distinction between real-versus-apparent *power*, there are other bases for constructing hierarchies (such as prowess in sport, ancestral connections, etc.), not to mention the corresponding hierarchies in the *perceptions held in the minds* of the many participants — and of course these may all differ from each other to a greater-or-lesser extent.

[105] Hence Vygotsky's alleged fondness for citing "In the beginning was the *deed*"— a quote from Goethe's play, in which Faust rejects the "In the beginning was the word" of St.John's gospel. — See *section 2.1* for the background Piagetian theory in which "the deed" does play this crucial role.

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Moreover we will see that the very concept of a hierarchy is slightly unsatisfactory even in its mathematically pure form (thanks to Gödel's theorem discussed below). Furthermore this 'hierarchy' is open to even more criticism in its social application, notwithstanding its undoubted usefulness when used prudently. Indeed, *even if* we use this hierarchy conceptual tool *im*prudently, it is probably indispensable for any form of advanced mental processing — good or bad.

Anyhow, in order to minimize the confusion from conflicting manifestations of hierarchy, I will try to keep the notion pure-and-simple in the next subsection by *separating out* any conflicts on how to order any given system.

Also, at the risk of seeming a bit abstract, I will first concentrate on the *idealized mathematical* approach — with simple clearcut steps in the hierarchy, and neat unambiguous branching. Indeed many accounts unthinkingly take such simplifications for granted, and never address the difficulties that we will be looking at later in this chapter.

As long as this tree remains neat and regular like this, there should be no great problem in naming the levels numerically, as long as we can decide which is the "ground level". In pure mathematics this is no problem — we simply assume that *objects* (or rather symbols which could be interpreted as objects)[j] are at the bottom of the hierarchy, and then we can apply a *zero* to that level. See table 8-A, as follows.

Table 8-A: Normal Meta-Level Arrangement

analogy	common short name	new "algebraic" name	contents (for mind, or mathematics)
"Second Floor"	MML	M^2L	Abstractions about sets
"First Floor"	ML	M^1L	Sets, or symbols for sets
"GROUND FLOOR"	L	M^0L	Objects, or symbols for them

(2). Naming the various levels in a hierarchy — the M^nL notation for meta-levels

"Meta-" implies a step up in some hierarchy related to concepts or ideas.
So, starting from object-related items at the base-level "L", we may then step up to a generalized concept at the meta-level "ML" — then "MML", and perhaps further still. See *figure 8:1*.

The simple inverted-tree structure depicts the idealized "feudal" pyramid-hierarchy:
It is the basis of much of mathematics and logic — notably L for arithmetic, ML for its generalization as algebra, and MML for a generalized theory of various types of algebra — an algebra-of-algebras.

Sometimes names like "Level 1, Level 2, and Level 3" are used instead of L, ML, MML respectively. I would have no serious objection to this, except that it does not fit in well with proposals which follow. For these, I find it neater:

(i) to have a "ground-level" which is labelled as ***0***, rather than *1*,

(ii) a distinctive format — M^nL — unlikely to be confused with other algebraic notations, and

(iii) a capacity for notational variation, so we can distinguish different types of hierarchy which might apply simultaneously — S^nL, B^nL, C^nL, P^nL, or whatever — even though that may not make good linguistic sense.

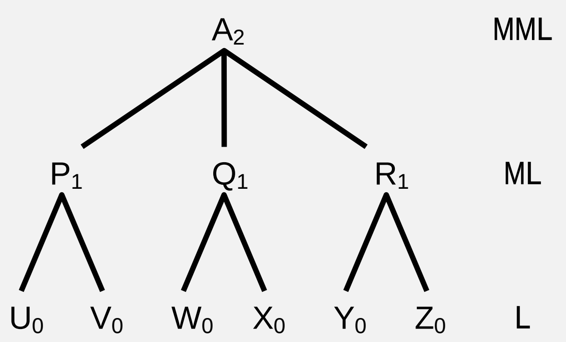

fig. 8:1. "Tree" structure
(an *inverted* tree actually!)

(3). Hierarchies in the outside world — beyond any individual mind

Four examples should suffice here:

"**S**". Firstly there are substructural-hierarchies: — The whole, then its parts, then the parts of those parts, and so on. —
Thus, to be more specific: *The Universe > Galaxy > … > Local environment-system > Tangible "Object" (book, hammer, person) > … > Molecule > Atom > Traditional Sub-atomic Particles (electron, proton, meson, …) > Quark sub-particles.*

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Here we might perhaps use the notation S^nL for the various levels. But what should we take as being the "ground level" S^0L? Theoretically we might like to choose the very lowest level; but there is some uncertainty where that lies, and also some doubt as to how to count levels back to the most-familiar levels of everyday life. So, for good practical reasons, it makes the best sense to choose the familiar level of "tangible objects" as the ground level. This means that levels below "ground" will now have to take negative values for *n* — giving us $S^{-1}L$, $S^{-2}L$, *etc.* as "basement space"…; but that is no great obstacle.

"**C**". For the second example of outside-world hierarchies, we may return to the familiar *control*-hierarchies in social organizations like large companies or government, referred to at the start of this section, (section 8.2). Here we envisage a status pyramid, topped by a *king or president* who can be seen as (i) having a more general access to the available information (though perhaps remote from the detail[k]), and/or (ii) having power to dictate to the rest of the people in the pyramid, whose power depends on how high they are in the pyramid.

Once again there may be some uncertainty as to what the lowest level really is. We may think of a slave-girl as being the lowest in a feudal system, but maybe she had power over farm animals, *etc*. Anyhow there may be some unsuspected feedback loops in such a system, as we shall see later. Nevertheless we may choose some certain level as a "basic" reference point to aid discussion, even if that choice is initially naive, or indeed perhaps quite arbitrary. Then we might perhaps call that level "C^0L" — the "ground-level" in this control hierarchy within society.

"**D**". As a third example, consider a Darwinian evolutionary tree, with some (perhaps unknown) common ancestral type at the peak of the hierarchical pyramid, and various lines of descent branching below that, down to *the present* collection of descendants — a level which we may call D^0L — and notionally on into the future, with *n* becoming negative. But note here that it is not at all clear what units we should use in counting *n* away from zero:
• Generations? — Ambiguous when comparing different species, and unwieldy anyhow. • In practice we would probably use a unit of time — perhaps 10000 years? But this hardly squares with the mathematical ideal in which *n* is a clearcut integer, and usually a smallish integer at that.

The concept of a measurable hierarchy is thus potentially useful, but it sometimes tends to become unruly. Thus it will help if we are prepared for such irregularities before we assume too much mathematical perfection. In any case, all such hierarchies which we are capable of comprehending must somehow become re-mapped into some structure within our minds. We might like to ponder just what those re-mapped mental structures might be like, and what they might have in common with each other — and with the outside hierarchies they portray.

"**K**". Finally consider the "Kind hierarchy" discussed by Thagard (1992). Typically Fido is one exemplar of *dog*; dogs are one type of *canine*; canines are one type of *mammal*; mammals are one type of *animal*; … *etc*. This is the essence of the descriptive Linnaean system[106] of classifying living things into embedded "kinds" according to similarities of their distinguishing features — with no pressure to ask *why* these graded similarities should exist.

Of course if we *do* set out to explain the cause behind the Linnaean kind-hierarchy (K^nL), then we are likely to invoke Darwinian theory, and apply an evolutionary explanation. That then invites us to convert our descriptive K^nL into the causal-historical family tree, D^nL. So there is an obvious connection, but there are also important differences.

In this biological case, the "0" of the K^0L must probably refer to specific individuals like Fido or John, and that is probably as low as we would want to go down the scale. In principle we *could* perhaps go into "basement" territory ($K^{-1}L$) with anomalies like identical twins, but otherwise the zero level seems fairly clear-cut.

(4). Hierarchies within the individual mind

> In Piaget's model of knowing…
> *"the structures are constituted such that the later ones incorporate what has been achieved at earlier stages, and enrich the earlier structures by their reconstruction and extension on a higher plane."*
>
> — Furth, *Piaget and Knowledge* (1969)

The Piagetian view is that there is effectively a hierarchy of schemes within the mind — a control-hierarchy in which some "supervisor" scheme elements arise, and they then orchestrate the activity of the member elements. That allows them all to serve together as a *set*, or as a sequenced *subroutine* — or other such useful collectives, even if they are not in the same physical region.

So far then we have a simple one-step hierarchy; but this procedure will often be repeatable at a yet-higher level, giving us a means for coordinating *ensembles* of sets. Then perhaps we can get one set to signify another set (within a common ensemble), and that is the basic requirement for *symbolism* and speech as we know it.[107] Moreover the process may be repeatable at yet further levels of abstraction. So we would then end up with a multi-layered "feudal" hierarchy; and, as mentioned earlier, that seems to be the crucial difference between humans and other

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[106] the system devised by C.Linnaeus (1707–1778).

[107] and many other activities involving algebra-like mental substitution — including the foretelling future consequences — and including the art of telling deliberate lies (the controlled substitution of one set of supposed facts by another set) — and also the ability to detect and correct the lies of others.

animals. For some reason, the other creatures have not yet acquired the trick of multi-layering with its seemingly endless ability to generalize recursively.[l (endnote L)]

Much of Piaget's experimental work was concerned with the unfolding of human abilities as the infant grew from birth to maturity. This progress (for a given ability) was seen as occurring in *four stages*[108] more or less in step with all other ability-progressions.[m] Each such *developmental stage* was marked by the acquisition of a new higher-level in the hierarchy of scheme-control.

Taking an average overall, that seems to account for the general trends towards qualitative step-changes during our growth to maturity — along with the blurred boundaries and occasional inconsistencies of real life.

What then is the "ground level" if we apply the hierarchy template to this system? Piaget takes the sensorimotor level (the reflex repertoire present at birth) as basic — and on pragmatic grounds I would probably agree. When it comes to deep theory however, I suspect that there may be one or two important levels below this familiar "ground level"; but I have no objections to these more-primitive scheme-systems being given negative *n* values — if indeed these extra systems actually exist.

As for nomenclature, we could use M^nL for Mind, but that clashes with "meta-", which already has the ambiguity of applying to (i) pure mathematics-and-logic, and
(ii) all hierarchies in general.
Other candidates might be: —
"$\mathfrak{M}$ or µ" instead of M —
"B^nL" for Brain —
"θ^nL or $\eth^0L$" for thought … —
or perhaps all of them on different occasions.

