A molecular basis for Piaget's "*schème*" (memory-code): Some surprising implications

These notes **supplement the "Power-Point"** presentation
www.ondwelle.com/MolecularScheme.ppt
delivered at the
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ABSTRACT

As epistemologist, Piaget studied knowledge-acquisition within the brain, but also within scientific society. Thus we can note his equilibration outlook on scientific method and apply it in *seeking a plausible real-matter basis underlying his "scheme" — his abstract element of thought/action*. The strictness of real-matter formulae are actually very helpful in narrowing the possibilities, leading to the surprise overall conclusion that there is a *second mode of fast neural activity* (involving RNA and infra-red akin to modern "broadband", and that explains several enigmas), and not just the acknowledged action-potential system (akin to Morse-keys and telegraph). Evidently both systems are important.

In detail, the provisional conclusions were:

- There must be stringlike *1D knowledge-coding* independent of the simultaneously-operating synapses!
- This text-like 1D-coding must be "RNA-like" (as considered by Piaget).
- The 1980s rejection of RNA was based on the false premise that such RNA could only act via synapses.
- Such *molecular* coding would require an alternative intercommunication method — almost certainly short-range Infra-Red (IR). Hence mysterious "ultraweak" escaped-emissions known since 1923.
- Myelinated nerve-fibres are the right size and shape to double as coaxial IR-cables!
- The RNA basis neatly explains inherited behavioural traits; but anyhow:
- all traits are seen as subject to mutation-and-selection.
- The huge population of candidate schemes now allows for radical trial-and-error anticipation instead of "tape-recording" — even during conversations, etc.
- Traffic management (a huge task) is possibly the main role for the synaptic system.
- The supposed presence of orderly IR offers solutions to some long-standing enigmas in growth-control theory.

(See www.ondwelle.com).

Topics: Piagetian theory, Epistemology (ToK), Scientific Method, Neuroscience, Theory of the Mind (ToM)

I. Piaget as Primarily an Epistemologist — a Knowledge Theorist

(a). He is best known for explicating how knowledge develops in the •*Brain* — our main concern in this paper.

(b). However he was also concerned to fix how •*Science-&-Society* seek knowledge —
and that is where we start here.

(c). (In fact there are at least *four*[1] such epistemological domains which offer helpful analogies about each other. Two others of interest here are •*Immunology* and •*Darwinian evolution*.)

II. Brain/Intelligence Theory as a problem in Scientific Epistemology (a Social issue)

(d). Note the unhelpful *vagueness* of psychological concepts (like "ego", "motive", or indeed "scheme"). Is there a cure for this vagueness? — something more definite and structure-based?

(e). Popperians and positivists emphasize direct observation as a path to such truth. But according to Piaget[2,3] these "*logisticiens*" are naïve: (They unwittingly take certain "useful" notions as axiomatic, though they should be analysing those notions too.)
Such overzealous empiricism is also particularly obstructive whenever observation is actually impossible (as in seeking details of thought mechanism — our concern here).

[1] •Popper, K.R. (1975/1994) "The rationality of scientific revolutions"; in Rom Harré (ed.) (1975) Problems of Scientific Revolution. Scientific Progress and Obstacles to Progress in the Sciences. Clarendon Press: Oxford. And there is also a more tenuous case for including *many other* domains: •Wikipedia (acc.12/12/2011) "Universal Darwinism".

[2] Piaget. J. (1949) *Traité de Logique*, Collin/Dunod. Introduction: "…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 logistique." I.e. "Whenever one reads the main 'logisticiens', such as Russell, Wittgenstein, Carnap, etc., one quickly realizes that they all depend on certain intuitions: — intuitions which are taken for granted, exactly in proportion to the extent that they evade verification."

[3] Piaget, J. & R.Garcia (1983/1989) *Psychogenesis and the History of Science*. Flammarion:Paris/Columbia University Press.

(f). Theory is the dialectical alternative used within this study, and that is where we need to work within the domain of *Social/Scientific epistemology* — seeking equilibration amongst all available evidence.

(g). In such theory-building, the immediate aim should be to find an "extensively plausible" model — if only as an "Aunt Sally" to be attacked and improved upon.

