How Popperian positivism killed a good-but-poorly-presented theory — Insect Communication by Infrared

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This paper is part of a project to find *sound biological explanations for human mental abilities*. The project soon split into two streams: .

STREAM 1 focussed on realistic *coding-mechanisms for memory* — an area in which lab-work can only scratch the surface, hence rigorous inter-disciplinary theory was invoked instead. This led to strong suggestions implicating *molecular* coding — ideas consistent with the theories of *Piaget* and *W.R.Ashby*.

STREAM 2 emerged as the parallel problem of *intercommunication* — but it's solutions then unexpectedly also offered explanations to other "unrelated" problems! (Moreover, lab-testing of *these Stream 2 ideas* is much more feasible, so we might now hope for such future investigations).

A **summary of the whole project** is now available: http://www.ondwelle.com/OSM12.pdf . 1-1-10

Minor Adjustments, 31 August 2008:
(1) Additional References which were not readily available in 2005, here marked dark-blue; — (2) "Housekeeping" updates, mainly on this page; (3). Type-enlargement etc. within tables to make them more readable. This includes a *link to an Appendix* which offers an alternative much-enlarged "Main Table" (Table 4.1): www.ondwelle.com/OSM03Tb.pdf (sorted three different ways)

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Two Abstracts

(A) *Scientific method and knowledge-theory — positivism versus explanatory coherence.*

Science has always had the problem of a balance between theory-acceptance and theory-rejection — of deciding initially which theories to take seriously, and then which of this shortlist to actually believe, at least for the time being. The excess credulity of the middle ages led to the positivist reaction which then insisted on supposedly hard evidence at every stage. Popper's *Logik der Forschung* (1934) offered a different positivist position which supposedly accepted any theory provisionally, but then set out to *disprove* it through hard evidence.

It turns out though, that the idea of "completely hard evidence" is an illusion, and that spoils the rigour of both types of positivist argument (though confusingly, positivisms can still have practical value at a *non-rigorous* level). Meanwhile the ultimate test seems to lie instead in a rating of the "**coherence**" (the *mutual self-consistency*) of concept-ensembles which will include any recognized apparent-evidence from the outside world. This approach also underlies Piaget's account of mental activity within the individual; and both have a formal parallel in Darwinian trial-and-error with its feedback loops.

This paper examines Thagard's computerized application of this coherence-approach ("ECHO" software designed to evaluate the comparative arguments in historic scientific debates such as oxygen-versus-phlogiston, and Darwinism-versus-creationism). It also considers acknowledged problems of applying ECHO to current unresolved research, notably the "Abstract (B)" example of column 2. The difficulty appears to lie in inadequate provision for hierarchies of concepts and for the gradual-and-piecemeal acquisition of concepts in real life, (though other unexamined Thagard work may perhaps deal with these issues). Meanwhile there may be value in applying some features of Piaget's biological "equilibration" formulation of the same epistemic problem in its own context.

(B) *Callahan's theory that insects navigate using infrared — a casualty of that positivism.*

P.S.Callahan, an entomologist with wartime radar experience, noted an extrordinary set of similarities between the strange shapes of radar/microwave aerials and those of the knobs, hairs, and spines on the outside surface of insect-bodies. This suggested a similar function in insects, but using the appropriately shorter *infrared* wavelengths. Meanwhile Fabre (publishing 1879-1907) and Laithwaite (1960) noted an uncanny long-range empathy between insects, even when the wind would have blown any scent-signal molecules away — apparently leaving electromagnetic signalling as the only possible means for this contact. Taking these facts together, explanatory coherence suggests an obvious common solution, but there was a *lack of hard evidence*, and a lack of explanations for the *logistics* of this feat.

Callahan proceeded to produce hard evidence — almost enough even to satisfy positivistic criteria. Unfortunately though, he also got bogged down in contests about short-range chemical-olfaction-theories which were (*needlessly*) seen as competing with the infrared account. In this, Callahan made several theory-mistakes and dubious extra claims which were exposed in the 1977 debate, and the whole theory was then abandoned by biologists.

Logically this need not have happened. If one accepts Laithwaite's advice and detaches this short-range problem, then the remaining long-range problem is comfortably solved theoretically, just using the available evidence — *vindicating Callahan's main thesis* on infrared-and-aerials!

Here Popperian policy was detrimental, though mainly indirectly: firstly by downgrading the obviously persuasive original analogy with radar-aerials; and secondly by encouraging a sense of finality after the debate — thus disguising some rather slipshod reasoning on both sides, and some rather careless editorial management.

1. Introduction

In the 1960s and 70s, P.S.Callahan promoted the idea that **infra-red** (IR) was the key medium for insect communication and navigation; and given the now-prevalent use of IR for TV remote-controls and for burglar-detection, this concept would be less surprising today. However, in a sudden-death debate in the *International Journal of Insect Morphology and Embryology*, the whole idea seemed to have been vanquished using quantitative physics arguments plus the tacit Popperian notion of the merits of heroic disproof. So the IR idea seemed to be dead, or at best consigned to footnotes — and apparently that was the end of the matter! (Callahan, 1975, 1977a; Diesendorf, 1977a, 1977b).

In retrospect though, one might find the finality of this conclusion open to question.

Firstly there has been an extensive rethink about *epistemology* (how knowledge is-or-should-be gained) — starting with the revolution due to Thomas Kuhn's book *"The Structure of Scientific Revolutions"* (Kuhn, 1962/1970). Naturally though, it took some time for such new thinking to be accepted; indeed I have previously suggested that 1978 marked the turning point in such expert opinion — just too late for the Callahan debate. (Ayer, 1978; Traill, 2000, footnote 6). As Thagard later put it: "*Typically, scientists do not react to failed prediction by abandonment of their theories, but instead try to adapt and improve them. A Popperian scientist (if there were any) would be like a person who threw a car away because it did not start one morning. Scientists typically abandon a theory only when one with greater explanatory coherence comes along."* (Thagard, 1992, pp95-96).

In the abovementioned debate, it seems to me that Diesendorf's criticism did indeed result in the whole "car" being thrown away. A close look shows that repairs were certainly needed, but surely not an automatic trip to the scrap-heap. One better approach which the editors might have used, would have been to withhold publication until the antagonists had actually got together and analysed their differences, perhaps with the help of a mediator. — A notable francophone precedent for this can be found in the "forced"-collaboration in the book: *"Mathematical Epistemology and Psychology"*;[1] but maybe that would be too extreme for the adversarial anglophone community. A different-but-compatible approach is could possibly be found in Thagard's algorithms for assessing the "explanatory coherence" of scientific concepts — (Thagard, 1992), of which more later.

The second reason for doubting the wisdom of killing off Callahan's IR theory, is that Diesendorf's criticisms may have applied to mere incidentals of the overall theory. By 1975 Callahan's account had grown to include a whole accretion of subsidiary hypotheses; and these tended to be increasingly jumbled up together, with the original rationale less apparent. This meant that any critic with limited study-time was virtually forced to rely on the latest versions, and treat their account as a packaged whole. In turn, this meant that any fallacies would tend to sink that whole interrelated argument, good-and-bad alike — and of course that fitted all-too-neatly with the Popperian sudden-death formula.

In this, Callahan seems to have been partly the author of his own misfortune. Not that there was necessarily anything wrong with ideas A, B, and C,... ; nor need they be kept separate as long as the reader can see clearly *that they are distinct points*; but their presentation has often seemed somewhat arbitrary, so that any logical connection is obscure. That not-uncommon fault may in itself be forgivable, but when it happens to be mixed with real-or-apparent erroneous concepts X, Y, and Z, then their author is simply asking for rejection even if that is technically unjust. Understandably then, Diesendorf

[1] Beth and Piaget (1966). Here, on *pages xi-xii*, Piaget writes :
"In 1950 I published a work on the operational mechanisms of logic ...: Beth criticised it very severely in the journal *Methodos*. Father Bochenski, who had requested this review, refused to publish my reply, which I then reduced to a few lines, saying, in effect, that if two authors fail to understand each other because their points of view are so divergent, the only way of achieving some useful and objective result is for them to co-operate in the preparation of a joint work, where the same data are investigated one by one until a mutually satisfactory assimilation of their positions is reached.
It was along such lines that ...... ten years later we were able to publish this present volume together."

identified the X-Y-Z defects, but failed to extricate the wheat from this chaff — perhaps leaving us the poorer for a generation or so.

Thirdly it seems bizarre to kill off any plausible *explanatory theory* when it has no known rival.[2] Surely even a questionable theory is better than none, as long as we acknowledge its provisional status. That way we do at least have a tangible target to aim at, a benchmark for hopefully better models, and a tool to aid technology even if empirical corrections are needed. After all, physics has no such reticence in working with some rather preposterous notions such as: wave-particle duality, universe-doubling at decision-points, and some aspects of relativity. These ideas need not necessarily be fundamentally correct, but they may have some *pragmatic value* meanwhile. And perhaps we could even say the same of Ptolemaic astronomy or the phlogiston theory — though only *before any better ideas were available*.

