Mechanisms of Human intelligence — From RNA and Synapse to Broadband

Abstract

Simple thought has been explained by the action-potential (AP) system with its synapses. In contrast, in-depth details for “*Declarative*” intellectual thought have been a complete mystery because (it is argued here) its main underlying mechanism is fundamentally different. Declarative thinking depends heavily on linear coding based on digit-like elements — something which an unaided AP system could never offer.

Looking instead to psychology, Piaget (1920s) proposed basic units of *action-sequences* (“*schémes*” whereby one could mentally construct object-concepts). There is now evidence that some ncRNA serves this *verb-like* action-coding role. — (Other ncRNA demonstrably serves as *adjectival/adverbial* “regulators” — while the remaining ≈3% of RNA encodes physical structures, the traditional *noun-like* role). If valid, then:—

•NEW FOCUS ONTO ULTRAMICRO: — The whole Piagetian structure-coding for a *concept* could fit into one of the many 125nm *capsids* (“granules”). Moreover, many more concepts (and duplicates) could fit into a *cell-body*. — The vast abundance of coding-sites would allow comprehensive “wasteful” rapid use of Jerneian/Darwinian selection instead of problematic “writing down” of new learnings. — Estimates of memory-capacity increase vastly. — And hereditary-schémes obviously explain inherited behaviour-traits. — Piaget’s other theory about developmental stages also seems compatible.

•Quantum-constraints ensure that such micro-sites would USE OPTICAL FREQUENCY signalling. That opens the way to greatly enhanced “Gigabit” rates, and optical-interference tricks.

•MYELIN gets the EXTRA ROLE OF OPTIC-CABLE. So nerve-fibres become seen as simultaneous paths for *two different types* of signal (also demonstrated by Sun-et-al, 2010), with AP still dominant in some roles, but subservient to “UPE” optical signals elsewhere.

•LOCATING MEMORIES? Choosing the right address means selecting some sort of “phone-number or numbered plug-socket.” That is best provided as an “address-label” sequence on the transmitted version of the schéma-coding — in which case, actual destination-location may be less important.

•“Moving-house” TO CORTICAL LONG-TERM MEMORY. The memory-move must preserve existing (i) memory-structure, and (ii) links to distant static archives.

This “impossible” task would seem feasible if memories are actually held within individual cells (as above). There is indeed lifelong flow of such neurons in some mammals; but these flows seem to cease in adulthood for humans and dolphins! So the search continues.

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For some time there has been an impasse on the details of mind/brain activity:

“... we seldom know what operation each [brain-]region is performing ... and in some instances we do not have even the faintest idea of what is going on.” — Crick (1979)¹³

Forty years later we still hear similar frustration from: Fuster & Bressler(2012)²⁰, Gallistel & Balsam(2014)²², Koch & Marcus(2014)⁴⁰, Trettenbrein (2016)⁹⁵, Horgan (2016)³², Brette (2017)⁶; — and even from Mattick’s team^{49, 17} although their ncRNA comments offer some hope as we shall see.

Some have gone further and doubted the legitimacy of such reductionist attempts altogether^{3,75}. But note that this all assumes that the all-powerful underlying mechanism entails synapses and action-potentials (APs) as the only significant material bases — and it is convenient to refer to this setup as the “AP” or “[A]” system.

Meanwhile, even alternative thoughts about “Computer intelligence” can be misleading. E.g. the computer does not have to attend to most of those “boring chores” like maintenance that beset a real-life system. So maybe it is time for a different (but bio-compatible) approach:

1. Seeking new brain-principles

Neuroscience has advanced notably in such areas as connectivity and related methodology (and details of simple “nondeclarative” nervous systems like that of *Aplysia*⁷⁹), but it has offered almost nothing coherent about detailed sub-mechanisms which might underlie human declarative thought.⁷⁵

Neurophysiologists seem to go as far as they can, given the apparent impossibility of studying any *Thought-X* at its most basic coding level — i.e. impossible using microscopes or known imaging techniques, especially as it has not been clear just what to look for at that level. Thus their progress has mostly been somewhat more macro in its scope (e.g. Squire & Kandel⁷⁹, Chs.4-6) — which clearly has its uses, but leaves us with the proverbial “Black Boxes” whose overt behaviour-patterns (and some chemistry) become known, but leave us largely ignorant about what *basic systematic internal mechanisms* cause that behaviour. And that seems to accord with the complaints from Professor Rose⁷⁵ and others.

Such an impasse might thus induce us to search elsewhere for an alternative approach. E.g. change our focus from trying to *observe* direct causes, and instead (i) *note* their detailed results, (ii) gather

comprehensive clues about *possibilities* for their mechanism-construction, and (iii) seek to **reverse-engineer** such bio-feasible mechanisms to explain those Advanced Thinking-Behaviour patterns.

However reverse-engineering can only work well if the key putative components are reasonably well-defined — having a *manageable* number of degrees-of-freedom. (E.g. Mendel’s *restrictive* gene-concept allowed genetics to develop). The trouble may be that our observations are not obviously reducible to those essential “well-defined” sub-components. And yet...

The potential breakthrough came in the 1920s with Piaget’s concept of the “schème” — a hypothetical basic *element of action (or its material encoding)*. Individually, each such schème *was* potentially well-defined (perhaps an RNA-like molecule), even if we could not measure its “well-defined” properties directly. More details below, but the point here is that this construct did-and-does allow for plausible model building — with Mendel, Mendelev, Bohr (*and* fictional detectives) as forerunners in that constructive art.

As long as such basic elements remain credible, or are replaced by other similar elements, then there is indeed a reasonable chance of making progress through this backdoor route. However experience has shown that the task is likely to call upon evidence from a considerable number of interdisciplinary sources — and a concerted effort to integrate their various findings.

Here such needed disciplines have included:

- Developmental-Psychology, • Epistemology (Knowledge-Theory), • General-Biology — these being Piaget’s own three specialities.

Then • Physics (especially optics, cable-theory, and the history of their developments), • Orthodox-Neurophysiology (especially synapses), • RNA and related issues; — plus • Neuro-anatomy, and • Telecommunications-theory.

Studied in isolation, many of these specialities have made their own vain attempts at the mind/brain problem, but the prospects improve if their insights are instead applied collectively. Here, these contributions will largely be introduced individually, but that discussion will make better sense if we first “cheat” — and look at the “answers at the back of the book” to see where the collective argument is going. So here is a preview outline of the earlier conclusions — some of them surprising:

(1) That there are TWO simultaneous modes of fast transmission in myelinated nerve-fibres; the extra one involving low-intensity photon-beams of

infra-red (IR) &/or some rainbow-colours — using myelin as a coaxial cable; (first discussed as a biological *high-frequency-circuit* possibility in Part B of⁸⁸, and in⁸⁹.)

(2) This photon-mode (with its optical effects) probably predominates within the inner parts of the brain, while peripheral nerves are likely to mainly conform to orthodox AP-accounts.

(3) Short-term memory is composed and stored as ensembles of language-like code using ncRNA.^A

(4) The existing idea that Long-term memory is probably held as DNA is thus made more plausible.

(5) More about ncRNA: About **98%** of human RNA is *NOT* involved in protein-production.⁴⁷ Some of this “ncRNA” is explained as having a regulatory role, but much of it has been left unaccounted for. Significantly though, about 40% (of “Long” ncRNA alone) are found *only* in the brain.^{26, 7}

The conclusion here is that much of this remainder probably serves as modifiable *basic action codes*, either for random (Darwinian) action-trials, or as important inherited behavioural traits, (mannerisms which are thereby easily explained!).

(6) Such coding intercommunicates using the photon-mode — at a vastly greater “Gigabit rate” than action-potentials (AP) could ever achieve.

(7) Likewise the potential storage capacity (and systematic order) of the brain increases by several orders of magnitude — allowing the use of “wasteful” mass Darwinian trial-and-error strategies in learning (a strategy identified clinically by Piaget, and noted separately by Jerne in 1955 regarding *immunological* knowledge-acquisition,^{34, 8, 9, 35}).

(8) Meanwhile synapses and APs clearly still have a number of roles — perhaps tentatively best summarised as often relating more to 2D and 3D phenomena, including • *path-optimisation* and • *pattern-recognition*, • *primitive “non-declarative”* mechanisms as in Aplysia; — and obviously • direct interfacing with the outside 3D-world via the peripheral *sensory and motor* nerves.

(Such 2D/3D tasks contrast with the more 1D nature for much of logical thought, and its supposed basic encodings. — Moreover our full processing of visual images seems to require *both* approaches, usually simultaneously: The more active 1D-based tactics of Piaget/Pylyshyn, *plus* the more passive-and-holist 2D/3D account of Kosslyn/Bókkon);⁹⁴ — and see footnote “G” on page 6 below.

(9) Whatever the basic coding method (RNA or synapses, or any other less-than-perfect units),

effective memory will usually need to be held collectively by a coordinated “choir” of such basic units (to avoid any untoward individual fluctuations^B). — And note that it would be much easier to achieve any such sophisticated choir-*coordination* using RNA units than by attempting it with Hebbian²⁹ synapses within the AP system.