For the moment I shall just use M^nL anyhow for this mental realm,[e] as long as there is no great danger of confusion.

8.3 Mathematical hierarchical structure, and its undue influence on our theorizing

(1). The ideal mathematics of perfect self-consistency

Mathematics and logic aim at perfect self-consistency, using unassailable algorithmic[109] processes (with no room left for mere subjective guesswork), and no looseness in the definitions. That would seem to suggest a "totally-flat" organizational structure might be possible — a sort of leaderless Utopia of perfect beings, as an alternative to the feudal pyramid we have just been considering. (Meta-levels could still be allowed, but *ideally* they need not interfere with the "objectivity" of the lower levels in any way — like non-interventionist gods, who spy unseen on the doings of us mortals, and about which we can never know anything, except through dubious theoretical speculation) .

Such perfection and self-containment might seem comforting, at least to mathematicians, but we might ask whether that is really an issue in mind/brain theory where there seems to be an essential place for those other "impure" techniques which are *powerful-but-fallible*. (After all, this use of fallible Darwinian-like tactics for constructing knowledge has been a recurring theme throughout this book, especially in chapters 1, 5, and 7). We will return to this point later, but meanwhile let us continue to look at the controversy over mathematical purism.

First we shall see that mathematical purism cannot be rigorously followed. Gödel's theorem uses the purists' own terms to show that their own agenda can never be fully self-consistent. — But secondly I think we can then take the argument further. Even supposing that the purists were absolved from Gödel's theorem, I will suggest that their system would still not suffice unaided as a comprehensive model for our thought processes.

Why might this purism still fail? Because it ignores or glosses over certain operations which are so familiar to us that we usually do not see them as practical problems at all; and this list would probably include: • The *object* concept; • The origin and nature of *axioms*; and • The legitimacy of *mapping* our mental or mathematical models onto the real world, and back again.

(2). Schools of thought about the foundations of mathematics — and mind

When I talk of "purists", I am lumping together two conventional groups of theorists — the "logisticians" and the "formalists". Conventionally there is also a third group, the "intuitionists", who seemed to have been on the right track out of an impasse situation, though they were apparently still somewhat lacking in understanding of what their intuition process actually entailed — but it seems they

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108 Recall the very brief summary of Piaget's stages, and when they normally occur: "*sensorimotor* (0 to 2 years), *pre-operational* (1½ to 8 years), *concrete operations* (7-11 years), and *formal operations* (11+)" — (footnote 25, on page 12).
Also note the suggestion that we might expect to find another lower stage or two in the not-yet-born, (an extension which we may need if we are to explain concept development in detail). We can now see that, if these more-primitive stages exist, they would fit in with the $M^{-1}L$ notation which allows for unforeseen "below zero" or "basement" levels — page 60.

109 An *algorithm* is a recipe for reaching an exactly correct answer (provided no mistakes are made). In contrast, a *heuristic* is a procedure which has no rigorous justification, but is still useful for obtaining likely answers — and it may offer certain advantages such as being much faster, or serving where no algorithm exists (perhaps because the goal is ill-defined, or for technical reasons). *E.g.* "long division" is an algorithm, and Darwinian selection is a heuristic.

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may have inspired Piaget to have taken the matter further, with the aid of biological / Darwinian ideas.

Let us look at these accepted categories (George, 1972; *my emphasis, and editing of the references*):
"There were three principal views about the foundations of mathematics:…"
- "the **logistic** view, which is developed in *Principia Mathematica*[110] and which asserted that mathematics was a part of logic, and could be reduced to logic." — and implying the same for mind.
- "the **formalist** view, particularly associated with the name of David Hilbert.[111] This asserted that mathematics was a game with symbols, in which you could not necessarily argue that 1 + 1 = 2 was the same as 'one plus one equals two' … a formal game played according to formal rules." — *all detached from real-world meaning.*
- "the **intuitionist** view. Brouwer was the founder of this school and Heyting[112] one of its principal spokesmen. They emphasized that the concepts of mathematics were intuitively given."

In brief, it seems that the first two views are both overly obsessed with attaining perfect self-consistency, as a rigorous system of internal coherence — and that both schools had scant understanding of how their systems might relate to the outside world (external coherence). Whatever power they did have, came from their precision and rigour. These approaches clearly have their uses, but they are not enough for our present purpose.

The formalists tried to *exclude* any such connection to the outside world. Meanwhile the logisticians took too many features of the connection for granted as *supposedly obvious and unquestionable* — a point made by Piaget himself (1949):

> "… toute logistique s'appuie sur des présuppositions intuitives: à lire les principaux logisticiens, comme Russell, v. Wittgenstein, Carnap, etc., on s'aperçoit vite qu'ils se réfèrent tous à certaines intuitions tenues par eux comme allant de soi dans la mesure précisément où elles échappent à la vérification logistigue."

What then are we to make of intuitionism and its "intuitive presuppositions"? One could interpret this mystically in some occult way, but it should be clear that this book argues at length for an ultra-micro mechanistic basis for such activity. In short, "intuition" is seen here as an ensemble of potentially-useful knowledge-handling skills acquired either by the species through conventional Darwinian selection, or by the individual (using unconscious Darwinian-like processes to acquire this fundamental learning).

In practice, this will mean a trial-and-error strategy *using a mixture of internal and external coherence-seeking procedures* to select the most promising "arbitrary postulate-codings" from some large population. — At any rate, that is what is suggested within this present project. Others may well disagree, of course. — But in any case, this intuition-ability seems almost certain to depend on heuristic procedures, in part at least; and that implies an abandonment of any idea that the systems of mathematics (or mind) will be *purely* algorithmic or rigorously self-contained.[113]

(3). The limited direct-impact of Gödel's theorem

Kurt Gödel, in his famous theorem of 1931, showed that any system of symbolic algorithmic maths had to be either inconsistent at some point, or else it had to appeal to some authority outside the system[114] — and of course neither alternative would be palatable to any perfectionist mathematician. Such a never-satisfied appeal to "higher authority" means continually drawing upon a higher meta-level, and presumably that cannot go on indefinitely. Either way it follows then, that ultimate justification must depend partly on some *"unacceptably" non-rigorous criterion.* — So farewell to pure perfection; and a belated recognition for some unavoidable heuristics.[115]

The *near*-perfection of the system still has a lot to commend it, and it is the basis for our processes of logical reasoning whenever it attempts to be rigorous. This logic is a very useful approach for the study of systems (or parts of systems) which are comparatively simple — straightforward enough for us to expect fairly clearcut "Yes/No" answers when inquiring about each system-or-subsystem, as in the next three examples in the shaded panel:

The algebraic first example *is fully within* the logico-mathematical arena considered by Gödel, so its only rigour-limitation is the one identified by Gödel — but it is somewhat exceptional in our real-life experience. Case 3 (applying Newton's laws) does come close to it since we

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110 A.N.Whitehead and B.Russell, *Principia Mathematica* (Cambridge University Press, 3 vols, 1927). [First edition was published in 1910–1912]

111 D.Hilbert: "Die logischen Grundlagen der Mathematik" (1923); "Über das Unendliche" (1926).

112 A.Heyting, "De telbaarheidspraedicten van Prof. Brouwer" *Nieuw Archief voor Wiskunde* (2) **16**, 2, 47-58 (1929). —— [Also see Brouwer (1925, 1926) — RRT].

113 Here we are discussing physical bio-systems. But what if, for the sake of argument, we considered this process as occurring within an *occult* system (vitalistic or supernatural)? Even then I think we could still come to the same conclusion about heuristics and algorithms — that this intuition would still depend on heuristics *within that domain — occult or whatever.*

114 See Gödel (1931/1967), and the more readable commentaries such as van Heijenoort (1967), Penrose (1989), and George (1972).

115 Heuristic skills which had actually always been there, but hidden behind our complacent view of our own "natural transcendental" capabilities — mental powers which we either accepted unquestioningly, or attributed to occult sources.

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use the laws as axioms, and then apply logic and maths; but the laws themselves cannot come from pure logic, so their origin must already be "impure and non-rigorous" quite independently of anything Gödel's theorem might tell us.

As for Newton's laws themselves (Case 2), their appeal rests partly on their mathematical neatness — that well-known heuristic trick of "Occam's razor" which we might see as part of the repertoire of internal coherence-testing. Of course the laws also depend on experimental findings by Galileo, Tycho Brahe and others — a process which I choose to refer to as external coherence-testing. Here we are already heavily involved in non-algorithmic procedures, and Gödel's theorem becomes increasingly irrelevant in such cases.

Then in the last three cases, strict-logic becomes even less involved, especially as the boundaries are now fuzzy, so Occam's razor is particularly difficult to apply with any claim to credibility.

(4). The iconoclastic *psychological* impact of Gödel's theorem

Strict algorithmic logico-mathematics cannot solve all our problems unaided. That should have been obvious all along because the task is just too demanding. But it seems that the message just didn't sink in thoroughly until it was seen that logic had feet of clay *even within its own specialized realm* — though actually that was for different reasons.

Unsound myths may sometimes be toppled psychologically through some minor viewpoint change, even when that change is not strictly relevant. It is said, for instance, that European colonialism in Asia was doomed once the Japanese *destroyed the myth* of white-superiority, during World War II.

Logico-maths never was invincible without the aid of heuristics, but the *myth that it was* had a certain currency amongst modernists. Gödel *killed this myth* for those who could read and understand him, but it took until about the 1960s and '70s for the message to sink in enough to spawn widespread postmodernism[116] — a rather indiscriminate rejection of all ideas seen as preconceived, presumably because they had no valid "logical" basis, and this has left a somewhat anarchic free-for-all in some areas.

Arguably though, iconoclasm is not enough; we need to understand those bases for knowledge which do not fit into the traditional logic-algorithmic mould so that we can then critique the "preconceived ideas" more sagaciously and, where appropriate, **re-construct new idea systems** which are hopefully more in keeping with the real world. That is the agenda which I have called "***post*-postmodernism**" — and it has been my guess that this can be best carried out through a balanced application of internal and external coherence-seeking. Of course others may have better suggestions, but these further alternatives have not yet come to my attention.

Is it true that $(x + a).(x - a) = x^2 - a^2$?	**Yes**, for all x and a values.
Are Newton's laws of physics correct?	**Yes** (near enough usually[117])
Are conclusions based on them correct?	**Yes** (to that extent)
But: Should NATO have bombed Serbia?	highly debatable. (but implies a Yes/No)
and: What dose & what drug to cure …	? (but we feel our way towards a "best")
and: What is the best way to treat crime?	??? (Where do we start!)