1.2. The double aim of this paper: Specific science, plus Method

As the title implies, we are here concerned with two separate issues: About 55% of the concern is with ***Scientific Method*** (or more generally with *Epistemology*, the theory of knowledge-acquisition, which also includes Brain theory).

The remaining 45% of our concern then will be to come to some reasonable ***scientific conclusion*** about insects and their communication capabilities — a conclusion which might perhaps do better justice to our picture of reality.

2. Some conventions and definitions used here

2.1. Some ambiguities due to the mixing of disciplines: "coherence" and "antenna"

Coherent (or **Coherence**): (1) Within *epistemology* it entails *forming a self-supporting ensemble of concepts*. However for *physics*, the meaning is quite different: (2a) Within *normal textbook physics* it usually means that all quantized waves in a beam of radiation are in phase across any cross-section of the beam. (2b) For *nanophysics or biophysics* it might be better replaced by the term "controlled-phase" — since here we are likely to be envisaging a complex interweaving of "sub-beams" which will produce special reproducible effects *if* the respective parts of the complex have a well-coordinated phase relationship. Callahan seems to have had trouble making this (a/b) distinction consistently, as we shall see.

Antenna: (3) Within biology, especially entomology, it obviously refers to the anatomical "feelers" on an insect's head. (4) Within electronics theory it obviously means the device for collecting-or-launching electromagnetic waves in their transition between "circuitry" and "free-space". To avoid the ambiguity, I shall use the synonym *"aerial"* for such devices. Thus we may speak of "an antenna possibly functioning as an aerial".

2.2. Symbols identifying the main works of the debate

The debate itself was in four papers published in this order: Callahan (1975), Diesendorf, (1977a), Callahan (1977a), Diesendorf (1977b). Here such annotation seems unduly cumbersome, so it may be helpful to label them instead as /1\, /2\, /3\, /4\ respectively. However some other works are understandably also important, and I label these /*\, /t\, /0\, as follows:

[2] The trap here is that *there are rival* "smell-detector" theories for *short-range* targeting. However there is no credible alternative when we look at long-range effects, as we shall see shortly in section 3.

/*	Callahan (1967), *Miscel.Publ.Entemol.Soc.Am.* **5**, 315-347; (perhaps his **best** account[3])
/0 *or* **/D0**	Diesendorf *et al* (1974) *Proc.Roy.Soc., B*, **185**(1078), 33-49
/1 *or* **/C1**	Callahan (1975) *International J.Insect Morph.&Embryol.*, **4**(5), 381-430
/2 *or* **/D2**	Diesendorf (1977a) *International J.Insect Morph.&Embryol.*, **6**(2), 105-109
/3 *or* **/C3**	Callahan (1977a) *International J.Insect Morph.&Embryol.*, **6**(2), 111-122
/4 *or* **/D4**	Diesendorf (1977b) *International J.Insect Morph.&Embryol.*, **6**(2), 123-126
/t	Callahan (1977b) *Tuning in to Nature*; (informal popular book, revealingly anecdotal).

3. The main issues regarding insect navigation

(a) There is an *extraordinary similarity in shape and electrical properties* between (i) the repertoire of aerials used in commercial-or-military microwave installations etc, and (ii) the innervated knobs, spines, and pits on the exoskeletons of insects and other arthropods. How can we account for this widespread-or-universal similarity unless they are serving fundamentally the same function of transmitting-or-receiving electromagnetic signals of some sort? And judging by scale, this would likely be infrared for the insects. (Callahan 1967, 1975, 1977b — *i.e.* /*\, /1\, /t\ — respectively).

(b) Fabre (1907/1912) and Laithwaite (1960) reported how some male moths can "smell out" their female target *over long distances — even when the wind is blowing any scent molecules away* from the males! — How could they possibly do this long-range targeting? By simple *elimination* it seems that this *must operate via electromagnetic waves*, and almost certainly that implicates infrared. Moreover such elimination arguments seem persuasive no matter what Diesendorf or Popper might say about any lack of further evidence — unless, of course, they could suggest a credible alternative which might upset the *single-explanation* status.

(c) *At short range* the situation changes because then it also becomes feasible to detect the concentration-gradients of odours — either directly as a distance-gradient *d/dx*, or as an increase/decrease over time *d/dt*, like the bacterium *E.coli* within its aqueous environment (Alberts, *et al.*, 1983, p758) — or other more esoteric mechanisms[4]. It is this choice of several short-range possibilities which cause much of the confusion in the debate — and much of Diesendorf's criticism is at this level.

(d) *Long-range versus short-range — Subdividing the study-area, and selecting the most-tractable part:* Laithwaite draws the line at about "100 yards" — *91 metres* — which seems reasonable. As this marks the distinction between a neat approach for the *long*-range — and disordered confusion in *short*-range theory, it is surprising that more advantage has not been taken of this distinction. Long ago Lamarck[5] (1809) advocated the advantages of first studying the simpler cases within zoology. This reduction in the number of variables should offer an obvious benefit, and yet most of the workers in this field, including Callahan, seem to have concentrated on the complexities of short range. (Perhaps to them the short-range *seemed* simpler — more familiar, closer to the human odour-seeking experience, easier to fund, and yielding more(!) data). However I choose to benefit from Laithwaite's boundary by

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[3] before he got too deeply into side-tracks of dubious relevance.

[4] such as the *varying frequency* emitted from nearby scent molecules (/t\, p187). Incidentally, this is one of those occasions where Callahan needlessly shoots himself in the foot, though it was probably published too late for Diesendorf to criticize it. The model may be reasonable, though it is not clear that it is anything more than hypothetical. (It depends on the emitted fluorescent emissions from pheromone-scent molecules varying in frequency depending on the local concentration, and therefore indicating proximity to the target). As the method apparently samples molecules over a somewhat extended local region, it might well average out some of the gradient-irregularities which Laithwaite mentions as one obstacle to long-range gradient targeting. However, even if this system does work, it is still hardly credible over the really long-range cases mentioned by Fabre and Laithwaite even if the wind were favourable. Nothing daunted, Callahan simply *denies* their data, and indeed implies that his frequency-measure system is the only viable one for all ranges! (/t\ p189). — That system does supposedly involve infrared, but in a somewhat heterodox way which surely does little to convince doubters.

[5] Lamarck's work tends to be underrated, perhaps because his name was somewhat unfairly coopted as meaning "anti-Darwin". Insofar as he did believe in the inheritance of acquired (learned) characteristics, then he was simply a creature of his time, and it was somewhat incidental to his main agenda.

concentrating on the long-range issue — mostly leaving the short-range issues aside. Thus, in a stroke, one can circumvent much of Diesendorf's criticism as irrelevant to the long-range issue. One is then free to benefit from his remaining comments about an infrared phenomenon which surely takes place at long-range *somehow*, regardless of his objections.

The main remaining questions then involve the logistics — the details of this presumed infrared transmission which is to serve as a "lighthouse beacon": (e) What device actually *emits* it? (f) Where does its *energy* come from? (g) How is it *modulated* so that it can be recognized for what it is amongst the random noise and the competing signals of other species? — And at the reception end: — (h) What is the relevant *reception aerial*? (i) How is the message conveyed to the *c.n.s.* (central[6] nervous system)? and perhaps the old neurological problem of: How does the c.n.s. then produce relevant *behaviour*? Meanwhile, (j) Can such systems prevail against the signal-noise of their environment? — and (k) Can they cope with absorption bands in the atmosphere, which block out certain frequencies?

4. Hypotheses, facts and evidence bearing on these issues

4.1. Introducing the Table of Propositions

It may be instructive to look at a reasonably comprehensive list of such propositions relating to the debate, to see what sense we can make of them. In the following table there is a list of 95 items, including some deliberately contradictory hypotheses (in the spirit of *competition between rival theories*), and three sets of multiple entries in a half-hearted attempt to cope with the complexities of "all/some/none" (as expressed in logic by "∀" and "∃") — viz. items 7-9, 11-14, 3-4. Each item is identified both by a number from 1 to 95 (columns "#" and "#2"), and also by a three-character mnemonic in the "mn" column — both allocated somewhat arbitrarily.

In the "References" column, details are often given in the form *"p135c2.7"* or *"p135.7"*. Here the "c2" means *column 2*, and the decimal figure (0-to-9) suggests how far down the page one should look. "NEW" indicates new suggestions which are introduced here for the first time.