§6 will then describe attempts to apply these apparent insights in explanations of mechanisms for storage and retrieval, plus (§7) the conversions of memory, thus:— immediate memory (imM) → working memory (wkM), and then → Long-Term (LTM).

Meanwhile:—

2. The Suggested Photon-Mode (added to AP)

The idea comes historically from two independent sources:

- A logical consequence of Piaget’s “schème” concept and the RNA-interpretation of it, introduced above and discussed below; and:

- A consequence of the work on “Ultra-weak Photon Emissions” (UPE)s^{10, 11, 92 (§#C)} started by Gurwitsch in 1924^{24, 25} — But note that such UPE-radiation is a general phenomenon found in *all* living matter,⁹⁶ so its mere presence need not necessarily relate to neural-transmission as such. Or, to put it another way: Might we expect that UPE communication evolved first, with nervous systems later arising as an “add-on” facilitation? After all, *plants* figure significantly in the history of UPE studies — and APs have not always had their clearcut millisecond “spike”, which had to evolve from less effective chain reactions.^{5, 88(ch.B5)}

Anyhow it was this latter context which inspired the immediately-following important investigation:—

2.1 New Evidence for this Double-Effect

Sun et al (2010)⁸⁰ applied optical stimulation at one end of rat spinal nerves, and measured autographic optical responses^C at the far end. Such signals seem to have been normally transmitted by *both* the traditional APs *and* by photons. When *both* were suppressed, the signal stopped; but transmission continued when only one of these two

^A ncRNA is “Non-Coding” for protein production, but that leaves it free to code for other tasks. See Mattick (2001)^{44 ff}.

^B “Choir” is perhaps also needed to produce an approximate-laser effect, through well-coordinated photon-emissions.

^C Seen via the well-known photographers’ use of photon-detection by the effect on silver nitrate (AgNO₃) in close contact.

modes was suppressed^D — which implies that the two modes *are alternatives* at least within spinal nerves. — A sort of “Plan B” arrangement.

That does indeed seem to justify the key claim for a two-fold mechanism, and that is encouraging for the UPE case; but we will see that it overlooks some features that the Piagetian/RNA interpretation would require for a more thorough picture:

Firstly the study *did not tackle deep-brain communication* where photon transmission is a crucial part of the argument.

(Indeed, as one might expect, the Sun-*et-al* experiment focussed only on nerves outside the brain-proper. Hence its success showed only that photon transmission was feasible *in some nerves*, which is helpful; but even if it had failed to find photon-effects in this PNS context, there would still be room for suspecting the effect *deep* in the brain — consistent with the account offered here).

Secondly it made *no mention of cable theory* (see below) which might have carried the input signal by uninterrupted transmission, and deposited it at the detection end (intact, apart from any transverse effects if the nerve-fibre cable were too wide, see footnote “U” below). Instead they postulated a chain of photochemical reactions between quasi-neighbouring cells, with successive regeneration of new photons.

Thirdly it seems almost incidental here that their *initial stimulation* was optical. The use of six different input wavelengths/colours evidently made no significant difference, so maybe other types of stimulus could have had the same effect, especially if any sort of relay is involved initially. However that does not upset their case, provided that the EM (electromagnetic) part of the signal does promptly become transmitted photons.

As a further comment: If this had been a fibre from the inner brain we might be left wondering whether the photon-radiation might be carrying sophisticated messages (not just *present-vs-absent*) — in the way that such radio-like transmissions are theoretically able to do. With that in mind, let us start with some new distinctions:—

2.2 Grades of Radiation-Signal

Déjà vue! — During the 1800s, ideas about the electro-magnetic transmission of messages went through a whole series of increasingly sophisticated steps; and it now looks as though our claimed-

understanding of brain signalling could be passing through similar stages (but at a vastly smaller size-scale) — rather like the following sequence:

(a) Simple on/off switches-or-alarms, perhaps responding to thresholds. Cf. AP and Hebb (1949)²⁹

(b) Loose bundles of such wires, e.g. each lighting-up a letter of the alphabet in sequence. Useful but cumbersome. — Or tight *well-organised* bundles conveying 2D image-pixels; e.g. Retina-to-Occipital-Lobe, (though with some processing *en route*).

(c) Morse code on single telegraph-lines. No clear brain equivalent despite some focussed searches.

(d) Thick cladding to cope with under-water capacitance for trans-Atlantic cables at low transmission rates. Wm.Thomson (Lord Kelvin)⁸³ — Myelin maybe evolved initially for similar reasons, though with AP beneficial-complications?

(e) Improved design of cable geometry and components to cope with *HIGH FREQUENCY* and much greater throughput (Heaviside, 1894)²⁸. Vertebrates acquire a new myelin-forming protein (PLP instead of P₀) which produces more compact-and-tidy myelin³⁹ — presumably producing significantly greater throughput and precision for electromagnetic signals (whereas such tidy geometry would offer very little new benefit to the accompanying APs).

(f) The incidental invention of radio (Hertz), and its commercialisation (Marconi) — as an extension of high-frequency cable transmission — allowing *wire-free* transmission, and hence vastly greater flexibility.

Likewise, possible leakage of any high-frequency *neural* signals as UPEs — either by accident, or as short-range excursions from myelin: This could allow signals some freedom at the far ends of their myelin paths if the “terrain” were suitable: (as if “walking home after getting off the bus”).

(g) Crude telephony-attempts to transcend morse-telegraphy, though with voice-distortion problems. Any bio-equivalent? No clear answer, though some speculation that some bio-systems might actually *depend on* such distortion for repeatable “format change”! See §C6.7 of ⁸⁸, especially fig.C6.7/2a added in 2006.

(h) Use of modulated carrier-waves largely fixes voice-and-picture distortion, and enables channel-separation in increasingly sophisticated ways. No information yet on any such bio-system, but it would be prudent to watch for it.

^D They used *procaine*, to stop AP-transmission &/or *2-deoxy-D-glucose* against the metabolism assumed to be behind photon regeneration.

(i) Such quasi-stable radiation enables the use of optical tricks like standing-wave patterns, GPS navigation, etc. — and it seems likely that our mysterious ability to assimilate binocular vision (with both Piaget/Pylyshyn and Kosslyn/Bókkon interpretations simultaneously: action-based *plus* pixel-based), and binaural hearing, may well depend on such tricks. But perhaps time will tell.

(j) Likewise, WiFi is a way of handling message-transmission when the intervening optical-paths are in a state of flux, and otherwise-likely to interfere with each other. Such an ability could be very useful within the brain, as we shall see in §5.5.

Note that most of these special features would not be available to any pure AP-system.

That completes the preview of signal-transmission alternatives to AP, (items (1) and (2) in §1). So now let us turn to RNA/DNA as memory-storage alternatives to any synaptic arrangements — items (3)–(7) in §1.

3. Memory, 1D-Code, and Intelligence

How do we handle thoughts? That is primarily a matter of *epistemology* (the study of knowledge: how it is acquired, stored and retrieved, in the brain *or elsewhere*).^E

Here the two most relevant epistemologists are arguably Kant (1724-1804) and Piaget (1896-1980). Unfortunately neither were particularly lucid in their prolific writings, and there are translation-and-paraphrase problems. But they still deserve close attention, emphasizing what micro-abilities a brain-like system *needs*, rather than what seems most salient.

3.1 Some important ideas from Kant

(K1) the *Schéma* — σχήμα: form/shape, (plural “schémata” or “schemas”) — an idealised^F general-

mental representation (probably inspired by Plato e.g. of a *triangle*, or a *dog* etc.: ... “always a mere product of the imagination” {Kant³⁷ p118, & see (K3) below}, “but it mustn’t be confused with an image” (Kant & Bennett; p.92)³⁸; and “without being restricted to any one particular shape.” (*ibid.*)

Piaget later developed this idea significantly, as we shall see. (Indeed any such subsequent trend toward physiological interpretation should surely be taken seriously, at least initially; and whether Piagetian or not).

(K2) *Synthetic a-priori*. Is all our knowledge learnt from scratch? (If so, then how do we *know how to learn*!?) It seems we must have some startup knowledge — some inherited-or-mystical “*a priori*” knowledge which was difficult to explain, especially before modern evolutionary and epistemological theory. Kant fudged a bit here, calling it “*synthetic a priori*”; supposedly comprising our basic axiomatic “categories” of space and time dimensions etc. Later improved by Piaget.

(K3) *Action first — before learning*. Inspired by some seemingly back-to-front Copernican logic, Kant made the important proposal that suppositions about the world *originate haphazardly in the brain*, and are *then* tested by the reality outside (rather than recorded by passive absorption); (p14).³⁷ That can allow the solving of “intractable problems” by massed trial-and-error (when there is nothing better to guide us).