Thus Ptolomaic astronomy was technically wrong, but it did at least offer a definite model; and when Galileo etc matched reality against that model, various anomalies became clear. Such anomalies can then be a powerful incentive toward future progress — provided that we are prepared to *acknowledge the anomalies and adjust our thinking to this new task.* (Scientific "accomodation", not just "assimilation"!)

Piaget & Garcia[3] (Chapter 7) offer a fairly detailed explanation of this evolutionary development of theories — involving an interplay of "theoretical" and "empirical" concepts (and the somewhat fluid definitions distinguishing these terms!). I commend their account for consideration, but I will not go further into it here. Instead I have modified their diagram *just to emphasize my point that theories* ***often do evolve*** in this way — and I have simplified their *complex* of arrows into nondescript two-way arrows (⟺).

III. Brain Theory rethought, applying Info-tech Theory, Physics, and Epistemology

(h). Helpful theory needs: ●relatively-stable elements, ●discernable interaction between them, a ●holistic awareness, — and ●not so many possible-solutions that we are overwhelmed; (easiest if there is only one real solution, but the trap is this: Nature is often unexpectedly more complex!). — Plus ●testability of some sort (be it Empirical, **&/or** Tests for self-consistency within a comprehensive model).

All P&G's examples[3] seem to be taken from those traditional "hard sciences" (*Physics, Maths,…*) for which it is easy to identify well-defined basic elements such as particles or certain reliable formulae.

In contrast, the purpose of this present paper is to apply such theory-handling methods to a "new" field *without* clearcut basic elements. That challenging field is **Piaget's own concept of Mental-activity**. At least Piaget did offer such an *in-principle* element (the "schème", as an encoding of some element of action) — but he left it as a somewhat mysterious *abstract* entity. Further progress surely requires a physical interpretation of that schème — and as empirical lab-work alone is unlikely to enlighten us, one is forced to use the above-mentioned theoretical approach (whilst acknowledging its fallibility).

(j). Piaget's potentially stable element-of-thought is the *"Schème"* (*each a hypothetical encoding for some specific action-sequence*, whether internal or external, overt or covert, genetic or "learned").

There has been some ambiguity about the "Schème and Schéma" terminologies (see "*Thinking by Molecule…*", pp.21-22).[15] In particular, there is occasional confusion over whether such words imply
{1} *single* elementary encodings (for which I suggested "Taton" as an explicit alternative-name),
{2} *a composite* of such tatons, linked such as to "sketch" something more complex such as a profile (and the word "schéma" is best used here); or, as we shall see shortly:
{3} a "chorus" of nearly-cloned Tatons.

As our present need is to identify *basic elements*, we should obviously focus on case {1}, the "Taton".

(k). Topology of the scheme: Action-sequence as a "**list**". Also Piaget implies such 1D coding — (and he *did consider* RNA as a possible physical embodiment).[4,15]

(L). Advantages of 1D (one-dimensional, text-like) coding:— ●compact, ●economical, ●easily-scanned,●copiable, ●manageable-transmission-paths (usually just in/out), ●it can coexist with 2D/3D coding or even embody them (as in TV); — and as a precedent: ●1D-coding is used in *all the three other* knowledge-systems listed above.

In brief, *that 1D-property* gives us a provisional model-element — a template for assessing available *physical structures* as candidates for the role of elementary-schème (alias "taton"). Our safest first-choice will then be the one which generates *the fewest unsolved anomalies* when we try to fit it into the total picture. — And if that eventually gets us nowhere, we can just backtrack and start again.

[4] Piaget, J. (1967/1971). *Biologie et connaissance: Essai sur les relations entre les régulations organiques et les processus cognitifs*. Gallimard: Paris — *Biology and Knowledge*. Chicago University Press; and Edinburgh University Press.

IV. Implications and Consequences

(m). Physical 1D schème-candidates: RNA has **the best** "text-like" properties: — flexibility, some largely-forgotten direct evidence! (e.g.Hydén[5]), and now up to "97%" availability[6] as *ncRNA*;[7] … etc.