Many of these propositions may seem to be irrelevant, at least for the time being, but that surely is the nature of any investigative enterprise at this comparatively primitive stage. The real-life task is like a large jigsaw puzzle, but with extraneous foreign pieces added as if to mislead us, and no doubt there will be some pieces missing as well.

Here the items have been sorted into three groups, *viz.* (i) to segregate out those items deemed irrelevant to Laithwaite's "long-range" targeting and hence to be largely excluded from the present discussion, as decided above in section 3(d). These items are listed in the top section of the table (defined by a blank in the "far" column) — so this is one "corner of the jigsaw-puzzle" which need not concern us for now. Also segregated, at the bottom this time, are (iii) items which are more in the nature of side-comments, metascience statements, or mere redundant duplication. They are defined by a capital letter in the "ext" column.

As suggested by the above subheading, it is important to distinguish between "hypotheses, facts and evidence" — though that is not always as easy as it sounds. Thagard's ECHO system depends on such distinctions, and with this in mind the items here are labelled in the "ty" column as: **H**ypothesis, **A**uxilliary hypothesis, **F**act, or **E**vidence — but this allocation is largely subjective, and should not be seriously depended upon. Likewise the strange entries in the "sub" column are simply sort-codes for one attempt at meaningful grouping.

[6] not necessarily as centralized as in mammals, but centralized enough to collate input and organize output.

MAIN TABLE — Table 4.1

(Here forced to fit onto one page — but see http://www.ondwelle.com/OSM03Tb.pdf for a more readable version and alternative sortings)