[116] Of course this supposed causal connection is somewhat speculative. But readers might like to ponder the possible connection for themselves.

[117] to a high degree of accuracy, except when speeds approach the speed of light.

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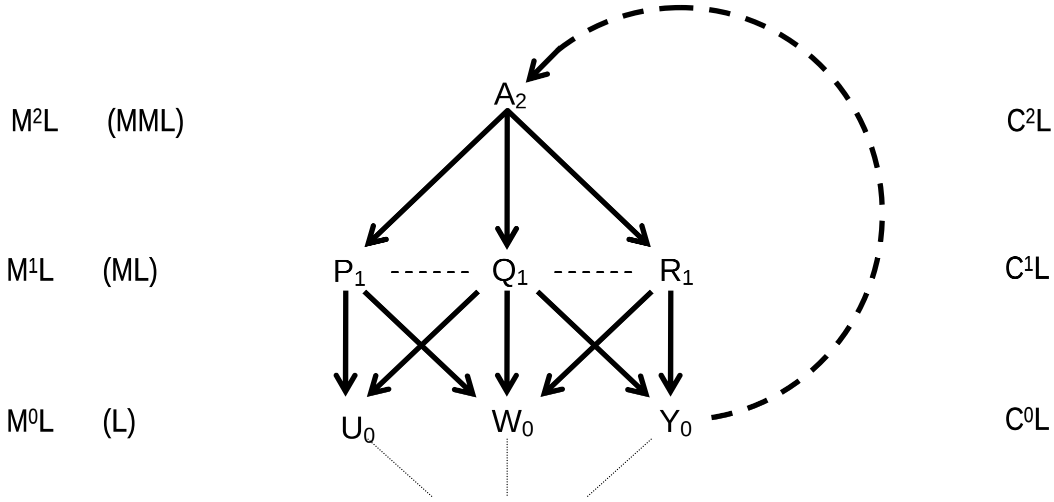

figure 8:2 Partial "Lattice" structure — with Feedback

branching *and* re-joining —
and more-so for a *full* lattice, as suggested by the dotted lines.
Then add the dashed-line feedback loop!

(5). "Democratic" pseudo-hierarchies for the meta-level structure

Hierarchies don't have to be feudal like the inverted tree we looked at earlier.[118] (Is there a cultural assumption that they should be?) Here I have suggested several departures from that mould as applied to a C^nL structure (a particular case of M^nL).[119] • For one thing, we can accept that different ML centres may have *joint "sovereignty"* over any individual L item — implying that it can belong to more than one "set". For example, an actor in a stage musical like *Showboat* would work under *three* bosses (be *a member of three control-sets*): under the director, the musical director, and the choreographer.

That plurality of control would seem to be an obvious non-controversial development; but it means that the "tree-branches" can now link up again at (say) twig level, so in fact we no longer call this a tree, but a "lattice".

• Next we allow *horizontal linkages* which would seem to be appropriate for the main entities discussed in the previous section (consistent logic systems, and also internal coherence criteria amongst items). We might also note that the business-theorist, Stafford Beer, emphasized that organizations only work viably when most of their communication happens *within* levels of the organization-chart, and with only a minimum of orders and reports etc. *between* levels. (Beer, 1972 — developing the ideas of W.R.Ashby).

• There are also other dotted straight-lines which descend mysteriously *below* the basic M^0L (or C^0L) level[119] — indicative of a descent into $M^{-1}L$ and perhaps $M^{-2}L$, as discussed above in *section 8.2* (page 60), and previewed in the list of Piaget's stages in section *2.1*[*b*].

• Finally there is the big curved arrow with its dashed line, depicting a surprising link from the bottom of the hierarchy back up to the top again. This implies that the serfs and vagabonds are dictating to the king or president. Indeed, for that very reason, I suggest we call it the *democratic* model. But note that there is an asymmetry of power here. At general elections we do certainly get some sort of chance to boss our leaders around, but this privilege is very circumscribed and infrequent. It is nevertheless a valuable guard against arbitrary excesses and imbalances.

This even has some bearing on the paradox arising from Gödel's theorem. On page 62 we saw that logic systems were still valuable and important (though not *all*-important) even though they could only be rigorously consistent by appealing to ever-higher meta-levels — and clearly this cannot go on indefinitely within non-occult nature as we know it. Presumably then, we have to "fudge" the top meta-level in some non-rigorous way — so why not some intuitive or heuristic input from elsewhere? And that input might as well come from the base level, especially if we can then also monitor the process via other levels.

Of course this suggests that, strictly speaking, the whole meta-level hierarchy is something of an illusion. It is "really" just a way of organizing items which are-or-were all ultimately of the same status in some sense — the "*All are created equal*" touch. Of course we should be wary of taking this supposed social-equality as literal "fact", and surely the same warning should apply over supposed equality within mind-hierarchies?

[118] at the start of section 8.2, page 58.

[119] as explained on page 60, the "C" implies a control-type of hierarchy specifically, while the "M" implies either (as here) an unspecified type of hierarchy, *applicable in general* — or else a strictly *mathematical* or *mind* hierarchy, when the context demands it.

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8.4 Mental hierarchical structure — and the human ability of abstract thought

(1). Should we assume that *symbols-for-objects* are the basic mental elements?

Those working on Logistic logic have assumed a vital point hitherto, and almost universally! This assumption is that the *mind symbols which represent objects*[120] must somehow be basic — *the basic* most-elementary entities underlying our thought processes. That is evidently also what the lay public would accept. Indeed, apart from Piagetians, nearly everyone else with an opinion on the matter (lay *or* expert[121]) would probably agree.

A minor consequence of this is that we might as well accept this "object-concept level" as the zero-level (M^0L) for our mental-hierarchy nomenclature, as long as we are prepared to accept negative values for any levels which do then turn out to be lower, despite the assumption. As we have seen in table 8-A on page 59, that zero-choice can be taken as an essentially arbitrary decision, so it need not bother us. In fact it is convenient here to have some grounds for consensus over this non-crucial point, even if those grounds are ultimately questionable.

But we can be seriously misled if we have a faulty view of a mechanism and its components — a mistaken idea of how our ultimate "nuts, bolts, and girders" behave within the brain's more secret domains. As long as we assume that the object-symbol is functionally indivisible, then we will have cut ourselves off from even considering some otherwise-plausible mechanisms. And if any such excluded mechanism is actually the right answer, we will meanwhile either fudge the explanation somehow (unconsciously, no doubt), or we will give the project up as intractable, and go off to investigate something else instead.

(2). The Piagetian view — that the coding-for-action is the most basic mental element

Now as we saw previously, the Piagetian view is that the primitive "*scheme*" is the basic mental element underlying mental concepts, and that the object concept is a secondary construction built up from these action-code elements — related to the actions we might make when handling or visually exploring the objects. These basic schemes then must be what is in the *true base-level*, and this must be the "basement" below L, and we call it $M^{-1}L$ for want of any better term.

So now we have something like table 8-B.

Table 8-B:
Meta-Level Arrangement with "Basement" added

analogy	common short-name	new "algebraic" name	contents (for mind)
"Second Floor"	MML	M^2L	Abstractions about sets
"First Floor"	ML	M^1L	Symbols for Sets
"GROUND FLOOR"	L	M^0L	Object-symbols
"Basement"	…	$M^{-1}L$	**Primitive "Schemes"**

Note the potential versatility of the simplest-type scheme (if it is indeed an "RNA-like" strip of linear coding, or a synchronized ensemble of such items as proposed earlier in this volume). It can be loosely interpreted as a coded *sub-routine to "sketch" something*, or rather to make some such similar movement (not necessarily in 2D). And given a sufficient number of suitable "pen strokes" which are also coordinated by some *internally acting* subroutine/ scheme, we can effectively construct a mental-model "*object*" as a sort of 3D drawing: Firstly with muscle-based manipulation externally, but later probably using only internalized components within the mind.

Here then, we have one possible account of how an object in the real world outside can become mapped onto a (two-level?) mental hierarchy with scheme-elements at each of these two levels, though these elements would probably be of types different from the original object.

Such a brief account leaves a lot unsaid of course; but the point I want to make is that this approach does offer considerable scope for further plausible investigation. That is the goal at the moment: simply to suggest a way ahead.

If, on the other hand, we simply asserted that the external object is just "somehow" represented by some "object-like" entity within the mind, then that does not get us very far.

[120] Note that we are talking about representations of objects, not the objects themselves. (Of course actual objects fall into a hierarchy directly involving the structure of *matter itself*, *eg.* see chapter 5, or the discussion of S^nL on page 59). Right here we are concerned instead with mental or mathematical symbols *which somehow stand in for the objects* — as part of a mapping process onto our current *different* hierarchical domain, M^nL. Our question then is this: What are the most elementary elements within this mapped M^nL domain? Do they correspond to real-or-supposed objects? Or (as Piaget would claim) are they something more basic than that? — *viz*. action-encodings — his *elementary simple 'schemes'*?

[121] Traditional tracts on mathematical logic seem never to have considered any possible substructure below the "object" concept. See appendix C.

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How can we even start to explain the actual dynamics of the production and use of this internal "mirror image" of the outside object? How did the linkages come to be set up? — And what can you do with a lump-like object-symbol, unless it can somehow tune in to action-codes?

Now let us move on from objects to something else. What about modelling some real-world hierarchy such as S^nL, the substructural "*this is part of that*" system introduced on page 59? Of course, at this stage I do not *know* exactly how we construct such concepts, but once again the raw materials available lend themselves to a plausible account. Let us suppose something like the following sequence of steps can take place:

(1) The main entities at S^0L are treated mentally as if they were tangible objects (and they may well be just that, in many cases). As "objects", their mental models could *each* be constructed anew, as described above; or they could be produced from the adaptation of "object-concept templates" which could well be available given the familiarity of the object concept once one has developed beyond infancy. That might mean that it was no longer necessary to handle or eye-trace the real-objects.

(2) This process could be repeated with new ***wholes*** — "object-like" ensemble-entities *compounded* from the original "objects", which would now be mere parts of the new bigger whole. In the real-world hierarchy (S^nL), these new "whole objects" would belong to those levels higher up, with *n* positive. In the corresponding mental map, these constructs would simply be additional "object"-symbols with a slightly different provenance in each case.