The idea has its limits, but it can *now* be seen as the *ultimate default starting strategy* of all epistemological systems, viz. The ●Brain, the ●Immune system, ●Evolution of DNA across the generations, and the ●Society-as-such (as partly embodied in its scientific establishment).^{91(§8f), 90(ch.4)} To partly transcend this robust-but-tedious Kantian-(Darwinian) process requires an *intelligence-mechanism* (not necessarily conscious), and of course that is what our present study seeks to explicate. Which leads us to:

(K4) *Transcendental Schémata* — with no direct reference to outside objects or events, but instead referencing lower-level schémata (which *are* outward-looking), thus offering some extra organization (Kant³⁷, p65). — Though I may be reading more into his account than is warranted. — Anyhow that seems to offer a basis for Piaget’s well-known “Stages” theory which does seek to explain intelligence in terms of control hierarchy. See below, (plus figs (i)-(iii) on p.14 of⁸⁶).

^E I here take “knowledge” to mean any encoding of what purports to represent some part of reality. It need not be true, and it certainly need not be conscious, though it can be either or both.

^F How could a practical system (like the brain) cope with this seemingly intangible idealized *schéma-entity*? One solution could be to compromise slightly and accumulate a large-and-varied collection of relevant images-or-templates (if there is enough storage space), and use powers of interpolation etc. to assemble a generalized impression — somewhat like a successive-approximation method in maths. (Not strictly correct, but like π -evaluations, usually amenable to asymptotic improvement as far as needed.) That could actually fit quite conveniently with the apparent simultaneous need for a “choir” of similar codings — (as noted in §1 above, and §4.1 below). — Note too some similarity to our successful *interpolated approximation* between frames of a conventional movie-film, with its 24 frames per second.

3.2 Piaget's Key Ideas

Piaget seldom mentions Kant explicitly, but the connection is obvious (if only from some titles of his earlier works, e.g. on space⁶⁸, time⁶⁷ and causality⁶⁶). His main concepts are:

(JP1a) In about 1946 he made a *significant distinction* between “**schéma**” (e.g. for a *whole* conceptual object or event), and “**schème**” for elementary constituent *actions* underlying a schéma concept — a distinction not always observed by translators, nor sometimes even by Piaget himself! ^{91(p.22)}

(JP1b) Importantly he saw a schème as being an *action* and *not* an object-like entity as most people would assume.

I take his “action” to include “*encoding* for that action” though he might not have agreed. Anyhow actions in *scanning* objects like “Teddy,” (by hand &/or vision etc.) would seem easier to encode meaningfully from scratch, rather than coping with the less analyseable “photographic-pixelated” object itself.^G More-so if the child has to find ready-made *a priori* schèmes to build with — in accord with (K3) above, and (JP3) below.

(JP2) Piaget showed experimentally that Kant was wrong about his “aesthetic” schémata of *space and time* (etc.) being inborn. They are actually developed during infancy.^{66, 67, 68} Nevertheless Kant was still apparently right *in principle*, in that *the more fundamental-and-micro* constituent items — basic schèmes — were likely to be available instead, to serve as the “axiomatic” *synthetic a-priori* elements.

(JP3) Action first. Yes, Piaget certainly agreed.

(JP4) Not just one transcendental layer, but an actual control-hierarchy developed during the growth *to adult-level mental-ability*. This is the basis for Piaget's best-known theory, about the **stages** of development: — from *Sensori-motor*, to *Pre-operational*, to *Concrete operations*, to *Formal operations*; (e.g. Phillips, 1969).⁶⁵ Each level evidently has its own rank of schémata monitoring the next-lower level. (It can be convenient instead to call them “M⁰L, M¹L, M²L, M³L,” respectively; where “M¹L” = ML = Meta-Level” etc.).

Note that Ashby² designed a mechanical model on similar principles, though that was a quite independent elaboration of a thermostat-control type

of device. The two models have been compared in some detail.^{88 (ch.C1-C5)}

4. Material Bases for These Constructs

4.1 Miniaturization and a Need for Redundancy.

Note Piaget's scale-shift down from schéma to schème. This was a step toward smaller, *more mechanically describable* entities. That was arguably a step in the right direction (which worked very well in chemistry, leading to the Bohr/Schrödinger atom and an understanding of its properties.⁶⁴).

Meanwhile though, in modelling the mind/brain we need to ensure that decisions and behaviour are not usually dependent on any such *single* microstructure — because that would often lead to very odd-and-capricious changes of behaviour whenever the single encoding was revised-or-damaged. Accordingly it seems necessary to postulate a normal largish population of “redundant” closely similar encodings, forming a sort of **choir** (which must learn to act in unison, or at least in synchrony) — as introduced in §1 above.

Also, that choir-need should apply to *any* system of not-quite-reliable components, *viz.*: (i) any new RNA-based system (“[R]”); — or (ii) any Hebbian²⁹ AP-system *IF* we were to still believe in it having a role in this intellectualisation task (though it is difficult to imagine how such a choir-organisation could be managed for such AP-type systems).

Meanwhile (either way) that redundancy helps explain the role of **practice and training** leading to *skilled behaviours* — building up the membership and coordination of such “choirs.”

4.2 Some Other Guiding Principles in this Bio-Context

Although not rigid laws, there are some practical guiding principles which seem (i) to be reasonable items of common-sense (even *obvious* in retrospect); yet (ii) easily overlooked. And often (iii) of practical assistance:

(a) **DualPlus**. Biological problems often have more than one feasible solution, and these can often all be true — even simultaneously in the same species, (or at least such an alternative might be found in *some* other life form). E.g.(1): Various respiration modes; (2) The postulated use of myelin for two different signal-modes (§2 above); (3) The apparent double-process of vision processing within mammals [Footnote G] plus other forms in insects etc.

^G This *line-tracing vs pixel image* is an important DualPlus distinction (see §4.2(a) below); — here between the “conflicting” views of Pylyshyn-and-Piaget on the one hand and Kosslyn on the other, as discussed in⁹⁴ which argues that *both* mechanisms are probably necessary (and in cooperation).

4.6 A Material Embodiment for the Taton?

What bodily items offer text-like structure, with well-defined “syllables”? The only candidates seem to be DNA, RNA, PNA, and protein. PNA is too rare, protein is too lumpy (or else unhelpfully repetitious). DNA is a possibility, though perhaps too stable except for *long-term memory* (LTM). RNA seemed the best candidate by 1975⁸⁶ (ch.1, p.10) encouraged by news of Hydén’s earlier findings of RNA-changes during learning (e.g.³³).

The doctrine until 2000 was that most RNA was mRNA coding for protein, but we have just seen that protein seems unsuitable for embodying tatons. But then, what if some RNA were free from traditional mRNA tasks, and instead available for message-coding *in their own right*?

Astoundingly this availability turned out to be at least 97% true 26 years later.^{44, 45, 46, 91}

(Significantly, this extreme percentage refers specifically to humans. Bacterial data misled us.)

However there are now also established claims that many such available ncRNAs (non protein-coding) serve as “regulators” (e.g. Mattick 2018)⁴⁷, which implies competition between *two different ncRNA role-types*. Or, to look at it another way physiologically:— Maybe our thought processes are *just one type of “regulator” amongst the others!*

4.7 How does New Learning get onto Tatons?

Could this new bio-learning be like tape-recording, (occurring automatically without interpretation)? Not likely at the Sensorimotor (M⁰L) stage: — That would require the prior evolution of purpose-built recording devices and ways to maintain them.

Maybe at M^{high}L stages though:— After all, we do have human-designed (external) recording machines thanks to M³L *intelligent* thinking, but it is not at all clear whether such M³L schémata could work the same wonders within the brain itself.

In general though, such learning is likely to be heavily reliant on the same Jerneian-Darwinian-Kantian trick used in immunology (as noted earlier in §1.(7) and §3.1(K3)):— *viz.* Rapidly vet a huge number of assorted candidates, and *select* any which seem (by chance) to already encode the right message.

The method is only feasible if you have a large number of expendable candidates — and that is made possible within the (ultra-micro) RNA-coded system discussed here; where high-speed is also achievable.

The notion of the expendable random candidate corresponds to the term “*objet trouvé*” (page 24 of⁹⁰), borrowed from the art-theory of Marcel Duchamp. It also sheds new light on the concern that much of our RNA may still be “junk” (Palazzo & Lee, 2015)⁶⁰ — whereas such “junk” may be a necessary stock of raw-material (like never-used antibodies in the blood), which is otherwise harmless apart from the logistics behind its upkeep.

In any case, how can a mere observer (as yet) tell which of the brain’s ncRNA molecules is “potentially useful junk” and which is an already-ordained taton (selected *or* inherited)?

Then again, the ncRNAs surveyed⁶⁰ seem to have been all-or-mostly from *non-brain* tissue — in which case any “unsuccessful candidates” will have been “waiting in the wrong queue” and hence really will be junk presumably!

5. Linking such Candidate-parts

5.1 Assembling Taton Units into Schèmes and beyond

A strip-cartoon once depicted an office-scenario:

VISITOR: So, what filing system do you use here?

CLERK: The Biblical System

VISITOR: Oh! — What’s that?