Other "RNA-like" scheme-candidates would be: DNA, PNA, and Proteins — and much of the following discussion could apply to them (instead of RNA) if subsequent investigations require that.[8]

> But what about that obvious "text-book" candidate: *a string of whole neurons and their synapses?*
> Clearly these orthodox effects are crucial to the last stages of muscle control (or the first stages of sensory perception); so at that level, we might expect at least some "schèmes" to be encoded as whole neurons. Indeed there is some recent evidence to justify that idea, at least regarding reflexes etc., (e.g.[9]). —— Note that these have (until now) all apparently been **outside the brain itself**, in the Peripheral Nervous System (PNS), as we might have expected; and also note hints that they are relatively inflexible.
>
> Are these PNS "schèmes" comparable to those other schèmes discussed above as providing advanced intelligence in the CNS? In one sense, yes: If they formally resemble *1D lists* we can still think of them as schèmes — but such schèmes would probably be of a different type, constructed differently, and be below the sensorimotor "ground floor" of Piaget's hierarchy. Thus if we express the successive Piagetian levels (starting with sensorimotor) as: M^0L, M^1L, M^2L, M^3L, …,M^nL, — then the "brute force executive" schèmes "in the basement" would have to be $M^{-1}L$, and maybe even lower.[10, 16]
>
> In this context, the taton emerges as the most basic "list" within sensorimotor (M^0L), but having the job of triggering or controlling those executive neuronal "machines of action" in the PNS. This may leave some doubt about exactly where the "class boundary" might be.
> However that detail is hardly relevant to the present discussion which is mostly concerned with advanced thought: — those levels of the hierarchy for which all activity is within the brain proper, and probably in the cerebral cortex.
>
> (Meanwhile it would be wise to remember that even the CNS is obliged to perform other tasks, — not only the intelligence task considered here. That would probably generate some of the inconvenient complexity and ambiguity mentioned at the start of section (h).)

Returning now to that question of advanced thought.
If we tackle it using information-technology and physics, then the synaptic arrangement is just not credible as a medium for our 1D logical thinking (despite its proven value for 2D pattern-recognition etc., a rather different skill).

For building sophisticated hierarchical organizations, the synaptic model has just too many anomalies: •vague local coding (analogue rather than digital?); •inefficient waste in using a whole synapse-or-cell, when a molecule could be better; •the need to inactivate most of the usual dendritic branches; and •no proper explanation for how the necessary dynamics would be driven.
In any case, •no-one seems to have observed such stringlike structures in the CNS (though of course that could change).

This then, is one of those cases where
an anomaly forces us to re-examine existing assumptions.

(n). The independent pre-1980 enthusiasm for RNA (based on assays, by Hydén[5] etc.)

But at that time, the theory was encumbered by:
(i) the questionable assumption that it must relate directly to synapses, and
(ii) a bizarre extra speculation that the supposed RNA-memory could be transferred to other individual animals via injection or ingestion.[11]

The RNA issue faded unjustly when the two (irrelevant?) effects failed to find convincing support, and presumably also because the related concepts did not really "cohere" as a sensible self-organizing system.

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[5] Hydén, H. (1967). "Biochemical changes accompanying learning". In G.C.Quarton, T.Melnachuk, and F.O.Schmitt (eds), *The Neurosciences*, pp.765-771, 913, 914. Rockefeller University Press. — *etc.*

[6] •Mattick, J.S. (2001). "Noncoding RNAs: the architects of eukaryotic complexity". *EMBO Reports* **2**(11), 986-991. http://emboreports.npgjournals.com/cgi/content/full/2/11/986
•Mattick, J.S. (2003). "Challenging the dogma: The hidden layer of non-protein-coding RNAs on complex organisms" *Bioessays*. **25**, 930-939. www.imb-jena.de/jcb/journal_club/mattick2003.pdf

[7] In 2001 it became clear that only 3% of RNA fulfilled its "textbook" role of producing protein! Some of the remaining 97% has been claimed as "regulators", but the rest still seems available for such tasks as memory. — Indeed memory systems might perhaps be classified as just a special type of "regulator"!

[8] Moreover our choice *need not be exclusive*: It is possible that there could be a *combined effort* from (say) epigenetic switching on the DNA which then biases subsequent RNA scheme-coding (which might then be subject to "mutation" in its own right).