(3) Much the same again for ***parts*** of the original "objects", with *n* negative now. Once again, the mental models of any parts would be only marginally different from the models of any other real-object.

(4) These entities would need some form of attributed linkage. In principle that could be supplied by an action-encoding (perhaps using a simple uncompounded scheme element), and/or some other means whereby members of a "set" are held together in some sense (physically or communicationally). This could be done through the "*intensively-defined*" or "*extensively-defined*" means of specifying a set; (see page 58).

Once again, I am not trying to claim a proper explanation yet, but merely to suggest a plausible way of proceeding in a field where leads for substantial progress have been rather slow in materializing.

8.5 Further departures from mathematical perfection

(1). How sharply "integer-driven" are the steps between mental-hierarchy levels?

Let us consider the idea of any single step (between two adjacent levels) within a mind-based hierarchy such as the obvious step up from the supposedly basic "object" level ("M^0L") up to its meta-level (ML or "M^1L"):

Most Pure Mathematicians simply accept this perceptual "master-servant" relationship as a given. After all, we adults readily identify simple things and classify them into "appropriate sets", and this ability seems so natural that we scarcely question it. Yet it is all too easy to forget that infants and some drug-takers or psychotics may fail at these "simple" tasks, suggesting that the recipe for these tasks is not necessarily God-given or eternally automatic.

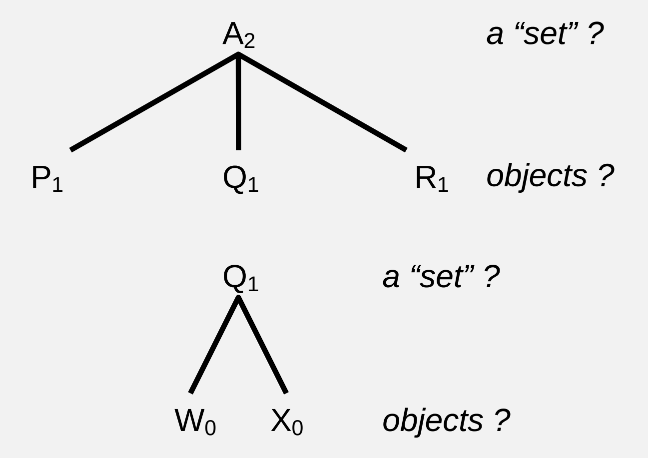

Fig. 8:3

Two single-step substructures from within a mind-hierarchy

In other words, if we really want to be thorough in explaining the mechanism behind our perception of a set, we really ought to go into a bit more detail; and this will probably mean postulating some intermediate "somethings" in between the supposedly clearcut L and ML levels, etc.[122]

If we contemplate any such dissection of "mechanism *within*-a-level" — and if we assume an ordered ladder hierarchy of such levels — then this leads us to consider the possible pattern-sequences of submechanisms both within each level, and in recurrences of further levels. For instance:

(i) Each level might repeat the same basic pattern of sub-mechanisms, as we climb the hierarchy:

$ABHGX(A_{next}) - ABHGX(A_{next}) - ABHGX(A_{next}) - ABHGX(A_{next}) - \ldots$

i.e. $A_0B_0H_0G_0X_0 – A_1B_1H_1G_1X_1 – A_2B_2H_2G_2X_2 – \ldots$ *etc.*

(ii) The pattern might be essentially "messy" and non-recurring, and our choice of where each level finishes may

[122] Of course we may then want to go further than merely making postulates; but we have to start somewhere, and I am not aware of any other comparable suggestions to date.

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be arbitrary diktats just to suit our convenience, shown in bold type:

A F J Y G D L **N** G F K J L **N** J G D Z –
W F C T **R** P S M G F **S** M H V J **K** ,

in which case, the integer *n* presumably has no intrinsic significance — just whatever meaning we choose to bestow upon it.
(iii) Some compromise between these extremes — and for what it's worth, my guess would be in favour of minor variations on the regular "(i)" case.

Of course this all depends on whether the hierarchical structure actually exists. But if it does, there must surely be some substructure for each level rather than the purity of mere diagrammatic arrows?

(2). The case for two-or-more sublevels within each "meta-level"

So what might these "somethings" be, bridging the gap? It is not the place of this introductory text to go into much detail; but a few brief suggestions should suffice for the moment anyhow. One clue lies in the Piagetian concept of the elementary "scheme" as being an *action* (or perhaps rather the *encoding for an action*) — as discussed in *section 2.1*, and more recently in subsection 8.1 (3) on page 58 and thereabouts.

Gap: **Levels -1 to 0**. Recall that the *mental model of an object* was seen as being made up of a set of scanning or sketching actions. We might think of this object-model as a *noun-like-thing* being defined by *verb-like-entities* — whereas we might have expected nouns to be basic instead. So what bearing does that have on our hierarchies? The conventional hierarchy is drawn showing the noun-like entities only, at each given level — objects, then sets, then ensembles of sets, and so on. But the object concepts at zero level (M^0L) have, according to Piagetian theory, been constructed via actions — and ultimately from the encodings for these actions (on RNA, or whatever).

But what level could we expect these actions or encodings to inhabit? Presumably not the zero level itself. Maybe the actions themselves are insignificant here, and we need only be concerned about their encodings, presumably placing them at level -1, ($M^{-1}L$). Or maybe we should place the actions half-way at some *"-½ level"?* — And then perhaps there are other unforeseen items of the process which should also fit into fractional positions between -1 and 0; or maybe there is a complexity here which would be more properly said to spill over "down to level -2"?

Whatever the answer eventually turns out to be, it seems prudent meanwhile not to be too much seduced into believing that the neat clearcut model of the mathematicians will always be applicable. On the other hand though, this model probably still has much to offer us, as long as we do not accept it too naively.

Gap: **Levels 0 to 1**. A similar problem arises when we contemplate just how the mind could possibly construct models of sets from its models of objects. Almost certainly we will need to invoke verb-like entities here too — and they would arguably need to occupy a sort of *"level ½"*, on the way up to the *level 1*.

Whether the actual details of the operation would be closely similar is by no means certain. Nor is it clear that the same physical mechanisms or locations would necessarily be involved. (Strict recursion[123] *would* require such an identity, but I doubt whether strict recursion applies at these lower levels, as I have already mentioned). Nevertheless the principles of the activity are likely to be comparable — and even if they were not, we would still be wise to be on the look out for between-level complications arising from the applicable activity, whatever that might be.

Gap: **Levels 1 to 2, *etc***. Likewise we might have to consider possible activity at *"level 1½"*, and suchlike. Any higher levels would probably follow the same pattern also, especially as genuine recursion would be more likely to have become established by now.

In general.
The traditional hierarchy-chart is "noun based", focussing on *object-like* entities at the various levels, with additional neat-but-sterile lines to link these levels. If we are serious about explaining the mechanisms of mind, then we surely need to envisage more detail than that — even if we can only do so *in principle* until we can get some hard evidence. This suggests the existence of intermediate sublevels, probably "verb based" involving action-like entities. In fact, to take Piagetian action-based principles to their logical conclusion, perhaps we should eventually re-draw the charts focussing on the actions/verbs *instead of* the present objects/nouns?

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123 Recall that recursion means applying exactly the same rules (or mechanism, or handling-procedure, or subroutine) at every level of a repetitive process — as in:
(i) *fractal-generation* — or in:
(ii) *evaluating* 7! (*i.e.* "factorial 7"):
7×6×5×4×3×2×1 —
with economical rules like this:
• Take the number (*m*), and let *answ* = 1 (tentatively).
• Now if m=0, you have finished;
otherwise:
• let $answ_{new} = m \times answ_{old}$
• deduct 1 from *m* — and go back to "Now". *I.e.* "**Repeat exactly the same formal procedure** until you get to the end."

Table 8-C: Alternative Starting-points for Steps in Mind-hierarchy

Object-based Levels the traditional approach. ("Noun based")	Supposed Mechanism-sequence as we ascend the hierarchy	Action-based Levels as an alternative ("Verb based")
Level 3 ?	**Object-like**	
	x-type	
	Action-like	Level 3 ?
	y	
Level 2 ?	**Object-like**	
	x-type	
	Action-like	Level 2 ?
	y	
Level 1 ?	**Object-like**	
	x-type	
	Action-like	Level 1 ?
	y	
Level 0 ?	**Object-like**	
	x-type	
	Action-like	Level 0 ?

But in either case, there will probably be a similar organizational pattern within each one-step gap — a repeating periodic pattern. So, as in the case of a sine-wave, it may often not matter much just where we assume the cycle to begin, as long as we are consistent within a given exercise. Thus, suppose we postulate a repeating pattern of submechanisms (in ascending order):
… Action —"*x*" — Object — "*y*" — …
(with *x* and *y* being hypothetical "fill-in" submechanism-types which might be there, but are currently unspecified). This would produce a cyclical pattern, and arguably we could start each cycle as shown in either the left column *or* the right. See table 8-C.

(3). Untidy "mixed levels" features

Let us not forget the untidy departures from the standard feudal pyramidal — departures shown in the lattice diagram on page 63 — departures which (if they actually exist) may well complicate the ultimate detailed account of the inter-level mechanisms. We need not discuss them again here, but we might usefully recall:
• Linkages within the same level, including self-reference (giving some scope for paradox);
• Joint control of an element by two-or-more items in the level above; and
• The paradoxical "democratic" feedback loop which can modify the "king of the feudal pyramid", (as discussed in a paragraph on page 64).

There is also the rather more mundane possibility that a high-level item can directly control items *two-or-more levels down*, as well as the normal single step. That is not particularly surprising and it is sufficiently orthodox to be recognized within mathematics, though sometimes precautions are taken against certain mixtures — as when one is advised against mixing together both *sets* and their *own members* within some common master-set.[124] At other times, such practices can well pass without comment. Thus consider a purely algebraic equation (arguably[125] it is itself at M^2L, and applied to M^1L sub-elements only):

$$y = mx + c$$

and compare it with an equation which is the same except for having an *arithmetic* value in it:

$$y = mx + 3$$

The "3" is one step closer to concrete reality, and so we might take it as being M^0L; so now we have a *heterogeneous* mixture of elements. That hardly seems to matter in mathematics — but such parallels within the mind might conceivably cause logistical problems when it came to practical "programming".