#	ty	mn	Description	sub	ext	nr	far	#2	References
2	H	<ch	We should distinguish 3 range-zones for any possible chemical olfaction: (A) **Contact** mol/ receptor; (B) "**Dipole-near**" (<50nm?); (C) "**Dipole-far**"			9		**2**	from standard Dipole Theory
7	H	ky2	(Almost) all insect "knobs" are lock&key contact-detectors for scent-molecules			9=		**7**	Kettlewell; /*\326c2"fit"
8	H	ky1	Some insect "knobs" are lock&key contact-detectors for scent-molecules			9=		**8**	
9	H	ky0	(Almost) no insect "knobs" are lock&key contact-detectors for scent-molecules			9=		**9**	
10	E	ky=	The immune system uses molecular lock&key contact-detectors for identification; (xyz)			9		**10**	well known
11	H	sAx	Any contact(A)-discrimination* between scents depends on molecule geometry (*xyz*) *See #2 and its nearness-categories A,B,C			9		**11**	
12	H	sBx	Some dipole-near(B)-discrimination* between scents depends on molecule geometry (*xyz*) *See #2 and its nearness-categories A,B,C			9		**12**	
13	H	sBt	Some dipole-near(B)-discriminatn between scents depends on electromagnetic *time-patterns* from the scent molecules (*t*)			9		**13**	
14	H	sCt	Any dipole-far(C)-discrimination between scents depends on electromagnetic *time-patterns* from the scent molecules (*t*)			9		**14**	
20	H	el:	Insect cuticle is capable of forming electrets			5		**20**	/*\p319
23	E	ecg	*E.coli* uses a *d/dt* gradient to find a **near** target			9		**23**	Alberts et al,(1983), p7[illegible]
33	A	d>>	For "far" dipole-range (d>λ), phase patterns are const with respect to t, so d "makes no difference"			9		**33**	**/C3**\115.1
34	A	d<t	For "near" dipole-range (d<<λ), phase patterns are **different**, *NOT absent* as Diesendorf, /D2\109.3 implies			9		**34**	NEW
44	E	dir	Wolf Spider points spines toward target			9		**44**	/*\p325, fig.14
46	E	irr	Moths have irridescence etc for IR frequencies			9		**46**	/*\p330
49	E	qm0	Some scent-atom/molec will start with excitation energy when they leave target [but ephemeral]			9		**49**	/*\p333c2.9
52	E	dk~	Wolf Spider finds prey or mate in total darkness (with respect to visible light), & without any antennae			9		**52**	/*\p326, /t\p133
57	A	#mm	Irrelevant here: how *mammalian* olfaction operates			5		**57**	/*\p341c2.3
59	E	fla	Moths follow pheromone long-range, but then candle-flame at short-range			9		**59**	/*\p343c1.4, (Fabre,1913; Shorey&Gaston, 1965)
61	A	flc	"radiation-pumping" of molecules can mislead closeup (especially near Humans), so alternatives could help			9		**61**	
62	E	fld	Despite the case for closeup homing via "2 & 3", insects *are* still misled — as if using "1" alone			9		**62**	Fabre
63	H	fl2	Use of close-up homing-method 2: "normal" incoherent-light-or-IR vision —			9		**63**	common assumption
64	H	fl3	Use of close-up homing-method 3: traditional olfaction via concentration-gradient (perhaps via some roundabout effect)			9		**64**	/t\p187
65	A	cg1	Insect's sensing of concentration-gradient is by d/dx: comparing 2+ sensors simultaneously;			9		**65**	common assumption
66	A	cg2	Insect's sensing of concentration-gradient is by d/dt: remembering + retesting — like chemotaxis in Escherichia coli bacteria			9		**66**	Alberts *et al* (1983), pp575-579
67	A	cg3	Insect's sensing of concentration is by the frequency of its nearby stimulated emission;			9		**67**	/t\p187,fig.20
79	E	mir	Mirror-walls→ increased mating-rate;			9		**79**	/*\p343c2, /t\p152
80	E	leg	RatMites detect IR (incl. specif. freqs) via setae spines on front leg-tarsals			9		**80**	Bruce (1971 jul)
82	E	mol	Enantiomeric (opt.isomer) forms of scent molecs → different responses after conditioning to one of them — in locust & bee — *cit./D2\p108.4 (#logic!)*			9		**82**	Kafka+3(1973)[*JCompPhio***87**,277;+(1971?)]
83	E	odi	Circumstantial evidence favouring contact-mechanisms for odour detection in insects, eg template "lock-&-key" fit for specific molecules			9		**83**	Kaissling (1971)
84	E	odm	Evidence (incl elimination) favouring contact-mechanisms for odour detection in *mammals*, eg template "lock-&-key" fit for specific molecules			9		**84**	Altner&Prillinger (1980), Davies (1971), Beets(1971)
3	H	ae2	All (or nearly all) insect innervated "knobs" & pits are electromagnetic aerials (capable of *time-pattern* discrimination, like TV)	b+		5=	9=	**3**	Callahan
4	H	ae1	Some insect innervated "knobs" & pits are electromagnetic aerials (capable of *time-pattern* discrimination, like TV)	b+		5=	9=	**4**	Callahan
6	F	ae=	TV, radio, radar, etc have "knobs" which serve as electromagnetic aerials capable of *time-pattern* discrimination	b		5	9	**6**	well known
15	A	bod	Some (discriminable) IR signals come from the target's body heat; (≈29)	a.		5	5	**15**	Laithwaite (1960 Jul); critic/0\34.7
16	H	bwi	Any "bod"(15) IR signal is modulated (made discriminable) by *time*-code of wing-flaps etc; [*t*-code]	a.		5	5	**16**	Callahan (1965a, ...)
17	H	ant	Whole antenna could theoretically act as an aerial for FIR (20-200μm);	b		9	9	**17**	Laithwaite (1960 Jul)
18	F	+++	Whole antenna is like a military "fishbone" aerial array for radar;	b		5	9	**18**	Laithwaite (1960 Jul)
19	E	off	Signal "switched off" soon after mating;	a			9	**19**	Laithwaite (1960 Jul)
22	E	fab	**far** detection is possible (when no scent molecules could be reaching the receptor)	a			9	**22**	Fabre, Laithwaite
24	E	pit	Grant's pits have geometry compatible with their being electromagnetic aerials;	b+		9	9	**24**	Grant (1949)
25	E	pir	Grant's pits: size is such that, if aerials, they are appropriate for IR reception	b+		9	9	**25**	Grant (1949)
26	A	pi=	Grant's pits seen as aerial types	b+		9	9	**26**	/*\p138, Grant (1949)
27	H	phm	Some (discriminable) IR signals come from pheremone molecules;	a+		9	9	**27**	Diesendorf:/D0\34.7
28	A	+sp	Energy for pheremone IR signals can come from mere black-body spontaneous emissn; [*denied by Diesendorf*]	a!		9	9	**28**	/D0\42-3
29	A	+bo	Energy-supply for any pheremone IR signals must be adequate & sustainable (≈15)	a.		9	9	**29**	/D0\44+
30	A	+ru	Some Energy for pheremone IR signals from rubbing;	c		5	9	**30**	/C3\p113.38: Q: /D2?\1[illegible]
31	F	+fl	Some Energy for pheremone IR signals via fluorescence ex blue/UV/...; ≈60	a:		9	9	**31**	/C3\p113.38: Q: /D2?\107.1
32	A	peg	Grant's "peg" = pit-sensilla, well-placed to "fire" dendrite; → action-potential spike (or TEM mode fibre-optic signal! — NEW)	b		9	9	**32**	Diesendorf:/D0\36.8, Grant, NEW
36	E	rub	Insect is "constantly rubbing" especially in humid conditions [This "must have some meaning"]	c		9	8	**36**	/C3\p112.2
37	E	vib	Oft-seen "vibrations" of antennae [These "must have some meaning"]	c		9	8	**37**	/C3\112.2 — + (C/*\321c1> 1965b[*AnESAm***58**:159-69])
38	A	oft	Oft-seen behaviour or bio-structures must have significance (else eliminated by evolution)	c		9	8	**38**	/C3\p112.2
39	H	spi	Assume any IR reception → response via action-potential "spike" **"[A]"**	b^		9	9	**39**	physiologists' standard assumption
40	E	sp#	Seems: No reported direct evidence that *IR*→action potential spikes —— [yet Callahan did find such spikes for *visible* light ("gating": see "spL" (94)).]	b^		5	5	**40**	Callahan(1968)p1425-; Hsiao('72), Diesendorf
41	F	key	Consistent phase-control could serve as callsign ID, different from noise & other signals	a`		9	9	**41**	/*\p343c1.2 (implied)
42	E	ge1	tapering & other geometry of macro dielectric aerial → match impedance free space [engineering] ≈43	b.		9	9	**42**	/*\p323c2
43	E	ge2	tapering & other geometry of (micro) dielectric insect spines ↔ macro dielectric ≈42	b.		9	9	**43**	/*\
45	E	win	Atmos windows for IR match corneal lens transmission windows	d/			9	**45**	/*\p338-9
47	E	amp	"Maser-like" Stimulated-emission can → amplification	a^		9	9	**47**	/*\p331
48	E	tow	Maser-like Stimulated-emission is very common in IR → amplification	a^		9	9	**48**	/*\p333c1; Townes(1965)[*Sci***149**]p837
50	F	co/	optical "coherence" can be partial	a`		9	9	**50**	/*\p334c2.9
51	F	co^	partial "coherence" can, in principle, suffice to override random background noise	a`		9	9	**51**	/*\p334c2.9
53	A	drx	Molecules do act as dipole aerials — (Townes, 1965; Drexhage, 1970)	d:		9	9	**53**	/*\p335c1.7; Drexhage (1970)
54	A	dco	Human retinal cones may well serve as dipole aerials — [eye oscillation — NB]	d:		9	9	**54**	Myers (1965) /*\p342c2.4
56	E	eyI	Corneal lens is an "eye" for incoherent IR — & better than the bee-eye (for visible & UV)	di		9	5	**56**	/*\p338c2
60	H	flb	IR attraction operates via "radiation-pumped molecules" — (method "1": RRT) ≈31	a:		9	9	**60**	/*\p343c2.2
68	H	cg#	Frequency of the target-female's pheromone IR emission indicates its concentration, hence how near it is. Could aid targeting.	a		5	5	**68**	/t\p189
69	F	c~3	The concentration of a scent affects the frequency of its stimulated emission;	a		9	9	**69**	/*\p175-7, 187, **211**
70	A	t&e	Spines can have dual roles: tactile AND electromagnetic	b		9	8	**70**	/*\p342c2.8
71	F	ir^	Ambient IR remains abundant at night	a		9	9	**71**	/*\p344 (eg)
72	A	irS	Ambient (incoherent?) **short**-wave-IR offers source of pumping-energy	a		9	9	**72**	Callahan
73	H	irL	Ambient (incoherent) **longer**-wave-IR constitutes **noise** which will kill the needed signals. [NEG]	a`		9	9	**73**	Diesendorf
74	E	irH	Rising Relative-Humidity increasingly kills off IR signals	d/		9	9	**74**	/*\p336
75	E	ir#	At High Relative-Humidity, insect mating etc fails to occur	d/		9	9	**75**	/*\p339c2.4
76	E	ir/	At High Relative-Humidity, arthropods spend much time wiping antennae etc (even to exhaustion)	d/		9	9	**76**	/*\p339c2.8
78	E	u&s	Strong interaction effects increase the mating-rate, [eg. UV *PLUS* pheromone-scent — see "u:=" (95)];	a+		9	9	**78**	/t\p149-162 (e.g.)
81	F	las	VisibleLight: Laser efficiency in producing action-potential "spikes" in nerves >> mere mixed-phase monochrome efficiency (by 42×),	a^		5	5	**81**	Callahan (1968)[ApplOpt7:1425-30] Bruce(1971)[*AnESAm***64**:925-31]
86	H	sp~	IR reception can be conveyed direct to the dendrite **as** natural IR, (without needing any "spike"); — then conducted on dendrite surface [RRT] **"[R]"**	b^		9	9	**86**	NEW; Schriever(1920)
88	E	res	IR → measurable response (whatever the route)	di		5	9	**88**	Callahan
89	E	nat	Natural coherence (phase correlation), eg for expts in Fresnel's day	a`		9	9	**89**	NEW (in this context)
90	A	dst	Geometry, frequency, & phase distributions (or cloud emission) — "bullseye" model	a+			9	**90**	NEW
91	F	cld	Female moths & food crops → pheromones or other chem "odours" — but which may also have significant IR-optical properties	a+		5	9	**91**	Callahan etc
92	F	wvg	Time-pattern information capture from macro-waveguide → TV demodulation etc	b			9	**92**	well known
93	F	mye	Time-pattern information capture from myelin segment → molecular demodulation?	b			9	**93**	Traill (2005b)
94	F	spL	Callahan did find action-potl. spikes for *visible* light ("gating" the IR reception throughout the antenna). — [but apparently no spikes from IR itself]	b		5	5	**94**	Callahan(1968)p1425-; Hsiao('72), Diesendorf
95	H	u:=	UV *PLUS* pheromone-scent → IR through fluorescence; [& this IR is what increases the mating rate]	a+		9	9	**95**	/t\p149-162 (e.g.)
77	H	coh	For Callahan (/*\p316+) (& perhaps Groner, his source?), "coherence" actually means *"consistent phase-control"*		D			**77**	NEW
35	A	d<x	Diesendorf /D4\125.2 "then...molecular structure"[xyz]; anyhow "sensilla shapes become irrelevant to...olfaction" cf.array		F		?	**35**	NEW: see Amoore (1971), etc.
21	H	elt	Electrets might serve as memory elements (& collectively: like a Lamarckian tape-recorder)		L	-	-	**21**	/*\p341c2.6
85	A	emp	Proof of C's ae(1 or 2 — idea of A→IR→Z) requires positively demonstrating IR→Z in absence of A. [Empirical insistence]		M	-	-	**85**	/D2\p106.6, 106.7
1	H	<yd	We should distinguish Laithwaite's 2 target-range-zones: near (<100yds), far (>=100yds)		M	*	*	**1**	Laithwaite (1960)
55	E	wHi	High relative.humidity blocks IR Duplicates irH (74) qv		X			**55**	/*\p336
87	E	lip	IR signals (as such) may travel along dendrites, thus obviating any need for Action potential spikes (& explaining why C didn't find them); Dupl 86		X			**87**	NEW
58	A	#zz	Irrelevant here: What happens when directly-destructive intensities are used?		X	5	5	**58**	/*\p341c2.4

(i) Short-range only (not discussed further here)

(ii) Long-range; (may apply to short-range also)

(iii) Metascience, remarks & dupl[n]. (some are tacitly used in the text here)

4.2. The Propositions, as used to explain Long-range Targeting

At the close of section 3, we were left with questions (e)-to-(j) about the logistics of long-range insect targeting, having already decided (as definitely as possible) that the basic medium had to be infrared. Callahan's work is a useful start, and indeed it is incorporated into the proposition list, but the ideas clearly need reworking — especially considering his preference for the short-range case, and his occasional disconcerting errors.[7] Anyhow let us now consider each question in turn:

(e) What actually emits the infrared (IR)?

These seem to be the relevant propositions here:

15	A	bod	Some (discriminable) IR signals come from the target's body heat; (≈29)	Laithwaite (1960 Jul); critic/0\34.7
27	H	phm	Some (discriminable) IR signals come from pheremone molecules;	Diesendorf:/D0\34.7
95	H	u:=	UV *PLUS* pheromone-scent → IR through fluorescence; [& this IR is what increases the mating rate]	/t\p149-162 (e.g.)
47	E	amp	"Maser-like" Stimulated-emission can → amplification	/*\p331, Einstein (1917)
48	E	tow	Maser-like Stimulated-emission is very common in IR → amplification	/*\p333c1; Townes(1965) *Sci* **149** p837

From these we might conclude:

● (#15) Black-body radiation from the insect's body would not suit at all. It would be much too feeble, and anyhow it would be indistinuishable from the multitude of other sources. — Instead then:

● (#27) Quantum emission from the female's airborn pheromone molecules[8] could be distinctive in their frequency (or frequency-*pattern*), and they might be strong enough ***if*** they can get enough energy from somewhere; — see below on both counts: (g) and (f) respectively.