[9] Hooper, S.L. (2001) "Central Pattern Generators" *ELS Online*: http://crab-lab.zool.ohiou.edu/hooper/cpg.pdf

[10] Traill, R.R. (1978/2006). *Thesis*, [Sections C3.1 and C5.4] www.ondwelle.com/Mol-Intel-C1-5.pdf

[11] That is clearly a separate issue. Such drastic "surgery" could upset an unpredictable proportion of the normal effects — especially wherever the encoded memory actually depended on its exact geometrical position. In fact that spatial dependence seems quite possible if optical effects are involved — *ibid.*, [Section C8.1 (Espec. Fig.C81./7)] www.ondwelle.com/Mol-Intel-C8.pdf

(o). So, **a suggested policy change**: De-throne the synapse as *the* supposedly-key memory element (at least regarding intelligence) and replace it with the "RNA-like" scheme. [Likely remaining roles for synaptic systems include:
•Contact with the outside world (obviously!);
•Pattern Recognition, and •"Directing Traffic"].

V. Two Anomalies which Challenge the RNA-Schème Model

(p). An *individual RNA-string would not be reliable*, (and probably not stable either):—
So an actual scheme would probably need to be *a near-unison "chorus" of nearly-cloned elements*.

Note 1: This problem would arguably also apply to any similar *synaptic-string* model. So it would need our attention anyhow!

Note 2: It seems possible that honing a skill such as diction or piano-playing could consist of *building up the population* of such chorus-sets, and adjusting their precise relative-timing. Moreover it should not be too difficult to envisage plausible mechanisms causing such proliferation during repeated practice.

Note 3: Single uncorroborated taton-elements would usually come to be a nuisance, so the fact that isolated RNA molecules are only moderately stable could be very useful as *a forgetting-mechanism*.

On the other hand, we would want to retain any sufficiently large "chorus" of such elements as being a useful memory of the relevant 1D coding. Thus it would be very useful (and a typical biological trick) if any sufficiently large chorus-ensemble were to gain *collective stability by virtue of their intercommunication &/or proximity-effects*. Presumably there is not yet any evidence that this occurs, but it might serve as a useful working hypothesis.

(q). Consider the traditional action-potential, (the millisecond "voltage-spike" signal along a nerve-fibre). This pulse is much too coarse for routine intercommunication between RNA-based molecular sites. The only plausible alternative turned out to be IR (Infra-Red) signalling[12] — usually very short-range (about 20 μm) unless it can use a fatty medium. In particular, it just so happens that the physics and geometry of myelinated (fatty) nerve-fibres seem appropriate as coaxial cables for IR signals[13] (in addition to their accepted role) — and later evidence has seemed to validate this notion,[14] though more such experimental evidence would be welcome.

Moreover this has had promising unforeseen "broadband" implications[12] — and in general it looks as though responding to the challenge of this anomaly has been rewarding. But ultimately, time will tell.

VI. A New Vista of Opportunities: Darwinian Read/Write! — and the special design-power of Piaget's Stages.

(r). The focus-shift from synapse to molecule offers a **vast increase** in memory-capacity and precision:

The huge number of elementary code phonemes: We can estimate that synapses are 1000-times the diameter of RNA code-sites (about 2 *microns*, and 2 *nm* respectively). This then suggests RNA sites should offer a **10^9× times more efficient use of volume**, (or more if we take precision into account). ——. Thus if there are 10^{14} synapses, and we suppose an equal allocation of volume to each of the two systems, then the RNA system should consist of about 10^{23} coding elements — though of course such an equal allocation of volume might not be needed.

The speed and efficiency of signal transmission: The traditional action-potential pulse lasts about 1 millisecond (10^{-3} sec) whereas a typical 3 micron wavelength of near-IR passes in 10^{-14} sec — about **10^{11} times faster**, with correspondingly better capacity to carry signals with high megabyte-rates. Even making allowances for significant error, and the possible need to count perhaps 100 wavelengths to make up a signal "phoneme", that hardly affects the apparently *huge advantage* of IR-signals over the text-book account — except where IR would not be satisfactory for other reasons.