CLERK: “Seek and ye shall find!”

For that under-organised office, it is implied that the only way to find an item is through **recognising** it by its intrinsic properties (not its category or provenance) as one arbitrarily scans the relevant domain — perhaps the proverbial “needle in a haystack”. Technically this is an “INTENSIVE DEFINITION” for that item, or for the class of all such “needles”. Such a formulation clearly has primitive validity and a (limited) practical usefulness, especially if the items are identified by clear *essential properties* (properties which endure even if the item is otherwise “lost” in amongst other randomly distributed items, or left unfiled, or even wrongly filed).

In the mind/brain context, let us take this as “specification type-**{0}**”. And note that it does also have other bio-application, especially in immunology with a particular antibody *searching just in case its matching antigen* should happen to invade the system (in which case it will promote protective measures). — In that example, identification is said to occur by a “lock-&-key” recognition-mechanism.

Alternatively we can use an EXTENSIVE DEFINITION for all those items *captured* into a group in some specified way (presumably to save us the inconvenience of *repeated* haystack-searching! —

though note that some semi-hidden use of this initial-identification {0}^H will presumably still be needed):—

{1} “Glued” — direct “**contact**” (thermodynamically stable as in chemical compounds, via weak bonds). But let us distinguish between **{1a}** those joined by side-additions (perhaps via chemical side-chains, and maybe due to editing); e.g. *fig. 1* if its links were material rather than “virtual” — and **{1b}** those joined end-to-end (perhaps as read directly from DNA).

In accord with DualPlus, both seem likely although the end-to-end version {1b} now seems rather attractive because (i) that 1D organisation-mode seems to suit DNA and RNA, even when the external transactions seem somewhat remote¹; and (ii) most of the available ncRNA is *long* (LncRNA, >200bp).⁷ Note that such a linked ABCD could be essentially the same as CBDA and yet be taken as different when observed in the laboratory; so identification of substrings should be helpful (as with introns and exons).

{2a} **Tethered** physically by a rope-like leash — (a variation of {1a}).

{2b} **Quasi-tethered** by a *dedicated* telegraph or “audiofrequency telephone-line, (pre-1950)” — or its analogue: a traditional nerve linkage, usually tacitly *assumed* to be signalling somehow by AP-based Morse-like codes. (Such *discrete* coding has never been found and now seems improbable; but instead, any signal seems simply to be in the *statistical rate* of AP-spikes).

{2c} **Quasi-tethered** by a *dedicated local* “optical-frequency cable” (myelinated), or an equivalent commercial TV-or-microwave cable. HOWEVER such frequencies can (in the right circumstances) break free from the cable and be broadcast-or-else-beamed (as with Hertz’s discovery of radio in the

late 1880s), which takes us instead to the less-local {5} below, with call-sign-variety the limiting factor.

{3} Held captive within some **boundary-or-box** (notably within a cell or vesicle). See §(5.2), below.

{4} **Highlighted by focussed beams** (by centrally controlled simultaneous “searchlight”-beams of UPEs or any other radiation capable of sufficient *focus* and sufficient *ability to penetrate* the prevailing medium predictably) — an alternative to using dedicated pathways as in {2}.

IR-frequencies would be poor candidates on one-or-both counts. UV_A (or nearby visible-light quanta) seem more promising, especially as it seems plausible that *long* mitochondria (recently identified) could be *acting as lasers* (using an optical trick to gain the special boundary-reflection conditions needed at such frequencies).⁸²

This might perhaps accord with Pascual-Leone’s focus-model for the special case of “attention”,⁶² but there seems no pressing other reason to see them as relevant for practical everyday memory-linking, especially given the complications they would entail, and given the {2} alternatives.^J

{5} **Reachable items with the right Name/Label.**

A member-specification which relied on *complete* descriptions would take us back to intensive definitions, case {0}, which will often be unworkable. So instead names/labels are used as a shorthand, supposedly representative of the rest of a taton (or at least some common role with others so labelled).

Such labels can then be called upon to ((i), in logic) specify the members thus defined, &/or ((ii), in microphysiology) to establish virtual links within some part of the Piagetian M⁰L–M¹L–M²L... hierarchy. And, given the supposed molecular scale, such labels would have to be activated by electromagnetic signals within the IR-to-UV range, in a way similar to that depicted in *fig.(iv)* of⁸⁵ — or, analogously, as has come to be used with a “URL address” on the internet.

Thus their efficient use might free us from any absolute need for *dedicated* neural-or-telephone pathways (a freedom already well known for the internet).^K

^H These various “{...}” distinctions need not be absolute, but it will perhaps suffice to see each as the main applicable tactic within its given context.

^I This idea of remoteness when crucial entities are confined to a single one dimensional string has obvious application, both to intron/exon matters, and to these supposed end-to-end joined-up tatons of case {1b}. It also matches the not-too-serious discussion of hypothetical 2D and 1D beings in the book “*Flatland*”¹ — which (e.g.) raises the question of two 1D beings seeking to mate, but with no prospect of any physical contact. As one step towards feasibility, such a system would presumably need a very efficient message-coding system to allow highly selective virtual contact — and that might have some bearing on the present discussion (which at least allows messages to take short-cuts through the 3D medium — and access to *other* 1D entities).

^J Of course such focussed laser beams may well have important roles in cell-division and growth as the history of Gurwitsch’s “mitogenic” UPEs attests; but that’s arguably a separate issue.

^K Meanwhile note that such matching phone-numbers or “labels” are TIME-based “lock-and-key” arrangements analogous to the SPACE-based codes well-known to immunologists and bacteriologists — already discussed above in §4.4. This might help our understanding of DNA organisation. One might also

Anyhow, one can imagine variations on this URL theme, invoking lists of “link-names” which may (i) be mere repetitions, (ii) items otherwise apparently unrelated, or (iii) near-repetitions for *similar* items: e.g. in *fig. 1*, the “ α - β_1 - β_2 - β_3 ” could represent a taton at level M^1L which derives its significance through its link to nearly-identical tatons (a_1 ..., a_2 ..., and a_3 ... — a very-small “choir” perhaps, with names a_1 , a_2 , a_3).

Fig.1 depicting the postulated “higher level” linear element (α - β_1 - β_2 -...) serving to construct, physically, an extensively defined set or list of “lower” elements.
(Abridged from *fig.C5.2/3* of ⁸⁸)

{6} Orphaned Tatons, and Tenuous Memory

First consider short-term-memory (STM). Any such coding *left unlinked*, is likely to be left out of system activities, until it simply “times-out” naturally and disappears unnoticed.

In contrast, any long-term-memory (LTM) which seems to lack current links will (i) have time on its side, and (ii) doubtless have some surviving historical linkages (however faint and remote), since otherwise it is unlikely to have reached long-term status. Nevertheless such memories can become more-or-less isolated, as in “What *was* that person’s name?! — I *do* know it but...” — and indeed one will usually remember eventually

(regaining some relevant linkages). Can we explain that?

Some relevant activity might include:

(i) periodic scanning (perhaps random, and perhaps various brain-regions at different times) inciting apparently dormant schémata to renew an old contact or two (via mechanisms considered in §6.3, below). Or (ii) such specific contacts might occasionally arise spontaneously unprompted. Or (iii), regardless of previous contacts, such “orphans” might have some means of “advertising” their characteristics.

In any case, it may seem to be necessary that they take some initiative on their own, and not just wait for some central controller to call on them unilaterally. (This being in the spirit of Kant’s “back-to-front causality” discussed above in §3.1(K3), or Piaget’s *Action First*).

{7} Any other defining-or-linking strategy that we have overlooked, and which we may find later on. Nature’s task seems formidable here, so it will not be surprising if it uses all the feasible tricks available — perhaps often concurrently or as hybrids. Indeed, if we think carefully about office-work procedures, most of them do involve hybrid techniques for re-locating records, or items, or staff.

The actual details of such technicalities are not crucial at this stage (especially as we are not sure of their identity, so better variants might be found); but the important point is that any attempt to assemble *material-embodiments* of mental M^0L - M^1L - M^2L - M^3L ... hierarchies (as implied by Piaget or Ashby) will be faced with • the task of keeping such subunits *linked in some way*; and we will probably • need *all or most of the above tactics* — both within the office and in ordered brain-intelligence. — Both being cases of DualPlus (see §4.2, above).

So if we are serious about Piagetian substructural model-building of the human mind/brain, we need to offer specific plausible material ways to *link* its tatons into schémata (by whatever means), thence into *new* M^0L -schémata^L — and then (separately) into the M^1L , M^2L , ... schéma-clusters which they must presumably form, in real or virtual space. Some suggested details for additional development were offered in ^{86(chs.1,2,6)} — invoking list-like linkages to lower levels], and developed further in ^{88(§C5.2)}

At the lowest levels, taton-interaction is likely to be essentially CHEMICAL (type-{1}: i.e. quasi-

enquire whether such analogy has any evolutionary significance.