● (#95) Such emissions could be expected whenever the molecules are able to *fluoresce* in response to a higher frequency radiations[9] — with incoming quanta having higher energy than those outgoing IR quanta — the "lighthouse beam" from the target.

● (#47) Such stimulated emission within a population of such molecules could, *in principle*, produce great amplification through a laser-like chain reaction. In real life, a much more modest effect might often suffice for the long-range targeting by insects, as long as any IR-sensors they had could effectively "see" the cloud of "specially coloured IR out on the horizon".

● (#48) In fact, Townes (1965) tells us that such effects are surprisingly common.

(f) Where could the energy come from, to generate these emissions?

29	A	+bo	Energy-supply for any pheremone IR signals must be adequate & sustainable (≈15)	/D0\44+
28	A	+sp	Energy for pheremone IR signals can come from mere black-body spontaneous emissn; [*denied by Diesendorf*]	/D0\42-3
30	A	+ru	Some Energy for pheremone IR signals from rubbing;	/C3\p113.38: Q: /D2?\107.1
31	F	+fl	Some Energy for pheremone IR signals via fluorescence ex blue/UV/...; ≈60	/C3\p113.38: Q: /D2?\107.1
60	H	flb	IR attraction operates via "radiation-pumped molecules" — (method "1": $_{RRT}$) ≈31	/*\p343c2.2
71	F	ir^	Ambient IR remains abundant at night	/*\p344 (eg)
72	A	irS	Ambient (incoherent?) **short**-wave-IR offers source of pumping-energy	Callahan
78	E	u&s	Strong interaction effects increase the mating-rate, [eg. UV *PLUS* pheromone-scent — see "u:=" (95)];	/t\p149-162 (e.g.)
95	H	u:=	UV *PLUS* pheromone-scent → IR through fluorescence; [& this IR is what increases the mating rate]	/t\p149-162 (e.g.)

● (#29) Such "lighthouse beacon" molecules evidently need a continuous energy supply, and not just some "skyrocket flare" as a one-off event for each molecule. Isolated molecules in the atmosphere could not carry such energy sources with them — nor call upon "landline" resupply from the target female insect either, even if she had the resources to supply such power-demands. So where could this energy be coming from?

[7] Errors such as his bizarre, though perhaps harmless, tallying of octaves, e.g. "17" instead of 10; (/*\p316c1). This is probably a sign that he has problems with logarithms (some 10-based, and some 2-based), but it is disconcerting nonetheless, and he should really have seen that some detail was amiss. The adjacent account on optical coherence might also raise eyebrows, and indeed that did provoke Diesendorf later concerning a similar account in /C3\ — see footnote 13.

[8] or, if a food-supply is the target, scent-molecules from that target.

[9] These *incident* radiations, need not all be tidy, monochromatic or coherent (though we would expect at least some such properties for the subsequent *emissions* — some of which can also serve as feedback, thus amplifying the effect). The art of handling such specifications is intimately tied up with maser-and-laser development; though here we are more concerned with systems which merely *tend* toward laser-like efficiency, and may well fall far short of being "lasers/masers" as we understand them. Callahan has much to say about "maserlike/laserlike" systems, but he could have done more to explain this comparatively faint postulated trend.

• (#28) Mere random black-body radiation (as a direct spontaneous emission signal from the molecule) hardly seems the answer for would-be emitters which must remain at approximately-normal temperatures. Anyhow Diesendorf and his colleagues go to some pains to discount any such suggestion (/D0\p43.0)

• (#30) Energy generated by rubbing-or-grooming is scarcely credible either, especially if the effect is supposed to continue for remote molecules. Callahan does invoke rubbing *for other laser-related contexts*, but he claims that Diesendorf has misunderstood him on this point: (/D2\pp106.6, 107.1; /C3\pp113, 118.0).

• (#31,#60,#71,#72) Fluorescence? Yes surely! This entails the harvesting of any readily available free-floating radiation[10] with adequate quantum energies capable of "pumping" energy into the would-be re-emitters (/C1\p422; /C3\pp117.8, 119.0). Note that for such *IR re-emission* tasks, this quantum requirement is not very demanding, since IR (especially FIR, "Far InfraRed") needs comparatively low energy per quantum. Logistically, the process may perhaps be likened to sailing — using spare energy arbitrarily provided by the winds — rather than trying to carry your own supply of fuel. Of course we humans see nothing of such IR effects, nor are we normally aware of the significant night-illumination in these frequencies, so it is easy to overlook them; however any trip to a "black-light theatre" would suggest the possibilities, with actors brightly lit up by the fluorescence of their costumes powered by the hidden power-source of ultraviolet (UV, with its higher-energy quanta). Despite Diesendorf (/D2\p106.8), I do not see it as essential that such emissions must necessarily be coherent, though I would be surprised if they were not partially so (Einstein, 1917); and any such dependable coherence would doubtless contribute toward Ashby's "requisite variety", as we shall see in subsection (g) below.

• (#78,#95) Fluorescence as an *interaction* effect. Sailing requires both sail *and* wind. Sails during a dead-calm get you nowhere, and wind-without-sail can be positively counterproductive if you are near a rocky lee-shore! Likewise the fluorescence for Callahan's insect cases requires both the pheromone *and* the higher frequency pumping radiation (e.g. UV, blue light, or NIR — for stimulating FIR). Such a logical interconnection offers useful experimental possibilities, and Callahan has taken advantage of this opportunity — establishing the effect, apparently beyond reasonable doubt. (/t\, Ch.9).

(g) How could such signals be labelled or "modulated" such that they are identifiable?

15	A	bod	Some (discriminable) IR signals come from the target's body heat; (≈29)	Laithwaite (1960 Jul); critic/0\34.7
16	H	bwi	Any "bod"(15) IR signal is modulated (made discriminable) by *time*-code of wing-flaps etc; [*t*-code]	Callahan (1965a, ...)
90	A	dst	Geometry, frequency, & phase distributions (or cloud emission) — "bullseye" model	NEW
6	F	ae=	TV, radio, radar, etc have "knobs" which serve as electromagnetic aerials capable of *time-pattern* discrimination	well known
92	F	wv	Time-pattern information capture from macro-waveguide → TV demodulation etc	well known
41	F	key	Consistent phase-control could serve as callsign ID, different from noise & other signals	/*\p343c1.2 (implied)
19	E	off	Signal "switched off" soon after mating;	Laithwaite (1960 Jul)

Identifiability is a competitive business, as any casual supermarket inspection of brand-identifiers will tell us. Here it may help to be aware of the problem at a technical level, though there seems no need to go into the matter too deeply, at least for now. Ashby (1956, Ch.11) states it as "The Law of Requisite Variety", and explains it informally as "only variety ... can force down the variety due to D [competing forces]; **only variety can destroy** [unwanted] **variety**." (Ashby's own emphasis, p207).

• (#15, #16) The primitive "morse-code" created by flapping wings could conceivably convey some useful information, though surely that would only be at short-range. In any case, on its own, it would hardly offer enough *variety* in Ashby's sense of the word. Any such contribution is thus probably no more than peripheral.

• (#90) Other likely sources of variety? — *Frequency* (IR "colour"); *time-patterned* fluctuations in this colour (frequency modulation, "FM"); or fluctuations in its amplitude ("AM") of which the wing-flapping is a crude example. *Spatial patterns ("xyz")?* — Callahan (/t\pp175-189) made much of how the emitted frequency varied with concentration, and hence potentially offered moths a "progress

[10] Note this *indirect use* of some of the black-body radiation *from the environment*; unlike the "(#28)" case.

report" when they were near the target. But consider this instead as a *long-range* sign: The IR-coloured fluorescent "cloud on the horizon" would now offer different "colours" at the centre and at the periphery — analogous to a fuzzy archery-target tending to blue at the edges, around a reddish "bullseye".[11] That trend could presumably offer a moderately useful increase in variety between the signal-codes of various species. Other more esoteric possibilities follow, and such cues will probably act cooperatively to increase the variety in a sort of multiplicative progression[12]:

• (#6,#92) The intricate coding within TV signals shows the sort of performance that electromagnetic transmissions are capable of, though of course insects will probably have discovered a different ensemble of strategies. (The TV signal does not just encode the pixel details, but other complex "housekeeping" details as well).