(4). Psychosis and genius, as departures from the "normal" tuning of meta-levels or sets

In the ever-changing everyday world we live in, we are constantly being challenged to classify things and events and people — to also *keep* re-classifying them as time unfolds — and in different ways for different purposes. That is a tall order, and in some tasks we must all surely get it wrong fairly often — yet as long as we are not too far off-beam, we will probably muddle through. This is a sort of hermeneutic "internal-discussion" process, where concepts are constantly being marginally reshuffled in the hope of improving their collective coherence. In fact it can be a delicate balance to reach the "right" compromises, and to reconstruct basic concepts wherever necessary — and even the "necessary" will not always be possible!

Creative thought. At their best, deviations from standard protocol will give us *creative thought* and even *genius* — involving the use of non-obvious ways of re-construing commonplace knowledge though "lateral thinking". Indeed such breaks from tradition are probably necessary if we are to solve our more intractable problems.

124 Some computer languages, like PASCAL, are designed to *prevent* the programmer from mixing such different types of item within the same set.

125 One might quibble over just what integers might best apply. However the main point here is obviously to indicate their *relative* level within the meta-*mathematical* hierarchy.

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Psychoses. Psychosis can present itself in numerous different ways, with different clinical sets of symptoms. However I am tempted to believe that these various conditions all have one causal feature in common — a malfunction of "set control", with some coordinating scheme at meta-level k failing to "correctly" coordinate its supposed member-elements at level $(k-1)$.

Now the failure at one k-level would produce symptoms quite different from those at other levels, so it is worth considering that the different clinical categories may be due primarily to differences in the k value. There might also be secondary differences due to selective failures in different regions *within* a particular level, though then the symptoms would probably be more recognizably equivalent.

Malfunction at a higher level (like M^4L or M^3L) might well pass unnoticed since many people make no effort to operate at that level of abstraction anyhow. That is the realm of arcane theorizing about abstruse fundamental issues of "*life, the universe, and everything*", and any such isolated offbeat thoughts will not usually make any practical difference to anyone unless these thoughts are then adopted by a significant social group. But if such thought aberrations occur in the mind of a powerful dictator like Hitler or Stalin, the consequences may well be disastrous to society as a whole — though the dictator himself may see no problem in his own capabilities, and opponents might simply see him as *evil or stupid* (rather than psychotic in any sense — high level, or low).

At the other end of the scale, the effects would normally be much more personally disastrous for the individual. If, for example, we cannot achieve or maintain mastery of the relatively straightforward concept of "object", then what hope do we have of making our way in the world?

Of course any such failure might only be partial, and indeed it is actually difficult to go too far wrong with the object concept because it is so comparatively clearcut. But the more we *do* fail to identify and conceptualize objects within our personal space, then the less basis we will surely have for understanding anything else either. After all, we depend quite crucially on that very-basic *object concept* at the foundational M^0L level in our thinking, even if it is not quite so basic as the simple Piagetian "scheme"-element. (Failure there, at $M^{-1}L$, would presumably leave us "vegetative", devoid of any practical mental ability at all).

One step up takes us to the classification of objects, as when the patient takes "shadows and scratches" to be integral properties of an object (Payne, 1962), and here we are merely considering problems with inanimate objects. In this middle-of-the-range we will also have (for instance) failures to classify social cues correctly, and other intangibles relating to interpersonal interaction. Here the symptoms may seem to be quite different again.

In each case, the main task seems to be: • identify relevant set members using their descriptive properties or "intensive definitions", and hence • set up a memory-structure which amounts to being an "extensive definition" — notions mentioned previously on page 58.

This account of psychosis is admittedly all somewhat speculative, and will remain so even when the full account appears later in this project. However it does illustrate one type of inquiry which might usefully emerge from the present ensemble of inter-related theories — and if the details later turn out to be different, then so be it.

8.6 Humour, play, and sleep — as re-adjustments within some meta-level

(1). Internal coherence through reshuffling the set elements at each level

Once again I shall offer the briefest of sketches of various commonplace phenomena which might be fitted into this structural plan. — Phenomena which are so commonplace that we nearly always take them for granted.

(2). Sleep and other 'rest-periods' — as reshuffle and tidy-up sessions

If our mental representations are indeed often composed of linear codes organized into hierarchies; and if their stability often depends on hermeneutic trial-and-error reshuffling in the testing for internal or external coherence — then we might expect nature to allocate *time* for these reshuffle processes to consolidate or maintain themselves. If so, it is tempting to see *sleep* as serving this role.[126] But there is a complication:

Recall the previous section, (8.5). There we have just seen the apparent need for a *sequence* of scheme-compounding — arguably from M^0L or lower, through M^1L, and M^2L, and then on up to M^3L or M^4L. The trouble now is that *each* of these levels may need time-out for maintenance or consolidation — and if their requirements differ, they might each need their own separate time allocation. (The relative needs of the various categories will doubtless change over time, as maturity progresses).

126 Indeed it is difficult to see what purpose sleep does serve if it is not some sort of mental renewal like this.

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Table 8-D: Sleep-Modes and their possible significance

1. Sleep-Mode (or what?)	2. The more-obvious features	3. Level of reshuffle (?)	4. Apparent "Psychosis" type if malfunction, or deprived	5. Comments
Meditation, Day-dreams	Assimilate ideas (**?**)	M^2L or higher	Irrationality**?** Misconstrues logic. (Seen as fairly normal**?**)	Intellectual activity; disrupted if hurry, etc.
REM sleep ("Rapid Eye-Movement").	Ego-involved. "Dreams" as we know them. Muscle suppression	M^1L	Social dysfunction Misconstrues: intentions of others, symbol versus real; *etc.*	20% of adult human sleep None in the tortoise, nor in the echidna. Very little in the hen.
Orthodox sleep, "slow wave"		M^0L	Misconstrues objects, and impersonal sense-impressions	80% of adult human sleep
(Genetic reshuffle**?**)	immutable in individual	$M^{-1}L$ *etc.*	"vegetative" incapacity to do anything much**?**	repertoire of standard simple schemes

Now it just so happens that there are at least two different types of sleep mode, (Jouvet, 1967):
• The "orthodox" or "deep" sleep which occupies about 80% of our adult slumber; and
• The so-called "REM" sleep in which our dreams normally occur (even though we do not usually remember these dreams unless we awake at about that time).

It seems reasonable then to postulate that these two modes may be associated with two different levels in the supposed mental hierarchy. We need not yet worry unduly about *exactly which* two levels might be concerned — just the idea that there is a pairing of some sort. However a plausible guess would favour the M^0L and M^1L levels respectively.[127]

But then why not have similar reshuffle periods *at other levels* below or above these two? — (See table 8-D).

Below? At the very lowest level the elements are presumably immutable *basic* scheme-elements (by definit-ion), so the issue of a reshuffle would simply not arise — at least not within that individual, though we *might* view genetic recombinations as serving the same formal role. Of course there might also be one or two intervening levels, but we can worry about that later — if ever the problem arises.

Above? Here we are coming up into the realm of intellectual thought, and surely any reshuffling of such ideas is likely to be done *consciously, in our waking hours*? We might nevertheless expect some detachment from the ordinary down-to-business thinking of the workaday world — a time-out for reverie of some sort. *Meditation* or *day-dreaming* perhaps? There might also be a role here for *mood*, though I suspect that this might serve rather to focus on this-or-that specialist area *within* some hierarchical level, and *not between the levels* themselves.

So what might be going on in these reshuffles? We might gain some useful clues from what we do consciously in our daydreaming etc., though that sort of process may be far from typical. Presumably we entertain new ideas or compound-schemes, all ultimately from random internal mutation, but some may have already been selected such that they "record"[128] influences in the outside world (thus expressing external coherence-tests). During a suitable sleep-like period, the incumbent schemes (compound or simple) would be assessed for their collective internal coherence, and then there would presumably be a discard-ing of ensembles which scored low for self-consistency.[129]

[127] and these *might* be tentatively identified with two of Piaget's stages: *Sensorimotor* for M^0L, and *Pre-operational* for M^1L. However, once again, it scarcely matters at this stage if we find some better way of matching the various scales. The main question here is whether there is a match of *some* sort — *any* sort within reason.

[128] As explained earlier, this will seldom be a genuine (Lamarckian) recording of events such that a highly designed tape-recorder would produce, but rather a Darwinian-like selection from a vast population of candidate encodings — a selection which then happens to *resemble* a recording.

[129] Probably, true to Darwinian "wastefulness", the whole of any low-scoring ensemble would be discarded. Alternatively, the poorly fitting items might be ejected and discarded individ-ually; though it might be less clear just how that could be achieved in an undesigned evolved system.

This would seem to require multiple replications, statistical effects, and sophisticated coordination. Given a coding system at the molecular level, and the high signalling and recognition capacity of IR fibre-optics, it might just be possible to meet these requirements.

Of course there is no guarantee that the conclusions reached would be either true or ultimately acceptable, but that may be the best practical way of groping towards these objectives. Anyhow table 8-D summarizes some of the ideas just discussed.

(3). Sleep deprivation — and psychosis-like symptoms

If sleep is needed for the proper consolidation of concepts at two of the M^nL levels, then clearly any long-term sleep deprivation is likely to upset our perceptions at those levels — and that is likely to lead to psychosis-like symptoms, as suggested in column 4 of table 8-D.

Of course this reasoning depends on the idea (raised in subsection 8.5 (4)) that "real" psychosis is caused by a dysfunction in the relevant set-handling. If that is indeed true, then it would seem to follow that *any* dysfunction in the set-handling, however caused, will also lead to psychotic symptoms of some sort. Presumably then, this argument would also apply to any dysfunction caused by sleep deprivation — whether of REM sleep, or of orthodox sleep, or both.

Anyhow it does seem to be the case that long-term sleep deprivation does lead to odd symptoms, and those symptoms could be seen as psychotic.

These thoughts invite an extrapolation into levels where sleep itself is apparently not involved. Thus if the higher levels depend on a measure of *simple meditation* for proper consolidation, and if life is too hectic to stop for meditation, then maybe one's rationality and logicality will suffer. At the other extreme, if we obstruct the normal genetic re-selection by inbreeding, then the "genetic coherence" may well suffer — and *maybe* that is an analogue of psychosis.

All these cases seem to need some periodic hermeneutic reshuffling to try to improve the coherence of their respective systems. Of course these lines of reasoning are open to question, but perhaps the ideas will at least offer some useful lines of inquiry.