^L Then keeping company with any *old inherited* M^0L -schémata.

contact, or subject to attractive forces, as with hydrogen bonding). But what then?

A little further up the hierarchy, any such direct-contact “{1}” arrangements, left on their own, would probably soon become unworkable due to overcrowding. — And any alternative low-frequency WIRE-LIKE LINKAGES ({2b}, usually assumed to adapt via slowish Hebbian procedures)²⁹ would seem barely workable for fast-moving multifaceted thought processes,^M though they do seem well suited to revising nerve-layout (as Hebb²⁹ suggested, but now with a change in its supposed significance — from actual memory-coding, to signal-channelling).

Meanwhile physical tethering {2a}, if it exists in this context at all, would perhaps have a rather specialised use which would probably not concern us here. So let us leave it aside as merely “in reserve”.

Higher in the hierarchy there would probably be a need for high-frequency (optical) coding of call-signs (names, labels) as in {5} and {6}, discussed above — along with constraints within “boxlike” enclosures {3}; which takes us to:

5.2 Cells as Possible Schéma-Files

Boxes, bags, and jail-cells are obvious ways of keeping members of a “set” together — and so are their biological equivalents: bio-cells etc., though it is too early to say with any certainty what aspects (if any) of the Piagetian hierarchy are consolidated in this way.

Moreover there is then the question of whether a cell might contain a single “choir-group” of one particular schéma, or whether it might contain various different (but presumably-related) schémata.

Then again, cortical cells are usually held in narrow **columns**,⁵⁸ and such columns might also be seen as somewhat *bigger* “boxes” to loosely imprison those particular whole-cells (each with its own imprisoned content of schèmes and schémata or whatever).

Seen that way, we have the possible basis for a hierarchical organisational filing-structure (here at its more-inclusive categories, using {3}’s boxes), whereas the most-specific categories would be embodied by quasi-chemical contact {1-2a} by the memory-entities within the cell — or whatever the smallest {3}–“prison” might be. Indeed that prompts a more recent thought about *smaller* boxes:—

^M Ashby had no such mechanical-linkage problem because he used recursive pre-made electrical devices, or just plain recursive mathematical theory. Anyhow he did not seriously tackle abstract thought except in vague principle.

5.3 Possible Role for virus-sized containers

As just implied, a neuron-cell might well have the space to house a whole family-or-tribe of related schémata, but new evidence now offers much smaller subfiles within the cell — “granules” (2004³⁶)^N — later identified as hollow (virus-like^{42,99}) icosahedral capsids made of *Arc*-protein (similar to the viral *Gag*-protein)^{15, 63, 14, 98} — “boxes” of about 125nm diameter. In principle then, these might offer the first fence-like constraint (type {3}) — after {1} and perhaps {2} have exhausted their capabilities.

The above authors and their immediate audience see the purpose of the capsids as “*to shuttle information between cells: a new form of cellular communication that may be the key to long-term memory formation and other neurological functions. These vesicles circulate throughout the body, but little is known about their function.*”⁷⁴ And that has useful implications which can be taken further (with modification), see §7 below.

In contrast, the present argument has hitherto emphasised a rather static classificatory role for any such “jail-like” enclosures — a way of contributing a post- $\{2\}$ practical stage to the structural “... M^1L - M^2L - M^3L -...” Piagetian hierarchy. However the two interpretations are probably mutually compatible — and another minor example of the DualPlus principle.

Nevertheless we may need to distinguish capsids according to the cargo that they happen to be carrying.

The official line suggests that they “*also move genetic material between cells*”⁷⁴ (in the form of *mRNA* &/or *protein*); whereas the present paper suggests *ncRNA* (specifically *tatons*) and at least some elaborations thereof, (i.e. schèmes &/or schémata — either singly, or as “choirs” with complementary action-codings). On present indications, both cargo-types seem plausible according to circumstance,^O though the supposed

^N “...RNA is transported as large granules, but little is known about them.” — “~200 nm in diameter...” — Kanai et al (2004).³⁶ Incidentally note that David Glanzman of UCLA (on YouTube and radio) implicates the cell *nucleus* as the repository of molecular memory; — a similar idea which adds to the possibilities.

^O “Arc capsids encapsulate both the Arc protein (maybe other proteins too?), its mRNA, and whatever mRNA [or *tatRNA*?] happened to be in the vicinity at the time of encapsulation. Arc capsids are able to protect the mRNA from RNAases.” (Neuronicus 2018)⁵² — This latter point (protection from RNAases) might also help explain *long-term memory as RNA-coding*, without necessarily invoking conversion to DNA to gain the required stability).

ncRNA-taton-cargo has not yet been considered experimentally.

5.4 Could these items fit in? — “Tape-measure” evidence

How big are schèmes and schémata likely to be? Could they (or their ensembles) fit comfortably into capsids — or at least into neurons? This calls for some rough, order-of-magnitude calculations.

5.4.1 Volume of single taton if <200b

I have hitherto taken a single **taton** to be a fairly simple “text” of RNA coding, so let us provisionally assume this will usually be a sequence of “short” ncRNAs: — “snRNA” (< 200b). The DNA version has a length⁴³ of about 0.34nm per bp (base-pair) — a total of up to 68nm, and it has a cross-section of about 3nm² — hence a volume of about 204nm³ — but a bit less for single-stranded RNA. So let us provisionally say that a taton is *approximately* 160nm³ in volume.

5.4.2 Volume: schème (as 20 short-taton “choir”)

If a **schème** is a choir-like ensemble of closely-similar tatons, then we need to guess the likely size of such a “choir” (ironing out individual discrepancies). Perhaps 20 members would suffice, especially as this whole subsystem might be duplicated elsewhere.^P That would take the volume up to 3200nm³.

5.4.3 Volume: schème (choir of longish-tatons)

Of course if a typical taton is actually LncRNA (not just 200b, but perhaps 1700b long, like mRNA, or a more modest 1000b for “Other LncRNA”)⁶⁰, then the volume of the 20 member **schème**-ensemble would be significantly greater: 27,200 nm³ — or the more-likely “modest” 16,000nm³.

5.4.4 Volume: whole schéma of longish-tatons

With *all* schème-components being “Other LncRNA”, then the **whole schéma** volume could be perhaps $10 \times 16,000 \text{ nm}^3 = 160,000 \text{ nm}^3$ — or even the immodest 272,000 nm³. —

Of course these are all just rough estimates to help clarify the possibilities.

5.4.5 Internal volume for a capsid

The external diameter of the analogous herpes-virus capsid is “~125 nm”,⁹⁹ and perusal of images

suggests that 60% of that diameter is internal, hence 75 nm, and hence an inner radius of 37½ nm, giving an **internal** volume of 220,893 nm³. — ^Q

That means that *a capsid probably does have enough volume to contain a whole schéma* complete with its constituent schèmes and their tatons — including reasonable provision for “choir-member” redundancy. However the threshold is narrow enough for the issue to be debatable regarding whole schémata — while clearly having adequate volumes for the less-demanding isolated schèmes (16,000 to 27,200 nm³ within the capsid’s 220,893 nm³.)

5.4.6 Internal volume for a cell-body

Neuronal **cell-bodies** have diameters ranging from about 7µm to 30µm (at least for inhibitory neurons,⁴ and that seems near enough for all cases considered here). So taking the smallest neuron-body, it will have a volume of about 179.6µm³ — i.e. just under $18 \times 10^{10} \text{ nm}^3$ — enough room to hold (close-packed) nearly 18×10^4 capsids (each $\approx 10^6 \text{ nm}^3$).^Q And of course this provides ample space *in each separate cell*, for a substantial Piagetian mental construct if it is embodied in the way outlined here — even if individual capsids cannot contain constructs larger than a schème. Indeed maybe schémata need the extra ample free-development space *amongst-and-between* the cell’s capsids rather than *within* those capsids — or perhaps that applies only to higher level schémata (M¹L, M²L, M³L...), rather than the basic M⁰L.

5.5 Conducting a link between distant sites?

The current tacit assumption seems to be that messages (of *unknown format*^R) are sent along the *mysteriously-“correct”* nerve-path. Also the destination site will *somehow “know” when-and-how* to act autonomously or else just obey — meanwhile somehow knowing how to use the right unidirectional “phone-line” *to communicate back* to the sender, or to other relevant sites.

Clearly that summary implies the need for comprehensive clarification, and more reverse engineering if possible.

Note firstly that, for a brain of any complexity, it is simply not possible to run a *separate dedicated*

^Q — since sphere-volume = $(4/3)\pi r^3$. Meanwhile the *external* volume would be 1,022,653 nm³ — about 10^6 nm^3

^R Of course it is also mostly assumed *that AP signals* carry the main brain-messages, whereas the view here is that electromagnetic signals (EM: infra-red IR, visual, or UV) play this main role — at least as far as 1D logical thought is concerned.

^P There is likely to be such choir-like redundancy at *every* M^mL level — not just the M⁰L considered here. So any given schéma is likely be reinforced by other near-duplicates.