[12] Traill, R.R. (2011) "Coherent Infra-Red as logically necessary to explain Piagetian psychology and neuro-microanatomy — Two independent corroborations for Gurwitsch's findings, and the importance of coherent theory". *Journal of Physics: Conference Series*, **329**, 012018. [Prague conference: *Electrodynamic Activity of Living Cells*; (1-3 July 2011)]. [doi:10.1088/1742-6596/329/1/012018] http://iopscience.iop.org/1742-6596/329/1/012018 .

[13] Traill, R.R. (1988). "The case that mammalian intelligence is based on sub-molecular memory coding and fibre-optic capabilities of myelinated nerve axons". *Speculations in Science and Technology*. **11**(3), 173-181. www.ondwelle.com/OSM10en.pdf .

[14] Yan Sun, Chao Wang, & Jiapei Dai (2010, Jan). "Biophotons as neural communication signals demonstrated by *in situ* biophoton autography". *Photochem. Photobiol. Sci.*, **9**, 315-322.

Taken together these drastic enhancements enable a ***radical Darwinian strategy of selecting*** from the nearly infinite host of candidate schème-thoughtlets — and (as in DNA mutation), not actually "writing" anything at all! This sidesteps the "too hard" enigma of how memories could be *written-down* as if by tape-recorder. Instead[15,16] it is now a question of *selecting* from the vast population of random candidate-schemes; (as in •*Immunology* and •*Darwinian evolution*), but much faster due partly to the smaller sizes involved.

(s). We can now see a close parallel between the four epistemological domains: (from "Table S", p.31 in Ref.[15]). Note that all now depend, at least partly, on (i) 1D code strings, (ii) Darwinian trial-and-error, (iii) a reality check against their outside world ("external coherence"), and (iv) a self-consistency check of their internal world ("internal coherence" or "equilibration").

(t). Non-random **design-ability** is sometimes possible, (meaning "deliberate" though *not* necessarily conscious and probably not inheritable); but it requires one epistemological domain to interfere with another.

For example:—

(u). Piaget's stages offer this sort of inter-domain interference. E.g. a "*Pre-operational*" scheme would normally be busy influencing the activity of (lower level) *Sensori-motor* schemes — the first step in developing intelligence.

VII. Intercommunication — Some unforeseen byproduct explanations from this batch of theories

(z). Details via website *www.ondwelle.com* and its links — and foreshadowed above in section **(q)**.

APPENDIX

Items which may be of some interest, but which were edited out of the live-presentation

(i). Start-up knowledge-acquisition "from zero" (in any of the 4 domains) seems to have *only one* plausible solution[16(Chapt.4)]:— That is the trial-and-error strategy, as best known in Darwinian-evolution contexts.

XX. Possible dynamics: The supply, randomizing, building and maintenance of schème systems

(v). This is rather more speculative, but is guided somewhat by our knowledge of the *adaptable part of the immune system* (which seems to have evolved, *along with adaptable intelligence* — in the early vertebrates).

(w). As a guiding analogy: The proteins for building the antibodies of adaptive immunity are generated as "loose prefabricated parts" and then randomly assembled. Maybe something like that happens for some ncRNA strings, though it is not obvious how that might work.

More likely some *limited standard range* of "default coding" is produced and then [1] subjected to likely "mutation" — &/or [2] randomly allocated to this-or-that "group", which then might (by chance) become an effective "chorus".

(x). In any case, various epigenetic "switch-settings" of the DNA &/or its histone-support may well bias the type of "*limited standard range*" ncRNA available as raw material for schemes — thus perhaps biasing mental development according to maturation, etc.

(y). There may be scope for altering-or-replacing individual ncRNA elements already installed in a scheme-structure — as part of an "accommodation" process.

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[15] Traill, R.R. (2008). Thinking by Molecule, Synapse, or both? — From Piaget's Schema, to the Selecting/Editing of ncRNA. *Gen.Sci.J.* http://www.wbabin.net/physics/traill2.pdf [French version: www.ondwelle.com/FrSM02.pdf].

[16] Traill, R.R. (1999). *Mind and Micro-Mechanism: a hunt for the missing theory*. Ondwelle: Melbourne. http://www.ondwelle.com/BK0_MU6.PDF ISBN: 0-9577737-0-6 — **§4.2**, and (p.26) **§5.3**.