• (#Extra) Polarization. Understandably humans tend to overlook the possibilities of environmental cues which they cannot themselves directly detect. IR (infrared) is one such overlooked class. Phase is another and we will come to that shortly. Yet another is polarization, though we can get some feel for that if we wear polarizing dark-glasses. Polarization-sense is evidently available to insects — indeed at least one of the Diesendorf team had previously studied such polarization matters for *visible* light (Synder and Pask, 1972a,b). At first sight that might not seem to offer much useful information regarding IR emitted from molecules *with random orientation*. However the Einstein paper (1917) suggests that stimulated emissions will perpetuate (and hence often magnify) the properties of the radiation which generated that stimulation. Amongst other things, this seems to suggest that the cohort of actual emissions from a pheromone cloud will all tend have a *common polarization, whatever that orientation happens to be* — and such consensus would itself be informative within an otherwise random-tending environment. Moreover that consensus might have been biased a certain way by the original energy source.

• (#41) Phase relatedness. Holograms give a spectacular demonstration of what manipulation of phase can achieve. Theoretically one can also see the huge variety-increasing possibilities of minute adjustments to phase, as long as one has a stable enough source — at least statistically. Unfortunately the mathematics and physics of such issues turns out to be formidable. Callahan certainly has problems here[13], and I am not sure that even Diesendorf, physicist though he is, has properly appreciated the

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[11] Of course whenever there is a strong enough cross-wind, this neat *target-and-bullseye* will become a *plume-with-cusp*. The detailed implications of this are fairly obvious, so I shall not complicate matters further here by pointing them out; but please bear that in mind in later references to "bullseye" etc.

[12] Scientist with a classical training will perhaps tend to seek single mechanisms like these, and deal with them *one at a time* to see what effect they might produce; but that means closing one's eyes to the signal-variety which evolution must surely have forced onto insects in their informationally competitive environment — ensuring that they develop multidimensional IR "combination-locks" as a badge of their species identity at long-range (as well as chemical badges at short-range). The "simple frequency-test" might well have worked for investigating the very earliest primitive insects exploiting an uncluttered airspace, but as a useful scientific approach this may now be some millions of years too late!

[13] Diesendorf (/4\p125.7) says bluntly that *all* of Callahan's (/3\) statements about optical coherence are wrong. — Indeed (in /3\p115.8 *and other texts*) Callahan explicitly explains coherence in terms which make it clear that often he really just means "monochromatic" — and yet he does give a classically-correct definition in the glossary of his popular work (/t\). As uninvolved readers, we can perhaps make some progress by reinterpreting Callahan's actual *use* of the word "coherence" as usually meaning

"phase-controlled or phase-related — such that interaction between various parts of the collective beam-system will produce interesting-and-reproducible optical-interference effects". — (#77)

As Popper (in a more constructive mode) used to say, there is no scientific merit in arguing over word-meanings. Thus we should just agree that So-and-so uses word X in such-and-such a way — or bypass the issue by using alternative words. In this Callahan context, I suggest that the term "phase-related" may often be more helpful than "coherent" anyhow. (That does not necessarily absolve Callahan from any errors or inconsistencies, but it might help us to make progress despite them).

The end-lesson then seems to be that optical-coherence can be partial, and that there can be useful outcomes even when this "phase-relatedness" is less than laser-perfect — merely a statistical trend.

potential for the ultramicro effects which are likely to be involved around individual molecules. In fact there are so many theoretical pitfalls here that it would seem unwise to rely on such reasoning as a basis for a Popperian disproof, even if one still believed in the legitimacy of Popperian disproofs. However, the point in our present discussion is that this is *a rich source of variety* — available for making identification codes distinctive — and perhaps, like our spoken language, new nuances[14] can always be added such as to cope with the evolutionary demands faced by insects.

● (#19) Signal Deletion. Laithwaite noted that soon after the target female had mated, even *remote* candidate suitors quickly lost interest. This strongly further-implicates IR signalling as the probable medium, whatever the mechanism; but we might well consider possible mechanisms nevertheless. It seems likely that the pheromone cloud-of-bright-molecules would not dissipate quickly enough to explain the evidence *unless* the female had direct control of the source energy such that she could simply turn off the "main switch" — and we have virtually ruled that out above in subsection (f). This seems to suggest that there must be an actual "cancel" signal, and here are two possibilities: Firstly, the sudden cessation of pheromone-emission could leave the cloud with a relative "hole" in the middle of the "bullseye target" as seen from afar[15] — and this revised pattern could act as a "turnoff". Secondly, as a variant of this, a different fluorescent agent could be emitted, giving a new IR-colour to the central "bullseye", producing a similar overall "archery target image on the horizon", but now a more distinctive turnoff.[16]

(h) What could serve as the relevant reception aerials?

6	F	ae=	TV, radio, radar, etc have "knobs" which serve as electromagnetic aerials capable of *time-pattern* discrimination	well known
53	A	drx	Molecules do act as dipole aerials — (Townes, 1965; Drexhage, 1970)	/*\p335c1.7; Drexhage (1970)
54	A	dco	Human retinal cones may well serve as dipole aerials — [eye oscillation — NB]	Myers (1965) /*\p342c2.4
18	F	+++	Whole antenna is like a military "fishbone" aerial array for radar;	Laithwaite (1960 Jul)
17	H	ant	Whole antenna could theoretically act as an aerial for FIR (20-200μm);	Laithwaite (1960 Jul)
24	E	pit	Grant's pits have geometry compatible with their being electromagnetic aerials;	Grant (1949)
25	E	pir	Grant's pits: size is such that, if aerials, they are appropriate for IR reception	Grant (1949)
26	A	pi=	Grant's pits seen as aerial types	/*\p138, Grant (1949)
42	E	ge1	tapering & other geometry of macro dielectric aerial → match impedance free space [engineering] ≈43	/*\p323c2
43	E	ge2	tapering & other geometry of (micro) dielectric insect spines ↔ macro dielectric ≈42	/*\
3	H	ae2	All (or nearly all) insect innervated "knobs" & pits are electromagnetic aerials (capable of *time-pattern* discrimination, like TV)	Callahan
4	H	ae1	Some insect innervated "knobs" & pits are electromagnetic aerials (capable of *time-pattern* discrimination, like TV)	Callahan

● (#6) First note the various existing forms of man-made aerials (some of metal, some of dielectric insulation or both), and that they serve to ease the transition from circuitry into free-space, or back again — with a minimum of unwanted reflection at this boundary[17], and often with definite intentions as to the *direction* of the resulting emission-beams. Note too that the size of the aerial tends to be about the same size as the wavelengths which the aerial can handle efficiently — though quantum emissions and absorptions, as in fluorescence, need not obey this rule.

The simplest text-book aerial is a basic dipole: ╥ or ┐┌ where the top of the "T" is the dipole ("+" one end, and "–" the other, then alternating according to the frequency), while the vertical parts together constitute an internal waveguide within the circuitry — or just call them "leads" if you prefer. However many aerials look totally different (as any glance at microwave or radar installations will tell us), and their waveguides often look more like pipes, or fibre-optic rods-or-threads.

● (#53,#54) Molecules attached to a solid ensemble are evidently able to function as aerials — some dealing in visible light (wavelength of about 0.4μm–0.7μm) as befits the size-range for larger molecules;

[14] For instance, such nuances might include such familiar devices as the optical analogue of musical chords (though perhaps with additional phase control imposed); or some form of optical-glissando (the "chirping" of femtochemistry?); not to mention meaningful geometrical patterns spread out in time-and-space — like the "archery target and bullseye"[15] or its "plume" variant.[11]

[15] See the "(#90)" paragraph on page 10.

[16] These "archery targets" (if they exist) might actually be seen by the insect's IR-sensitive compound eye (Callahan, 1965b), rather than via spines etc.; but this point would obviously need further investigation.

[17] In technical terms, this reflection-minimization entails *impedance matching*.

(/*\p335c1.7; Drexhage, 1970). Moreover even the retinal cone-cells of our eyes seem to fit into a similar category; (Myers, 1965; /*\p342c2.4).

● (#18,#17) Laithwaite (1960), noting the similarity between radar "fishbone" aerials and insect antennae, thought this might offer evidence that *whole* antennae did have an electromagnetic role. If the antenna does act as a single unit (rather than an array), then this would indicate IR frequencies in the FIR range, (Far IR: 20μm–200μm, or longer), and we might also ask what might serve as the related waveguide for making contact with the nervous system.

● (#24,#25,#26) Grant (1949) investigated the ennervated **pits-with-central-"peg"** found on the outside surface of insects. He concluded that they were probably aerials, and that their dimensions suggested infrared. At that time, few people (apart from military and technical specialists) would have thought of aerials as having such a form. In today's world of cell-phones (with no protruding aerial), such a concept might be more acceptable.