“*phone line*” between each pair of participating sites. (The required number escalates out of control; — and even if this were possible, that would not help much unless there were some means for *choosing* which line to use.)

The other extreme would be to *broadcast* the same current message universally to all sites, all the time — and that too would soon produce an unworkable system — a cacophony of jumbled messages, mostly irrelevant to any given recipient.

Countries and other large social organisations have very similar dilemmas:— (They too are all “epistemological machines,” each seeking to cope with a similar nearly-insolvable problem which is arguably formally equivalent in each case — despite outward appearances; see §4.4 above). Anyhow, this gives us some provisional license to draw on analogies, and consider, *e.g.*, how a large office (or even a nation) manages its information — though I will comment on only some features here.

Firstly, it needs a fairly-sophisticated and rapid (alphabet-or-phoneme-based) SYSTEM OF LANGUAGE — *not just* a system of “volume-controls” (no matter how detailed) as the AP system seems to be. Within society, with some overlap, this comes mainly as (α) written symbols, &/or (β) *acoustic wave structures*; — &/or, since Marconi: (γ) speech or code via *electromagnetic (EM) wave-structures*, including (γ_1) coaxial and other cables, as from about the 1850s; — plus (γ_2) radio, microwave, and infra-red (IR) — and now especially the multitude of short-range gigabit devices, notably using WiFi techniques for making-and-maintaining wireless connections through heterogeneous changing domains.⁵⁷

Here we are looking for speed-capability, (which is perhaps peripheral in α ’s case), but the other two are indeed fast — especially γ . So can we think of any other such *fast* external-transmission methods for society? Until we do, let us provisionally assume that (α)- β - γ is the full list, and look for corresponding (necessary?) analogues within the brain:

α . Taton-codings or schémata appear as “written symbols” (letters, phonemes or words etc., depending on the M^0L - M^1L - M^2L -... level), with schémata acting as sentences or concepts) — as discussed above from a quasi-static point of view.

β . Acoustic internal signals seem less important here, and can thus be bypassed in our immediate discussion.^S However:—

γ_1 . Compact-myelin axons (via PLP protein) offer efficient coaxial connections, as discussed above in (§1(1-2), and §2.2(d, e, h) — a definite parallel to technology if we accept this apparent EM-role within biology; and

γ_2 . EM can offer *radio-like* wireless breakaways from the cable-system §2.2(f, h, i, j). In principle this means that any two sites within the brain might be able to intercommunicate even without myelin (lipid) connections *provided that* there were an intervening “atmosphere-equivalent” which was *sufficiently transparent* for the main frequency in question! In practice, unaided, that would seldom be the case except at short range (*e.g.* < 20 μ m, or somewhat further-apart when the IR frequencies are closer to red-light-, etc.); but some assistance from WiFi-like adjustments, and from cables for most of the journey might often suffice. In that case, it would clearly be helpful if the AP system could (as classically suggested) keep upgrading the cable-pathways according to apparent need — using the well-known Hebbian principles of growth according to actual usage.²⁹

This idea that EM signals need not be confined to specific cables within the brain, may also help to explain a strange difference between the central and peripheral nervous systems (CNS and PNS):

In the PNS, myelin is provided by Schwann cells, each of which serves *only one axon*; whereas in the CNS myelin comes from oligodendrocytes, each of which serves *many axons* — which might well tend to allow “crosstalk” leakage from one serviced-axon to another. — But that would hardly matter if CNS fibre-transmission is just an aid to address-coded broadcasting in comparatively indiscriminate directions. Against that, peripheral nerves are presumably mainly concerned with traditional AP input and output signals, which *do* need to avoid crosstalk between dedicated links.

5.6 Attention-“centre” and the flow of concepts

Provisionally at least, it seems appropriate to postulate the existence of an *attention-centre* — deemed to be in temporary close-contact with whatever schémata are currently in play.

It can hardly be at any single point or micro-entity. Rather it must probably be some ensemble of privileged schémata or suchlike. Such entities are

^S (Acoustic excitons are arguably involved in playing the role of AP-analogues taking a trigger-impulse along a taton’s linear RNA-structure).

likely to be physically close to each other — though not necessarily so if communications are adequate. The nature of such links can be provisionally assumed to be similar to other intra-brain links (see §6.3 below), but privileged in some way, e.g. by proximity or pre-set dedicated lines.

The two-lobed thalamus offers some scope for plausible sites (&/or the prefrontal cortex with which it is in close contact); while the hippocampus seems not to, (see the discourse in §7.1 below, regarding “*patient HM*” with bilateral hippocampus-destruction). But for present purposes, the actual location of the “attention centre” is not vital to our discussion provided that some adequate internal-*linkage* is usually assured.

(It may be of some incidental relevance to note the famous apparently limited capacity of such attention centres:— about 7 items simultaneously at any one time (G.A.Miller, 1956)⁵⁰.)^T

6. Message-interactions

6.1 Message “programs”

Regarding coded action-programs, §4.5 above offered the likely basic taton format as:

[Label | Switches | **Program**]

Here the Label+Switches together act to filter out all supposed irrelevancies, so the taton will only act when stimulated with the right lock-combination. But what about the actual “**Program**”? What can it actually do at the micro level such that it will achieve its more-macro Piagetian action-component? It was presumed it would first need to coordinate with its fellow “choir” members, using cross-feed signals; but what next for this collective *schème* action?

At the basic Piagetian Sensori-Motor level (M^0L), its expected action will depend on whether it is “*sensory*” (input), or “*motor*” (output) in its nature.

If *sensory*, it will presumably send a suitable code to the relevant part of the thalamus (or suchlike) to be analysed as part of the overall input appraisal.

^T Some more-modern opinions (varying Miller’s “7”) have been offered in J.Pascual-Leone et al.(2015)⁶², invoking increasing values of his own metric “M” from $M=1$ (at 1-month) to $M=6$ (at 2-years), and $M=13$ (at adulthood). — Also he suggests that M at least partly determines the Piagetian cognitive stage; and, influenced by R.Case, he has revised the boundaries and names of those four Piagetian stages to *Sensori-motor* (1m-18m), *Inter-relational* (up to 5 yrs), *Dimensional* (to 11), and *Vectorial* (to 19).

If *motor*, we would expect it to participate in causing some muscle to contract-or-release — or a whole pattern of such muscle-responses if we are considering the combined program for a whole schéma. If such programs can indeed be fully coded within *individual neuron bodies* (as suggested above in §5.4), then they are ideally situated to launch EM signals into the end of the associated narrow myelin cable.^U

For other Piagetian levels (M^1L , M^2L , $M^3L...$) it will be a bit different — with contacts for M^mL schémata now being usually with $M^{m-1}L$ entities in the level below, (or indeed with partners at the same M^mL level) — but deep within the brain proper, thus having no direct access to the outside world. Fig.1 (p.9) suggests these two types of link, but says nothing much about the technicalities of linking sites which are not actually touching, (only suggesting vaguely “*seek and ye shall find*” — “mode {0}” — in §5.1)). Yet these distant links must become more important as the “*m*”-level increases, enabling increasing levels of mental-abstraction. So how could such sometimes-lengthy links occur in material terms?

The usual loose assumption is **that direct pre-determined nerve connection** is the answer (once it has been installed) — case {2b} in §5.1 above. That is clearly part of the solution, though it leaves some details unexplained.⁶⁹ However, for our present purposes we can simply accept such partially-adequate cables as given infrastructure, and seek further possible mechanisms (with a tentative expectation that they will be EM-compatible):—

(To make this discussion easier, it seems helpful to revive the word “*schemoids*”⁸⁷ to cover both “*schèmes*” and “*schémata*” collectively — though many authors (e.g. Phillips⁶⁵) simply use the two

^U This stricture would perhaps solve a technical problem:— Practical coaxial cables need to be somewhat narrower than the half-wavelengths of their intended signal-traffic, to suppress any tendency for these signals to bounce side-to-side in a zig-zag pattern (causing delay, dispersion, and hence distortion) — leaving only the straightforward “TEM” mode, parallel to the axis, which is theoretically unhindered by narrowness.

A new practical trouble is that it can be difficult to steer EM signals through such narrow aperture-holes (which is how we are protected from microwave ovens by the fine-holed screening of their windows). However the placing of the radiation source close-and-central (i.e. within the cell-body at one end of the axon) may well overcome the difficulty in this neuron/myelin case.

Incidentally, that constraint would also mean that EM signals would nearly always travel in the same within-axon direction as the APs — orthodromically, away from the cell-body.

words indiscriminately anyhow, as intimated above in §3.2(JP1a).)

6.2 Uniting sometimes-remote schemoids

The point is that the more complex schémata are here deemed to be constructed from an assortment of “lower” schemoids.^V And (as discussed in §5.1) the nature of the necessary structural *links* can be expected to vary in nature and distance from {1} physical contact, through {2} tethered-locally, {3a} “imprisoned” in capsids, or then to {3b} “fenced in” within the much larger neuron-cell-bodies.