(4). Humour — one form of play

Shultz (1976) offers a useful summary of the academic approach to this subject, with separate looks at what is funny to adults, or to children at various ages. One notable feature is the frequent play on ambiguity, and note that this amounts to *indecision as to which set some concept "X"* should belong to. (E.g. *'The duck is ready to eat'*, on his page 21 — with duck seen as diner OR dined-upon).

In real life we constantly have to make ambiguity-resolving decisions like this, though usually at a more mundane level. But in the relaxed atmosphere of a recognized joke-interlude, games like this give one scope to savour one's mastery over the set-manipulation required to recognize the ambiguity for what it is. Of course it will not be funny to those who have not yet achieved the relevant mastery — in this case, children below the age of about 12. At the other extreme, this example will not be particularly funny to many adults either, since they will perhaps no longer see any challenge in this simple ambiguity.

Incongruity (his page 22) is another play on set-allocation, so we may arguably interpret it in much the same way.

We might or might not recognize the infant's laughter as a response to "humour", but that seems to fit into a similar pattern, (Shultz, page 27). At that age, during the sensori-motor stage, the sets being mastered will clearly be much lower on the M^nL scale. Here the main challenge will simply be to fit any new percept into one of the pre-existing compound schemes — i.e. to *"assimilate"* it, (in Piaget's specialist terminology).

We could see that as reducing the *incongruity-or-ambiguity* caused by the intruding new percept, and that experience of infantile mastery seems likely to be what causes the baby's laughter — its own equivalent of seeing a joke in later life. After all, both are arguably experiences of achieving increased coherence within an unpressured play situation. In such play, the achievement itself may seem trivial, and indeed it *will sometimes* be of little direct value (which is why misguided puritans have long taken such a *killjoy* attitude). But meanwhile the individual has built up compound schemes for some skills or concepts which are likely to have important applications in "real life" later on — and this may sometimes be the only safe way of practicing these skills and concepts.

As just described, humour may be seen as one particular form of play. Tentatively then, let us suppose that all play serves the same general role of giving practice in important mental-skills and concepts. That is a view in accord with modern theories of child development, including those of Piaget (1966) — but I shall not pursue the matter further here.

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9. Summary and Overview

9.1 On seeing the invisible

> They are ill discoverers that think there is no land, when they can see nothing but sea.
>
> attributed to Francis Bacon

The modernist period (especially the 1870s to the 1970s) has been particularly insistent on *seeing-before-believing*. Such caution was adopted for understandable reasons, though that reasoning should not be above criticism.

But modernism has often gone even further and required *seeing-before-taking-seriously*, and that has made it very difficult to make real progress with any in-depth studies in disciplines like psychology.

I have explained, in some detail, why I feel justified in breaking this taboo (without, I hope, succumbing to the unstructured relativism of the postmodernists). — In brief this was an appeal to recent opinion amongst the philosophers of knowledge[130], and the related realization that even our hallowed "*seeing*" can only work because it uses hidden processes evolved to make sense of mass-data. Thus, at least in principle, seeing is very much like any other fallible knowledge-gathering process.

We thus need a wider criterion *which includes seeing as a sub-set*, and this wider criterion is "coherence testing". So now we have *external coherence* referring to seeing and experimenting; while *internal coherence* refers to such things as abstract theory-testing. Either type of coherence can now be offered as legitimate in the short term; but we need both to cooperate in an overall coherence test from time to time, so there needs to be a respectable balance between them.

My main violation of this old taboo was to postulate actual mechanisms as underlying Piaget's theories for the human mind, or as Piaget might have preferred to put it: mechanisms to explain *epistemological abilities of the individual* and how they develop from birth or perhaps even earlier. Piaget himself seems to have had some such mechanisms in mind to embody his abstract notion of *the scheme*; but he was hardly specific about it, and I can only speculate why he did not carry the idea further, though the taboo would not have helped.

A proposal like this leads inevitably to a host of other technical matters which need to be thought about. In particular: If the Piagetian scheme is embodied as a linearly-coded molecule (like RNA), just how could this code be interfaced to the rest of the nervous system? And could that explanation really fit in with what we now know about information technology and advanced human abilities? Or, speaking comparatively, could that explanation work *better* than some vague synaptic model which is supposed to do the job "somehow"?

In working through these postscripts to the original Piagetian idea, it became necessary to query some other assumptions; and of course that invites further accusations of heresy, especially if there is no clearcut observational evidence (and naturally there is unlikely to be much lab-evidence either way at this early stage).

Anyhow, on the next page there is a list of the main "heresies" introduced in this project so far; (see the shaded column of table 9-A). There is also a column for the older assumptions which they challenge; and a column on the right for doctrines which are *not under fire despite appearances*, (though they may now have to share the podium with a new-comer):

Looking at the shaded column we can see a list of some half-dozen unconventional views which some people will no doubt regard as heretical. Of these, *number 2* was the Piaget-based interpretation I started with originally. But as yet, none of these suggestions is backed up by conventionally adequate experimental evidence, so what right do I have to expect any of them to be taken seriously?

By now it will be obvious that I claim some justification through the self-consistency they offer. Moreover this *internal coherence* applies at two levels:

Firstly *for each individual system-type*, the innovation seems to offer a plausible explanation for that system; taken more-or-less in isolation. Thus (prompted by the rows in table 9-A):

(1) Scientific method as now seen by philosophy.

(2) Piaget's ideas, our starting point.

(3) Molecular embodiment of the "scheme" — implicit in Piaget (1967), but also in the info-tech requirements for any system with advanced human mental properties.

(4) Recapitulates an argument of the 1870s concerning under-water telegraph cables.[131]

(5) Society as its own knowledge-system (to some extent), a notion arising here from the analogies of chapter 4. It also reflects that faceless irrationality of bureaucratic systems, which we may deplore though the facelessness clearly exists anyhow.

(6) *Theory B* too has some appeal as offering explanations for the otherwise inexplicable.

[130] *I.e.* epistemologists, following through from the doubts of David Hume in the 1700s (and Plato and Descartes before him).

[131] Heaviside (1892), Nahin (1988), and Yavetz (1995).

Table 9-A: Innovations offered, and Old theories retained.

Area of Study	Innovations *OK?*	Old assumptions *X*	NOT challenged *OK*
1. Scientific Method; Criterion for judging a theory	coherence testing: external *and internal*	external only: (experiment or seeing, only)	value of experiment kept, (but now just part)
2. Piaget's Psychology ("scheme" etc.)	physical/molecular embodiment as mechanisms	entities incurably abstract (Freud's still are!)	existing theory, (but now more understandable)
3. Memory elements (for advanced human thought)	RNA-like molecules, (Piaget's *scheme*)	synapses *&/OR* dictionary-words underlie all thought	need synapses for: pattern-recognition, fine-tuning, etc.
4. Nerve's *Second* signal-model for molec.-interface	Infra-Red fibre-optics in myelin (as coaxial cable)	*"no such thing!"*	action-potentials (millisecond blips) still essential
5. Status of Society (with members, & using words)	epistemological system in its own right — *partly!*	just the "sum" of its members	some rule of reason and autonomy; (but less than we think!)
THEORY B: Control of Cell geometry,	optical interference (IR), may be an important factor.	purely chemical	chemistry still an important ingredient

There is some variation in the local coherence of these different accounts, and we may notice differing qualities in any rival accounts for each. On balance though, we can see each of the innovations as having some plausibility in its own right. But of course plausibility is not the same thing as proof.

Secondly there is the mutual support that each of these suggestions makes to the whole ensemble, offering explanations for many of those irritating little logistical details which arise when we look deeply into a new proposal like "(2)" above. In so far as the logistics are now accounted for, that does add power to the (2)-proposal; but it also lends credence reciprocally back to the other suggestions. After all, the total ensemble now presents a reasonably coherent approximation to a "whole" system.[132]

This is perhaps as far as one can reasonably go using internal coherence alone, apart from re-working the rigour of the case already put. Meanwhile it is arguably a suitable time for experimentalists to consider the above points, and then move on to testing some of them in the laboratory, where possible.

Finally let us not forget that *we cannot see atoms either*; yet few today would doubt their existence, despite some serious misgivings in the 1890s. Given enough plausible theory, and observable phenomena which cohere with that theory, we can end up picturing the atoms for ourselves and almost forget that real observation is actually beyond our powers in this case.

[132] Of course this is only an outline of a "whole" system, with the *main* theoretical obstacles apparently sorted out, but with many of the more trivial details left unexamined. Some of these details will be discussed in later works.

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9.2 Soul?

"Mechanisms are soulless!" — Certainly that is true of ordinary mechanisms. But we have seen how special systems with an escalating *orderly complexity*[133] can become more like humans in their behaviour, and for reasons which make coherent sense. So maybe we will eventually be able to explain soul in these terms.

But are we all agreed on what we mean by the word "soul"? Usually its meaning seems to have two main components: *personality* and *immortality*:

Unfortunately I cannot hold out much hope of the present system fitting in coherently with **immortality**. Nearly everything in this ephemeral 3D world will ultimately wither and die; so *if* a soul is to be eternal, it seems likely that it must reside elsewhere — perhaps in some hidden space (with 4th, 5th and 6th spacial dimensions) or some even stranger occult domain. I can offer no suggestions myself on how that might be explained; but for those who might like to try, the discussion in appendix C may be useful for identifying some of the issues.

However, if we are prepared to accept Jill's soul as being merely *mortal*, and as meaning much the same as her **personality**, then I suggest we do have a sporting chance of explaining its general principles in *micro*-mechanical terms (though never the full individualized details). Such an explanation is beyond the scope of this present book, though the personality issue should emerge again later in the project. Meanwhile it must suffice to suggest that one of its key components is likely to be the notion of *self-concept* or *self-identity* — seeing oneself as an object among other objects, *and yet* having very special emotional forces and pleasure-pain features, plus exceptional powers when it comes to possible wish-fulfilment.

This discussion of soul and personality leads to another question: *the **respect for persons***. I would like to think that we would all have respect for our fellow humans regardless of whether or not their souls are immortal, or how these souls might be structured. Thus I would like to think that we would all be kind to Fred while he is alive, and that we will not then feel that it was all a waste of effort once he has died, even if we believe that his soul died with him.

(In contrast, I might well feel that my effort *had* been wasted if I had re-decorated my house just before some new owner demolished it. But then we might agree that my house did not have a soul at all, neither mortal nor immortal — so it could not, in itself, get any psychological benefit from such "kindness").