● (#Extra) Callahan tells us that during World War II, he had the resposibility for looking after a radar installation in Ireland. There, being an insect expert (though hampered by the poor resolution of microscopes of the time), he was struck by the remarkable parallel between man-made aerials and the various knobs-and-protruberances on insects. This inspired him to take the matter further, and eventually to augment his knowledge of the relevant physics. (/t\pp96-107)[18]

● (#42,#43) This led to a detailed consideration of the aerial-related-properties of tapered dielectric spines, as discussed theoretically by Kiely (1953), and as found on insects in great numbers, often in large arrays. (/*\p323-327). Here the detailed parallel is impressive once more.

● (#3,#4) Since such spines, hairs and pits are *so universal* amongst arthropods (insects plus spider-like creatures), and since they are also innervated, very few people would doubt that these structures are sense organs of some sort. Then the fact that many-or-all of them also have shapes agreeing with engineer-designed electromagnetic devices makes it difficult to doubt that they too have an electromagnetic function, though that need not necessarily stop them having other functions *as well* — functions such as mechanical feeling or analysing odour molecules chemically.

(i) How might the received IR signal be processed and perhaps affect behaviour?

81	F	las	VisibleLight: Laser efficiency in producing action-potential "spikes" in nerves >> mere mixed-phase monochrome efficiency (by 42×)	Callahan (1968) ApplOpt7:1425-30 Bruce(1971) *AnESAm* **64**:925-31
88	E	res	IR → measurable response (whatever the route)	Callahan
40	E	sp#	Seems: No reported direct evidence that IR→action potential spikes —— [yet Callahan did find such spikes for *visible* light ("gating": see "spL" (94)).]	Callahan(1968)p1425-; Hsiao('72), Diesendorf
94	F	spL	Callahan did find action-potential. spikes for ***visible*** light ("gating" the IR reception throughout the antenna). — [but apparently no spikes from IR itself]	Callahan(1968)p1425-; Hsiao('72), Diesendorf
39	H	spi	Assume any IR reception → response via action-potential "spike" **"[A]"**	physiologists' standard assumption
86	H	sp~	IR reception can be conveyed direct to the dendrite **as** natural IR, (without needing any "spike"); — then conducted on dendrite surface [RRT] **"[R]"**	NEW; Schriever(1920)
32	A	peg	Grant's "peg" = pit-sensilla, well-placed to "fire" dendrite; → action-potential spike (***or*** TEM mode fibre-optic signal!)	Diesendorf:/D0\36.8, Grant, NEW

● (#81) Note the evidence that *visible light* can lead to a measurable physiological response — the well-known "spike" in the time-graph of the *action-potential* voltage of the nerve. That is almost universally deemed to mean that some hopefully-relevant signal has entered the nervous system and can then be assumed as a likely causal factor in subsequent behaviour. (It is also significant that coherent *laser* beams are much more effective, but that is not the point at issue at this moment). Here the crucial question is whether there is evidence for *IR* producing the same detailed effect — and if not, why not?

● (#88,#40,#94) IR does produce observable *behaviour*, but there is some doubt about the intervening *"spike"*. In the references cited, I found no explicit mention of such *IR-to-spike* results, though there

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[18] Incidentally, at the top of his page 97, Callahan (like most people) makes the questionable assumption that electricity travels *within* metals. From the Maxwellian viewpoint which mostly concerns us here, the electricity actually travels in the fields of force *outside* the metal. (Poynting, 1885; Heaviside, 1892/1970; Schriever, 1920; Traill, 2005a §3.4). This might not matter much here from a technical point of view, but it would perhaps tend to put physicist-readers offside. Moreover aerials and their transmission-dynamics make much better sense if one gets this point right.

was mention of *IR-to-behaviour* correlations with the tacit assumption that there must have been an intervening spike transmission. Such undetected spikes seem also to be behind the Diesendorf team's comments (/D0\p45.7, /D2\p107.6+) that the absence of an electrophysiological response would disprove[19] radiation theory (even in the face of observed behaviour?!), and Callahan's reply (/C3\p115.5) in which he defends himself, citing the above-mentioned *visible-light* study as if that simultaneously proved the case for IR, (Callahan, 1968).

● (#39) There is a tacit assumption here: that any *IR-to-behaviour* signal must pass through the *action-potential spike* stage. I find myself in the unexpected position of being able to offer a possible solution here — postulating a *denial* of this assumption that the action-potential is essential! (though of course it could be that the spikes have been there all the time, just tricky to detect):
In some apparently-unrelated work on mammalian brain-theory, I came to the conclusions:
FIRSTLY that myelinated nerve fibres can-and-do carry two different types of signal: the *spikes* as stated in the textbooks, **but also** *infrared* using the myelin dielectric as a coaxial optic fibre! (Traill, 1978/2006 part B, 1988, 2000).
SECONDLY (mainly on grounds of explanatory coherence within psychology, page 22 below): ... that much of the mammalian brain's actual processing is probably carried out *at the molecular level* — "RNA-like" — or — "[R]". Moreover any such molecular system would have to be using IR for its short-range "brainy" communication — though meanwhile it would be leaving the "power-engineering" tasks of muscle-moving and long-range communication to the traditional Action-potential "[A]" system. (Traill, 1978/2006 part C, 1999, 2005b).
THIRDLY ... that single-celled animals (which obviously must manage without nerve-cells) may well depend on "[R]" as well — in which case it may be the more primitive and universal system of the two. This might also explain why the average cell-body is only about *20μm* across, since this is about the half-life distance for IR within liquid water — though this depends considerably on the actual frequency and any significant presence of the more IR-friendly *lipid media* such as fat-deposits or myelin. (Traill, 2005b).

● (#86) Infrared communication ***within*** the insect? In the abovementioned project, I had not contemplated any implications for invertebrates since they lack the myelin which might serve as optic fibre. However it seems likely that if the "[R]" system exists at all, its IR-signalling probably would have *predated* myelin both in evolution and within the individual (Traill, 2005a). It could thus exist internally for insects as well, at least for some IR frequencies, and that might explain why Callahan could find no intervening spikes: Such spikes would presumably be redundant, as long as the unmyelinated nervous system could cope with the IR in the form it was received. (Visible light would presumably be more difficult to handle internally, hence the need for the spike system in that case).

As for the absence of the myelin dielectric, Schriever (1920) tells us, (to put it crudely), that the boundary between *any* two media can serve to conduct an electromagnetic signal along that boundary — though some combinations will induce the wave to travel mainly on this side or that. In principle it does not matter whether each of the two media are dielectrics, metals, or something in between, though of course some media will very quickly dampen down the wave to nothing if they get the chance. Thus myelin might be ideal (though maybe insect chitin[20] is even better?), but in principle almost any pair of uniform media will do if they are thicker than about half-a-wavelength, provided that the path-length is short enough for that particular media-combination.

● (#32) The ennervated "peg" in the centre of Grant's pit is thought to be well placed such that a wave resonating within the pit will be vibrating most vigorously in the centre of the pit, and hence most likely to trigger an action-potential spike within the underlying dendrite (nerve-branch). That is, of course, an

[19] Can one really disprove a whole theory (even assuming Popperian criteria), just from the fact that you have failed to find certain evidence? Such "anti-evidence" has its uses, especially for directing further inquiry; but generally one could hardly say that it proves anything "beyond reasonable doubt".

[20] E.g. see Pearson *et al.* (1960) *"Infrared ... Chitin"* — cited by Diesendorf *et al*. (/D0\p37.0)

orthodox "[A]"-type explanation, and it may well be true, at least on some occasions. However we can now contemplate an alternative involving "[R]" concepts: We might now see the whole pit-region as an aerial for receiving IR in a particular mode — the TEM mode which is the nearest cable equivalent to a wave in free space, and which is the mode used commercially in home TV aerials, with a central wire surrounded by a sheath of dielectric, and then a flexible metal cover. The "peg" then could serve as the lead in toward the central "wire", while the perimeter of the pit might be seen a the outlier for the equivalent of the metal cover. TEM does have the advantage of being theoretically free from the usual strict constraint against using wavelengths longer than about about 1½ times the cable diameter (Traill, 2005a)[21] — however, unlike the other modes, the TEM mode could only exist here if there is a central "wire", and maybe Grant's peg is intimately involved in that issue.

(j) Can such systems prevail against the signal-noise of their environment?