That repertoire might suffice to explain macro-schéma cohesion in many cases, but sometimes it will be important to include a link to some remotely-located schemoid (e.g. some vital hereditary schemoid) which is *not* locally available. What then? That takes us to feasible-option {5}: the use of coded “*labels, addresses, URLs, phone-numbers*” which can be used to establish-and-maintain *highly-selective* contact, *despite distance*.

That dependence on labels, takes us back to fig.1 (and indeed to the in-text sketch repeated at the start of this section). It is also a more refined equivalent to {0}'s “seek and ye shall find”—improved because we can expect it to be easier to find tidy *labels* than whatever complex entities are attached to them.

Note too, as implied earlier, that here we have a TIME-BASED lock-and-key coding (like a combination-lock), whereas the lock-and-key mechanism for immunology and embryology etc. uses solid 3D keys of shaped-protein: *X,Y,Z*-BASED. Thus, at least for the hereditary cases, both types of lock-code could even appear side-by-side on the DNA — the one leading to taton-ncRNA, and the other to mRNA — analogous perhaps to verbs and nouns respectively!

This all depicts a **quasi-static** macro-schéma — perhaps encoding some skill, but open to improvement. This could come through *rehearsal* which might have at least two different effects:
(i) encouraging local substitutes-for (or copies^W) of any remotely linked components, to make the arrangement faster and more efficient;
(ii) replicating (if possible), to add redundancy, as part of the *choir-effect* at this level (in addition to its

development at other levels). Both could be expected to improve performance.

But the topic of “performance” takes us to another role for distant EM linkages:

6.3 Activating remote schemoids

Moving now from quasi-static structure, to **dynamic activity** (though there is arguably a fuzzy distinction between them):

Whatever their groupings or locations, schemoids are there to *dynamically influence* each other during thinking and other mental activity. And it has been argued here that the only fast and potentially-accurate way to convey that influence within the brain-proper is by EM signals such as IR (with the traditional AP signals playing an important-but-secondary dynamic-infrastructure role). Moreover coded labels seem indispensable here, to achieve the necessary selectivity.

In essence then, these “talk” linkages are seen as closely similar to those offered above for holding the quasi-static states together — only here the case for using “addressed” messages is rather more obvious. In both cases it is difficult to see how a self-organising system like the body-and-brain could survive without such *well targeted* time-based messaging (just as they also need *well targeted* 3D-based physical linkages).

Until now, we all seem to have tacitly assumed that any transmitting site will somehow “know” which nerve-fibre to consign the message onto (and that every likely destination will have its own dedicated line, which is a further problem). But how will it know? OK it may well have an address-code, but will it then recognise the relevant “phone-line” for that address. *If most of our human society members can now be selectively contacted by mobile-phone (without any dedicated cable-link), then why not consider that nature might be doing much the same within the brain?*

Yes, in both environments there is a need for general-purpose cables-or-whatever to bridge the gap when long-distances are involved. (Hence the need for major nerve tracts within the brain, such as the corpus callosum connecting the left and right hemispheres.) No doubt some lines might be dedicated — in the optic nerve perhaps (though that has been questioned^{84:foot-27}) — but such dedicated private lines are arguably not the general rule.

There is still the problem of knowing the “phone-number” of the recipient (even if the traditionally-assumed *choice* of dedicated lines were

^V Such a schemoid hierarchy is formally similar to nested subroutines in machine-language computer-programming.

^W Copies — perhaps imported *physically* from that distant site! Maybe unlikely here, but this transport-tactic seems probable elsewhere (as we shall see below in §7).

to apply^X). In the case of essential inherited link-needs, it seems likely that the call-code is already pre-ordained. But for *learned* contacts, this code may well come from (Darwinian) trial-and-error — perhaps assisted by many candidate-destinations, each emitting an occasional “I’m here” signal (with its “return address”) to advertise its presence.

For the specialised apparently-pixelated transmission of *2D images*,^Y any pixel-address codings would probably derive from a systematic formula — which could actually then serve mainly for the pioneer fibres when they link up the solid connections for each dedicated pixel-line of the set — “docking” correctly.

6.4 Finding little-used schémata: Dim memories

As described so far, the *important* schemoids would all be (or soon become) readily accessible via (i) the conveniently placed network of the main myelinated nerve-fibres — updated by Hebbian²⁹ principles *favouring those frequently used*; and (ii) the ability of EM signals to travel freely for shortish distances without cable assistance.

Also note (iii), that it should usually be easier to access the *larger target* offered by a collective macro-schéma consisting of many “choir” members (e.g. spread across several cells). — The extra size being achieved typically through repeated rehearsal.

But, coming back to daily life, what about that *name, word or detail* which you thought had permanently entered your long-term memory (**LTM**), but you now have great trouble recalling? Like “Wallerian degeneration,” that could be because its disuse had allowed Hebbian procedures²⁹ to overlook decay-or-obsolescence of the cable access to your sought-for vicinity, whilst boosting other regions.

You might then remember *the half-forgotten name* in due course (at the whim of autonomous activity), but that might depend on the sought-for schéma emitting the afore-mentioned occasional “*I’m here*” advertisement, presumably with its return address or other “branding” to assist access.

^X i.e. Even if we were to fully accept the traditional AP model for coping with an incoming signal, there would still be the problem of: ‘How would the system “know” which of the available non-random paths or actions to take. E.g. could the message specify “Option X”? And if so, then how would it recognise that option? — By “Name X” or what?’

^Y Separate from the other parallel visual coding system, using vector linkages as advocated by Piaget and by Pylyshyn. See §1.8) above, where both-in-cooperation are deemed necessary (and exhibiting the spirit of DualPlus).

6.5 Fading schémata in the hippocampus

For short-term memory (**STM**) there is the more pressing issue of actual schéma-decay — perhaps by 20%-per-day of schéma-X’s choir-population — until there is nothing but a mere trace (if that) of it left in the hippocampus, with no guarantee of recoverability. That leads to a separate major issue in the next section, but first we need to clarify some terminology (which sometimes varies between authors):

“STM” is usually taken to include *both* “IMMEDIATE MEMORY” (gone after about a second-or-less unless rehearsed), *and* “WORKING MEMORY” (which may last a day or so, even weeks with some rehearsal or active usage). Here it seems useful to introduce the abbreviations “**imM**” and “**wkM**” respectively for these two types of memory — both still distinct from **LTM**.

7. Memory-Migration to Cortex

7.1 Patient-HM with no hippocampus nor “wkM”

The well-known account by Scoville and Milner (1957)⁷⁶ reports on three patients (HM, DC and MB) whose *hippocampus had been largely obliterated bilaterally*, and were no longer capable of holding **wkM**, nor of sending any new memories to the cortex as **LTM** — though they could recall material which had been stored in **LTM** *before* the operation. (The symptoms were essentially the same in each case, but HM is the one most discussed).

That clearly implicates the hippocampus as the key locale for (declarative) **wkM** — with HM etc unable to remember even what the last topic was during the previous minute, nor any other detail of the post-operation past.

However it is easy to overlook his ability to use *imM* in his **immediate present**. (Obviously any patients who could not, would hardly be in a fit state to be interviewed!) The importance of this is that it means that there must be a third domain for this extra memory mode — though we can probably identify it (abstractly) as being the “attention centre” as discussed above in §5.6 (and §6.1).

Plausibly then, such attention-centre activity was going on while HM was being interviewed. But note that he would meanwhile have to be accessing (i) his pre-surgery memories stored in his cortex (prefrontal or otherwise) — and (ii) the perhaps-numerous “housekeeping” *hereditary* schémata (wherever *they* happen to be stored). So there would have been significant trans-cranial fast-messaging, just to interact coherently in the “here and now” but with no need (in this task) for the destroyed hippocampus.

7.2 Properties of the imM (Immediate Memory)?

This apparently-necessary “*here-and-now*” feature (distinct from wkM) seems somewhat overlooked. So it may be helpful just to jot down some likely aspects:

This *imM* must be very dependent on new tatons acquired “just-now” — presumably acquired as partly described above in §4.7. This might include *editing*⁹¹ of any suitable pre-existing tatons, either by similar Darwinian trial-and-error or maybe (due to the special circumstances) by purpose-built “quick-recording” tactics.

Attention is called for here (whether conscious or not), so it seems reasonable to expect the main site of such activity to be within some sort of “attention centre” — whatever that might be, and wherever it is located.

For present purposes it is not vital to identify the location of the attention-centre, except that it is *not* in the hippocampus (at least not in HM’s case). Nevertheless it is convenient to provisionally assume that it is within the thalamus, and indeed circumstantial evidence rather supports that view:

Various parts of the thalamus clearly sort and then integrate various sensory signals. Notably: (1) *Auditory* signals (via cochlear, olivary complex and inferior colliculus) go to the medial geniculate nuclei of the THALAMUS — then sent on to the cortex. Meanwhile (2) *Visual* signals take at least three different paths [a] ≈2% to the *hypothalamus* (as a light-meter), but then [b] some to the THALAMUS’s *lateral geniculate*; while [c] some (via the superior colliculus) to the THALAMUS’s *pulvinar* — both then linking to the occipital lobe at the rear of the cortex (which then projects to • a dorsal parietal path, or • a ventral temporal-lobe path.^{41:(chs.9-10)} And most other senses also have a similar thalamic involvement.