We could ask, quite bluntly: "*What is our motive for kindness and respect for others?*" (i) This could be blatantly selfish (even if we do not admit it), to buy favour or approval from Fred later on — and perhaps for eternity if we believe his soul is immortal, in whatever form that immortality might take. In this case it does seem important to clarify the immortality question, as it amounts to a question of whether or not one's moral debts-or-credits are cancelled when Fred dies.

Alternatively (ii) our motive may be altruistic — perhaps "pure" altruism, but also even if our altruism actually expresses our personal psychological reward of feeling good from being kind. In either case, it seems that immortality need not enter the argument. In either case, kindness *is* its own reward, or *provides* its own reward — and does so at the time that it seems that it will cause happiness, with no obvious reference to future times after the death of the recipients. So in these altruistic cases, does it really make any difference whether Fred's soul is immortal or not? Surely he is worthy of respect and kindness in either case? His joy and pain are real enough to him while he is alive and conscious, no matter what the metaphysical nature of his being may be.

---

[133] This orderly complexity consists mainly of
(i) the hierarchical organization made explicit by Ashby in the 1950s, and discussed here in chapter 8; and
(ii) the profligate but orderly use of trial-and-error as a solution to many design problems.

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APPENDIX A: SCIENCE STUDYING ITS OWN METHODOLOGY: A SELF-REFERENCE PROBLEM

In this whole discussion we look at science and its learning process in two different ways, and that may well cause some confusion unless we are clear about this issue. We are looking at it as *a subject of study*, but we are also *applying it as if it were a ready-made tool!* If you are happy to accept this dual role, then there is perhaps no need to read the rest of this note.

However you may see something fishy or 'circular' in this. After all it does seem a bit like a brain-surgeon using her own brain to direct her activity while she operates on that same brain. Such chancy procedures are probably best avoided if possible, *e.g.* by using a second surgeon; but such divisions of role are not always possible. In particular if we are aiming at a *unified* science, we cannot exempt science's own activities from such scrutiny even though we are using them ourselves at the same time. Twentieth century science tried to achieve this 'objectivity' by separating the two roles, and like other forms of modernism it adopted certain tacit assumptions about how to proceed; but these assumptions were exempted from their own criteria of scrutiny, and so they lacked the reliability they were supposed to have. Distasteful though it may be, if we are really seeking after comprehensive truth, we ultimately have to find some way of coping without those 'authorities' or fixed assumptions, and the present discussion might be some help in this regard.

Postmodernists readily abandon the old authorities and assumptions, but they seem disturbingly ready to accept any new set of assumptions which seem expedient or coherent *within some limited context*. This may well be appropriate for social-cohesion purposes within a given culture; but wherever we are seeking a *unified* science, we will surely need to do better than that.

Any *supposedly general* solutions should surely, by definition, apply *generally* — so exceptions and anomalies deserve special attention until they too are accounted for within some *general* system (perhaps newly modified for the purpose). This may mean we have to accept some 'circularity' in our arguments; and often we will have to tolerate several rival general-theories, at least for the time being. If so, then so be it. Modernism had the worthy aim of transcending such limitations; but unfortunately its recipe was based on an illusion, and so doomed to ultimate failure in any search for *general* solutions.

APPENDIX B: "CAN WE MODEL QUALITIES LIKE *INTUITION*?"

A question from the audience (June 1996)

Q_1: Using the theory, would it be possible to simulate such things as *intuition*?

A_1: That depends on whether you mean that as a literal computer model, or simply a generalized descriptive "in principle" solution. Thus:

- As a practical-and-complete computer model? — No, probably not. There is the practical difficulty of complexity. Even if you simply take the current view of brain-cell connections, you are looking at perhaps 10^{13} synaptic-switch units; but if you then shift focus down to molecular level, you will magnify this number by many more orders of magnitude. The limiting problem would then be just how to fit all this onto a suitable computer system.

- As an *in-principle* descriptive problem though: Yes, in fact I've had a go at it myself.

PS_1: (an afterthought): On the specific issue of intuition itself, it might have been useful to comment that

(i) its *inherited component* is particularly easy to explain if we adopt the extended-Piagetian model in question; and

(ii) our intuitive judgements probably draw heavily on coherence-testing procedures (amongst others) — and that puts the knowledge-capturing procedures of the individual and society both on the same footing: The individual using coherence-testing (or "equilibration" to use Piaget's term) to intuit plausible solutions, and society using its own separate *institutional* coherence-testing as one means to evaluate new ideas and scientific theories.

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APPENDIX C:
THE ECCLES VIEW OF SUPERNATURAL INFLUENCE AT SYNAPSES

Another question from the audience.(June 1996)

Q$_2$: Had I read the book by Popper and Eccles (1977) ? And don't they have something to offer?

A$_2$: Eccles (1986, 1990) has the view that the neural synapse offers an interface between the physical brain and the supernaturally-situated *non-physical* mind. Taking this suggestion seriously, on a "what if" basis[134], we need to consider the possible nature of this hypothetical super-natural domain. Are we to contemplate the possibility that there is *structure* (in some sense) within this supernatural sub-world outside our own physical space and time? Supernaturalists may differ on this question, but I would put it to you that there must be some such substructure (however bizarre) if it is to have any relevance to science. — Please dispute this if you wish.

I do not rule out Eccles' suggestion on any *a priori* grounds; but if he is to make a scientifically credible case, I think he has to suggest — at least in principle — how information in our physical world might pass across his postulated interface in a two-way interaction with the structure in his supernatural mind-world. I do not believe he has done that yet,[135] but I would be happy to consider any such detailed proposal.

PS$_2$: It might be of relevance to look at the following table which I prepared for a now-discarded draft for the introduction to *Book B* — (a draft which *then* included a tediously exhaustive consideration of all conceivable inter-faces between the domains[e] in the table; but perhaps the table will largely speak for itself):

Table C-A: Interfaces between Three Conceivable Mental Domains (and with the environment)

		Signals FROM			
		Environment "outside"	Axon-Synaptic domain	RNA-like domain	Supernatural domain
INTO	Environ-ment	EE Nature's laws:	AE *Muscles, glands*	RE nil? (quantum action?)	SE ???x
INTO	Axon-synaptic	EA *Sense-Organs*	AA *m.sec. "Spikes" + synapses*	RA **Synchronized quanta?**	SA ???*
INTO	≈RNA domain	ER nil? (quantum sense?)	AR **Selects! during trial-&-error**	RR **Photon/phonon/ electron patterns?**	SR ???!
INTO	Super-natural!	ES ???x	AS ???*	RS ???!	SS ???

[134] I do not happen to believe this account myself, but it is clearly important to keep an open mind on such matters when considering them philosophically. For one thing, such a discussion can sometimes be helpful in unexpected ways; or it may lead to a useful *reductio ad absurdum*. Moreover many people *do* take such supernatural suggestions seriously (as this questioner illustrates), and they do so for defensible reasons given some unresolved problems with the other accounts. So this proposal merits serious discussion, no matter whether it is ultimately right or not.

[135] He *has* answered some objections; but his account still seems to lack the structural suggestions which I believe it needs to make it viable.

The Eccles-type interface would correspond to the [A-S] and [S-A] entries in the table, representing (respectively and hypothetically) input and output for the supernatural domain. But clearly I am more personally interested in the [A-R], [R-A] and [R-R][136] entries, in accordance with the extended Piagetian model ("*Theory X*"). See table C-A.

In effect this table says:

(a) I cannot yet see any role for the supposed Supernatural domain, but I am still ready to listen.

(b) I suggest that interesting things are happening within the "RNA-like" domain; but

(c) This R domain probably has no direct interface to the Environment outside,[137] so it must always operate through the traditional Axon-synaptic system, which is what many see as *the* physical brain.

So maybe the "R" domain fulfils the role often attributed to "S". Neither is normally visible, both seem mysterious and hence are easily thought of as non-material. "R" is actually material, but being on a very different scale of magnitude it can almost be said to lie in a *different* 3D space[138] — not entirely unlike one view of a supernatural mind-space — nor entirely removed from the medieval idea of heaven as a physically inaccessible space "*way up there beyond that crystal sphere which carries the stars*".

[136] The four domains discussed here [A,S,R,E], have some connection with the domains (A,B,C,D) discussed in connection with figure 5:5. The relevant equivalents are listed in the accompanying footnote 66, page 34.
There is also some connection here with the mathematical concepts of domain and codomain, expressing the two-way equivalence between a something like [E], and its "map" expressed within another domain such as [R]. However, the mathematical model is more of a passive (Lamarckian) equivalence, whereas the system discussed here is clearly seen as having an active (Darwinian) nature.

[137] *If there is* any such direct [E↔R] interface, it would probably be very limited and inefficient in its signal-transmission, at least in many-celled animals like ourselves. If there is any such effect at all, it might possibly be able to produce slight statistical effects, and these *could possibly tally* with some of the controversial claims in favour of ESP (Extra-Sensory Perception). But such freak results, if they genuinely exist, might well be seen as "exceptions which prove the rule" because any such psychic powers would be so marginal to most of our mental life; and, at best, they would be unreliable and ambiguous.
For single-celled animals, the situation would have to be different. By definition, they could not possibly possess a neural network [A], so they would have to use a more direct interface [E↔R] between their environment and any memory molecules they might possess. In their case, the interface *is* feasible because (i) their communicational needs would be very much simpler, and (ii) they have a close physical contact with their environment. These thoughts raise some interesting questions about the evolution of the neural net system [A], thus: at what stage of development did [A] become necessary, and was that innovation primarily a response to the need for an indirect interface?

[138] a point made by Rasmussen (1996): Thus it is often difficult to see anything in common between an electron micrograph and an ordinary microscopic image of the same thing, unless one also provides a series of intermediately-scaled images so we can picture the transition.

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APPENDIX D: LOGISTICIANS AND THEIR KANTIAN ASSUMPTION THAT OBJECT CONCEPTS ARE MOST BASIC

I am not aware of logisticians making any formal pronouncement on this assumption that "*object concepts are basic*". But it seems to be implicit in their illustrative examples.