Be that as it may; let us now return to the issue of MEMORY AND HOW IT MAY PROGRESS through the above-mentioned three domains: —

Attention-centre for imM,

Hippocampus (if available!) for wkM, and

Cortex for LTM. — And let us start with this (into-Cortex) last step, as it is better documented:

7.3 From Hippocampal wkM to Cortical LTM?

7.3.1 Here we provisionally assume that the relevant memories are already encoded within the hippocampus, held for temporary use but ready to be either forgotten as obsolete, or transferred to LTM.

In traditional AP theory, such coding (if considered at all) has been taken to be somehow embodied

in either (i) reverberating AP neural circuits, &/or (ii) some feature of the synaptic connections.

In both cases, there seem to be formidable problems if such encodings of compound-structure are to be re-located. They *could* perhaps { α } be translated back into virtual experience, and transmitted via AP messages such that the LTM could reconstruct them on a smaller scale — though that would seem to be unnecessarily inefficient and subject to gross error.

{ β } Alternatively, like moving an entire house, whole synaptic/AP structures *could conceivably* be relocated physically — along with some way of restoring the external links by changing to *new* dedicated nerve-fibres (like changing one’s address, plus landline-connection and its phone-number; etc.). That might be possible, but again it seems unnecessarily difficult, and indeed improbable enough to make one doubt the whole transfer enterprise.

Fig.2. Principal neural connections relating to intelligence. Note that, due to feedback loops etc., the neat sequence shown here is only a rough guide in tracing causality.

7.3.2 Looking instead at the *EM/schemoid theory*, the { α -(now micro)} virtual-re-enactment case still looks inconveniently complicated with its required reconstruction, but at least it does have the benefit of invoking EM signals with their vastly greater gigabit broadband — much more suitable for carrying complex instructions.

But with $\{\beta\text{-(micro)}\}$ “house-moving” we arguably *do have a workable system*: The coding is taken to be held by molecular-based schémata either as free-floating pseudo-molecules, or grouped into capsids, &/or already held within dedicated cells (which seems to tally with the account offered by Deng et al (2010)¹⁶ regarding mice.) — These new neurons-or-capsids would all be comparatively easy to transport as intact semi-nomad entities. Moreover, their links to distant archive sites (cortical or otherwise) are presumed to be more like WiFi than the conventional landline connections — so they would effectively have “mobile-phone” connection, not seriously disrupted by reasonable moves if adequate routers-&/or-cables were available.

7.3.3 Any Evidence for such a Schéma-flow?

There is indeed evidence for a flow of *new neurons* from the hippocampus to the cerebral cortex, even in adulthood. And such mobile neurons might well be carrying updated schémata. However the issue is currently in serious dispute in the case of humans (see §7.3.5 below).

The old doctrine was that there was absolutely no further increase-or-replacement of neuron numbers once an individual reached adulthood.

Nottebohm (1981⁵³, 1984⁵⁴, 1985⁵⁵) demonstrated that this was not true — *at least in the canary*, which apparently discarded its song-memory neurons at the end of the season, and then developed new ones later. Nottebohm (2002)⁵⁶ attributed this phenomenon to a need to abandon obsolete memory which might otherwise prevent new LTM acquisitions. That could be correct, though there is also a variation on this idea:— That, for bird-flight, weight is at such a premium that surplus semi-junk needs to be discarded *even if* it must be re-acquired later.⁹¹{§(14)}

Meanwhile there seems to be no evidence that such pre-programmed culling of LTM occurs in normal human cases — but do we actually *gain* any neurons? Rodents and many other vertebrates apparently do continue supplying new neurons into adulthood, (conveyed from the hippocampus to the cerebral cortex), but this *adult-supply* seems absent in humans and dolphins — as discussed in §7.3.5 below. But first let us look at how this transportation works, in-so-far as evidence is available, especially in infancy and earlier:—

7.3.4 Observed flow of Neurons into the Cortex

Let us initially leave aside the contentious question of *adult* migration, and look at pre-adult

developments. It turns out that *none* of the cortical neurons develop on-site.(Rakic, 2007)⁷³ I.e., they have *all* migrated, and he also reports that this idea was put forward by Wilhelm His in 1874³⁰ and 1904.³¹

Rakic’s investigations 1975⁷¹, 1985⁷² and reported on Rakic 2007⁷³; Cowan 1979^{12(p63)} showed that radial string-like glial cells served to guide the migrating neurons out of “the subgranular zone” (SGZ) of the Dentate Gyrus (DG) — though the “the subventricular zone” (SVZ) might also be involved.

Other treatments of this question of cell-migration are reported by Fuster (2003)¹⁹, Tan et al (2013)⁸¹, Sekine et al (2014)⁷⁷, Oyarce et al (2014)⁵⁹, plus Mayer & Fishell (2018)⁴⁸.

Moreover some have endorsed the Nottebohm notion of this migration persisting into adulthood — in at least some mammals: Gage (2002)²¹, Zhao, Deng & Gage (2008)¹⁰⁰, Ming & Song (2011)⁵¹, Hayashi et al (2015)²⁷, Gonçalves, Schafer & Gage (2016)²³.

7.3.5 Migration-failure in Primates and Dolphins?

However Rakic himself (2007)⁷³ had also noted a surprising conclusion that this neuron-flow to the cortex *ceased in primates* “without addition or turnover throughout life” and concluded that this “may be a critical step in the evolution that allows of mental prowess in Homo sapiens” ... with “a permanent population of cortical neurons [which] may be more valuable for survival of primates”.

Later, more specific human studies, tracing the increasing failure during the transition to adulthood were reported simultaneously by Sorrells et al (2018)⁷⁸, and by Weiler (2018)⁹⁷ — followed by a report which also noted this failure in dolphins: Parolisi et al (2018)⁶¹.

7.3.6 Interpretation and Possible-Solutions?

Maybe the flow of neurons, where it exists, is indeed no more than an initial-stockup or replenishment, as Nottebohm (2002)⁵⁶ and Rakic (2007)⁷³ suggest. — Maybe. — But ongoing memory is *SOMEHOW* conveyed from the Hippocampus to LTM in the Cortex, and the flow of any cells does rather look like a required mail-delivery (especially when it seems that cells-as-boxes may already be important for that other reason of defining schéma-ensembles; see §5.2–§5.4 above). Hence the neuron-migration in rodents and (most?) other mammals does make sense — but that “sense” breaks down for primates, so what are we to make of it?

If evolutionary nature persists with a change which seems counter-productive, then there are likely to be cogent hidden reasons. In this case such

reasons *could* be (1) need for more constancy in LTM, as Rakic suggested, or (2) some *better* method has evolved — and we might wonder what new facility primate brains have to offer which might promote such better methods.

One relevant asset may be the availability of higher meta-levels for schéma-organisation: M^2L , and (in humans) M^3L . It is not clear what difference this could make, but it might make possible more sophisticated coding such as would make broadband EM instructions more feasible, thus superseding the “mail” service by a “broadband online” arrangement. (In practice, that does not work well for *very*-large data-sets on the internet — where it is actually more efficient to record them onto a USB memory-stick, and mail it in the old-fashioned way). However maybe human complexities are such that LTM cannot cope with a mail-delivered onslaught, as Rakic implies.

As a variation of that idea, more sophisticated mechanisms could perhaps be assembled in the prefrontal cortex during infancy — mechanisms with a useful repertoire of promising *local* schémata, such that they could be invoked from afar with comparatively minimal instructions, thus making the other (high throughput) arrangements superfluous. (Maybe such developments *would* depend on $M^{\text{high}}L$ facilities).

However we can imagine that this could impose a certain stereotyped element into the mental world of adults — and some might say that this is “all too true”! Likewise it might be significant that adults find it more difficult to pick up a second or third language.

Another possibility is a flow of migrating *loose-capsids* (instead of cells), though it is far from clear how they could manage the journey. Presumably they would be ill-equipped to climb up the radial glia-strands in the way that mobile-neurons do — but it might be worth checking.

If no such method seems valid, then we had better keep looking for another solution, because adult humans surely do keep forming long-term memories, by one means or another!

7.4 Immediate-Memory to hippocampal wkM?

This is the preceding step, deferred earlier for relative lack of information, and that lack still applies. If necessary we might invoke the second step (§7.3) as a perhaps useful analogue.

However the problem seems simpler than that. Indeed the troublesome matter of major-transmission might easily be bypassed by supposing the hippo-

campus has enough independence to do some of the input-interpretation directly itself, without waiting for every report from the attention-centre. After all they are primarily operating simultaneously on the same real-time events — which of course fits with our using the term “STM” to include both.

Meanwhile it may still be possible to continue the reverse-engineering process embarked on earlier — but perhaps some additional clear data may be required first.

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