Thus suppose we take Whitehead and Russell (1910, vol 1, up to page 78) for instance, and focus on *what elements* they discuss (without being unduly side-tracked by the discussion itself). What *nouns* do we find *which denote-elements*? And how should we categorize them? I suggest the following as a rough guide to that text:

1. Nouns for fairly definite objects:	whale, sun, North Pole, London.
2. Nouns for specific people	Socrates, Napoleon, Dr.Cook, Commander Perry, Newton, Scott [*i.e.* Sir Walter Scott].
3. Nouns for definite part-objects	legs, feathers; (their page 24).
4. Nouns involving abstraction (for various reasons)	Mr A, one, number, "classes", "relations" — hemlock — philosopher, man, General, Apostle, King of France — "Waverley" [the book by Scott]
5. For action on object-symbols	{propositional functions} (their page 41).

We might quibble over the detail, but my point is their naiveté regarding basic elements:
• that none of these entity-*ideas* seem to be any more elementary than the object-concepts, (cases 1, 2 — *and even 3*, where legs and feathers are *conceptually still "objects"-in-the-mind*, no matter what their real-world counterparts may be);
• that the abstractions in "4" are *more* complex;
• that even any actions or functions (like "5") are also complex.

In contrast, the Piagetian idea is that there are action-elements which *are* lower down the hierarchy than the "basic object-concepts" themselves — and indeed they serve to *construct* our concepts of these objects. As this new postulate was made public only *after* Whitehead and Russell had published the text (of 1910) which I have just dissected, it is hardly surprising that this 1910 account says nothing about such innovations. *However most logic texts continue this omission unquestioningly*.

For *formalist* logicians, the issue presumably does not arise, since in any case they simply disdain any supposed connection between their systems and the real world outside it.

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(Errata in the first printing were mainly in this index:
Page 98 references were listed as "82", and the page 99 references were ignored altogether!)

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END NOTES

[a] In contrast to this *internal* coherence test, we should remember that the officially-favoured approach is still the "experimental method", and that amounts to tests of *external* coherence. In fact *both* are crucially important, but we can manage without either one for a while, as long as we do not forget to return to it. Right now it seems to be the turn for internal closure to come back into the spotlight. — After all, external closure has dominated science for most of the twentieth century.[b] However a *warning* is called for here:

If we seek truth rather than mere convenience, the basic logical elements of our internal coherence reasoning do need to be well defined and stable (see chapter 5). The less reliable these elements are, the more dubious our conclusions will be. *In particular such conclusions can never be any better than a mere suggested guide* ***in the social sciences*** (even if we have no better choice available!), and any prolonged attempt to overvalue such supposedly-eternal elements or laws in social policy-making will probably end in disaster, if only because social conditions keep changing and sociological "definitions" must always be somewhat vague. Many modern social catastrophes stem from this. Little wonder then that scientists have often rejected internal coherence tests. Nevertheless such tests do have a definite and *indispensable* place, especially in the micro-sciences, and especially if we understand how these tests should be applied.

(*From*: Footnote 4, p. 3; Chapter 1, p. 3; Chapter 2, p. 10; Footnote 101, p. 54).

[b] Back in the seventeenth century the imbalance had been the other way. Sir Francis Bacon "the father of modern scientific experimental method", was nevertheless well aware of the need for balance, and cautioned against letting the pendulum swing too far the other way. Alas for the caution — the pendulum did eventually swing too far the other way despite him. (Bacon, 1620/1960). (From previous endnote, a).

[c] Some of the credit *may* also be due to Vygotsky. He and Piaget were both born in 1896, and they were in contact academically. However Vygotsky died young, in 1934 (apparently of natural causes), and then his work was suppressed by Stalin. Most of his work remained untranslated, at least until recently, and I am personally not well acquainted with it. (I suspect though, that their common ground was more at the level of class-room application, and not so much on the fundamental theory considered here). (Chapter 2, p. 11).

[d] The details are not strictly relevant here, but in case you are interested: Heaviside's prescription was that we should ensure $R/L = K/C$ — and in practice this usually amounted to suggesting a considerable increase in L. That suggestion met with considerable scepticism. Indeed the powerful bureaucrat Mr William Preece (his arch enemy and former boss) dismissed the idea as absurd, and used his influence to have Heaviside's publications banned for some time, until wiser council eventually prevailed. See Yavetz (1995) and Heaviside (1887); while Baker (1976) gives an account sympathetic to Preece.

Alas for justice. When the formula was eventually taken seriously, one of Heaviside's "supporters" (Prof. Pupin, of the USA) then took out a patent in his own name, and made a fortune out of it. Heaviside did get some belated recognition (and another enemy), but not much more. (Chapter 3, p. 20).

[e] The word 'domain' is used here as roughly corresponding to its mathematical meaning — where domain and codomain *map* to each other, so that an item on one will correspond to an item on the other. (E.g. when $y = x^2$, then 12 in the x domain maps onto 144 in the y domain.) The main difference is that the mathematical relationship is seen as passive and imposed by human instruction (Lamarckian algorithms), whereas the learning systems are viewed here as ultimately constructing their correspondences by an active Darwinian process.

I find it convenient to restrict the word "domain" to those map-areas listed as (A,B,C,D) or [E,A,R,S] — *see* "domain" in the index — when used singly and alone. For any other cases, or for looser talk on such matters, I choose to use the word "realm" instead. (Chapter 5, p. 34; Chapter 8, p. 61; Appendix C, p. 76).

[f] The study of this sort of message-bearing dynamic system used to be called "*cybernetics*" (e.g. see Ashby, 1956), though that term has since been usurped by the popular press, and made to refer to futuristic robotics. A common definition of the term used to be: (a) "*the science of information and control*", though some might have preferred (b) "*the study of self-organizing systems*".

My own preference was something like this: (c) "…*whatever it is about complex dynamic systems which accounts for how they maintain their coherence and identity*" — and in practice that usually boils down to invoking *coordination through information-flow.* That almost takes us back to definition (a), but there is a significantly change in one word: (a) speaks of "control", while (c) refers instead to "coordination".

CONTROL seems to imply some *authoritarian* operator or designer, even if it is only the local control of one part of a mechanism dictating to another. — In the 1960s, cyberneticians themselves would have seen this in the context of mutual feedback loops and interaction effects; and the result would then tend to measure up, after all, to the intended democratic *self-organization* of the "(b)" wording. Unfortunately lay readers would often not appreciate the power of such networks, and presumably that is where the popular "cyber-robotics" notions came from — seeing only the one-way feudal possibilities.

COORDINATION *does* imply self-organization. (Chapter 7, p. 46).

[g] It may be of interest to know that the myelin is supplied from the outgrowth of a neighbouring cell (as also mentioned on page 51). This outgrowth first wraps around the axon and continues in a tight spiral of "wrapping paper", being fed still from the outside cell. However these details probably do not affect our argument because whichever direction the growth happened to take (inward or outward), the same "*invisibility of the far side*" would still hamper any pure-chemistry mechanism from gauging the current thickness. (Chapter 7, p. 47).

[h] A mathematical *set* is some collection of items. Its membership can be defined in different ways, with different practical applications and requirements. Thus: "*Intensively defined*" means defined by some common property, or combination of properties. "*Extensively defined*" means defined by some physical constraint — telephones are "tethered" to a particular network — things in my room are "bounded" by four specific walls — and the steel plates of a ship's hull are each "linked" to several other members of the same set (and hence to all members indirectly, if we allow other members to act as go-betweens). "Range-bounded" sets will figure significantly later in this project. Briefly, they include items which happen to lie between two different radius-distances of some signal source — *i.e.* within an annulus (2D) or a spherical shell (3D). (Chapter 8, p. 58).

[i] If we do *not* agree that minds are part of physical nature, then I can see two scenarios:
• **Unstructured-occult** view: occult views of nature that the mind is supernatural-or-vitalistic, and *unstructured*. The lack of structure would seem to place it outside the province of science, so I would probably have to agree to disagree with any proponents of this view.
• **Structured-occult** view: that the mind is supernatural-or-vitalistic, *but now having structure* which obeys its own rules in some perhaps-bizarre "other world" — but rules nevertheless. In extreme cases then, this will mean that the basic structural entities in the two domains might bear no resemblance to each other, but those in the mental-domain will presumably still be capable of constructing models of the "real" structures — somehow! (Chapter 8, p. 58).

[j] In our speech, thinking, and maths, we inevitably manipulate *symbols* rather than the objects-or-whatever that they refer to. In a discussion like the present one, we are considering both the objects and their symbols separately (and then maybe giving a new symbol, to each!) — so there is ample scope for carelessly slipping from one to the other by mistake. I shall *try* to avoid that error, though I think my main point will be clear despite any such slips.
(Chapter 8, p. 59).

[k] Autocrats may have a problem here over inevitably-limited channel capacity, and this will usually diminish their actual power to less than what it appears to be. (A.S.Beer, *Massey Lectures*: 1974). (Chapter 8, p. 60).

[l] We might perhaps debate whether human recursion is really potentially unbounded within our own mind/brains. (Maybe we can only achieve the highest levels through mathematical tools which we have invented, and maybe we should count them as part of a *social* intelligence which transcends the individual. Maybe.) But in any case, the human mind seems to involve a *tall* hierarchical pyramid; and no other animals seem able to match this feat — even if this feat still falls short of being "potentially unbounded". (Chapter 8, p. 60).

[m] An individual has many different abilities, and these may often have some degree of independence from the others during development. So one ability-type might be much more advanced than another at any instant — at least in principle — and clearly that does happen to some extent. However there are likely to be two influences tending to keep developmental stages in step across the various abilities. Firstly there will surely be some interdependence in most cases, so innovations in one ability will probably affect other abilities — a *cross-connection effect*. Then secondly it seems that evolution has left us with a genetically programmed series of special-abilities for learning — abilities which arise at different ages, and which tend to facilitate (but not actually cause) the stage usually predominating at that age. We may see that as a *maturation effect*.

We may reasonably expect to balance these two trends. At any rate, in practice, an individual's *overall developmental*-stage seems reasonably clearcut, but with definite blurring of the boundaries, and with the sort of inconsistency and ambiguity we might expect from statistical population-based phenomena which are not fully in step.

Incidentally, in so far as age-based maturational factors *are* involved here, I see that as evidence that the lower levels of the hierarchy *may* have a separate physical embodiment, and that perhaps only the higher levels develop the ability of (mathematical-like) recursion. That might well be consistent with the difference between humans and other animals. Maybe the non-humans have the first system but little-or-none of the second system. (And of course there might be *even more than two* physically different systems for different M^nL levels). (Chapter 8, p. 61).

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