73	H	irL	Ambient (incoherent) **longer**-wave-IR constitutes **noise** which will kill the needed signals. [NEG]	Diesendorf
41	F	key	Consistent phase-control could serve as callsign ID, different from noise & other signals	/*\p343c1.2 (implied)
51	F	co^	partial "coherence" can, in principle, suffice to override random background noise	/*\p334c2.9

● (#73,#41,#51) One can take a plausible pessimistic view, as Diesendorf does, and predict that ambient noise (or competing cross-talk signals) will upset any given signalling system especially for longer wavelengths (>5µm or so)[22]; and of course we all know that acoustic noise does sometimes kill conversation. However the proof of the pudding is in the eating, and if effective signals are actually getting through (as Fabre and Laithwaite attested), then nature must be doing something right whatever our theory might tell us to the contrary. However theory (in the form of Ashby's Law of Requisite Variety[23]) also suggests that the problem can-and-must be solved by having enough variety in one's own signalling code — so if that is failing, the only direct answer (if you can't remove the opposition) is to increase the diversity of your own coding system. That is probably one of the tasks which evolution is good at achieving, provided it has long enough to make the diversification changes — some of which we considered earlier.[23]

(k) Could IR-signals cope with absorption bands in the atmosphere which block out certain frequencies?

74	E	irH	Rising Relative-Humidity increasingly kills off IR signals	/*\p336
36	E	rub	Insect is "constantly rubbing" especially in humid conditions [This "must have some meaning"]	/C3\p112.2
76	E	ir/	At High Relative-Humidity, arthropods spend much time wiping antennae etc (even to exhaustion)	/*\p339c2.8
75	E	ir#	At High Relative-Humidity, insect mating etc fails to occur	/*\p339c2.4
45	E	win	Atmos windows for IR match corneal lens transmission windows	/*\p338-9

● (#74) Rising relative humidity does increasingly block IR transmission, so we might expect this to interfere with long-range insect signalling (and possibly short-range too).

● (#36,#76,#75) And in fact the evidence is that there *is* interference to insect activity at high relative humidity — though that does not, in itself, tell us whether the IR-blocking is responsible.

● (#45) There do also seem to be certain frequencies at which communication is simply not feasible. However the really interesting and significant point here is that insects tend *not to develop* spines etc (presumed aerials) which would have accessed these frequencies. That match in repertoires is hardly likely to be mere coincidence, and can surely be taken as further strong evidence for the insect-aerials-for-IR theory — the basic part of Callahan's theorizing.

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[21] Diesendorf may have overlooked this TEM loophole-possibility when he wrote *"Pore diameters...in grasshoppers, ...from 0.02 to 0.22 µm ...,* [so] *it is unlikely that the optical or infrared wavelengths could trigger the receptors directly."* (/D0\p46.4). On the other hand, there are other less-rigid limits on what TEM can achieve in practice, so he might still have a point.

[22] See Traill (2000, Ch.14), though this discusses the problem in terms of IR within the *mammalian* body.

[23] See subsection (g), above.

5. Explanatory Coherence

5.1. A brief Post-Mortem on the 1977 Debate

An important-but-underrated task in building up knowledge, is piecing together the largely disorganized mass of data and concepts which are already available. Just blindly gathering in more data, might then be counterproductive, yet apparently that is what society and its politicians expects scientists to spend their time on. An outsider who reads through the Callahan-Diesendorf debate is likely to be struck by its banal similarity to an exchange between opposing politicians, and by the thinly disguised contempt they had for each other. In such circumstances, it would not be surprising for the real scientific issues to be neglected.

There was also something abnormal about the staging of the debate: Firstly we are looking at a fairly new journal (at volume **4** by the time of the "/1\" paper in 1975). Callahan's ideas were presumably well enough known to act as a draw card, which no doubt prompted the invitation to him, and he duly produced the 50 page work. Secondly, papers /2\, /3\, and /4\ all appeared in the same issue of the 1977 journal, with no scope for external input (and with possibly uncomfortable pressures on both the participants meanwhile). Thirdly, I could find no editorial comment of any sort.

Meanwhile, it is not difficult to imagine that the complex and perplexing optics concepts were well outside the comfort zone of most biologists, which meant (i) that Callahan would usually not have been pestered by control from editors, who often would not really know what to make of it all; but then (ii) *when a critic was to be chosen* to review the work, there were not many feasible candidates. What else then but to appoint a known opponent from the /D0\ team, and — *"too bad we can't find anyone canny-and-neutral to umpire or moderate the conflict"*. Afterwards, when it looked as though all that complex mathematical stuff was just a mirage, ordinary folk could then just go back to their established routine and forget about having to brush up their physics. —— Of course that is all just my speculative reconstruction; but something like that might explain why the topic died so quickly within biological circles. (It was virtually a taboo topic when it came to my attention in 1988 — a disturbing sign of the realpolitik of science which recurs from time to time).

In any case, the terse pseudo-arguments within the debate probably made the messy topic even messier. This present paper has sought to tidy up that mess,[24] and produce one-or-more feasible accounts which do have overall *explanatory coherence*. It is now timely to look at the methods attempted — trying to trace causal chains and analogies. This initiative has been guided by two schools of thought with very different origins, but which happen to have converged yielding essentially the same approach. Let us look at them briefly:

5.2. Piaget's Epistemology and Psychology

I have discussed Piaget's work elsewhere (Traill, 2005b and 1999, §5.5), but the points most relevant here are that concepts (or "schemes" or "schemata") can somehow be built into closed logical loops and structures thus tending towards *"equilibration"*, which we can plausibly interpret as *"coherence"*.[25] This can be modelled by setting up concept-or-scheme nodes and trying to link them meaningfully such that they form the outline of a 3-dimensional "crystal" of closed simple loops — like the squares around a cube-skeleton made of 12 matchsticks, or else around a more complex object as in Traill (2000, *fig. 7:1*,

[24] Such reconciliation arguably goes against the throwaway tradition that
"if the system seems to have a flaw, we'd better just junk it — even if there's no replacement!"
(Did Popper inspire this? Inadvertantly?) Anyhow, once Diesendorf had reached a decisive Popperian "no" verdict on Callahan's IR work, he would have had no incentive to do any tidying in such projects — and presumably no editors would have been interested either, especially if the topic was beyond them.

[25] Actually, as Piaget must have known, that word-and-concept "coherence" was already well-known to philosophers. However philosophers generally did not hold the concept in high regard, and that may have discouraged Piaget from using this "coherence" word. But much more likely, he was more concerned to emphasize the *dynamic* nature of coherence-formation — as an equilibration *process*.

p.38). This does seem to have merit as a way to identify systems of thought which are mutually self-consistent. The problem is that this is all fairly abstract, and I have been keen to see this interpreted into actual practical mechanisms.

One practical application is amongst concepts-within-society (including science). Whatever mechanism is then entailed should hopefully be open to public inspection and participation, and Thagard's ECHO system seems a promising way of tackling this; *see below*.

Another application is the attempt to discover what nature is already doing *inside our heads* while we make sense of our perplexing environment, from birth to maturity and beyond. That was actually Piaget's main concern, but he was obviously hampered by not knowing what mechanisms might be carrying out the generation of coherence/equilibration — or indeed what his underlying "scheme" unit might be physically. We still do not have an accepted answer, but I have interested myself in trying to settle this issue, or at least offer a physically-feasible model to serve as a *tangible* target for constructive attack (Traill, 2005b).

(Incidentally, as part of the conclusions from that project, it seemed [a] that the basic physical mechanisms for *human-type thinking* must be-or-use linear strings of coding, [b] that nerve-cells as such could not fill that role unaided, and [c] that the only plausible candidate was RNA.[26] [d] If so, then the intercommunication mode between RNA molecules *would have to be by IR* and not action-potentials (except for contact with muscles and other *remote* sites). [e] That led to an interest in IR which also induced a watching-brief on IR in other biological contexts, including the Callahan-Diesendorf literature. Hence the first part of this present paper.)

However our concern here, (for the rest of this section 5), is to work on explanatory coherence within *society*, so let us consider Thagard and his approach:

5.3. The Awkward Question of "Hidden Basic Learning"

There is a trap for the unwary which we had better sort out before going any further. As adults, we are clever, and indeed clever to an extent that we do not usually appreciate! That is both a blessing (when we want to get familiar things done) — and a curse, when we want to analyse what is *really* going on in our subconscious. Those who are rash enough to try programming some simple real-life task into a computer *from scratch* (using machine language, and not the fancy "user friendly high-level" languages), will quickly find there is a whole galaxy of minute detail and decision-making to be solved. Yet these are tasks we cope with every day, and most of us do them so easily and automatically that we do not even recognize that there are problems there to be solved.

To add to the confusion, I suggest that there are several levels of this hiddenness, which seem to correspond to stages[27] of our mental-development as formulated by Piaget (and to some extent by Freud). This is not the place for a detailed account, but perhaps an impressionistic view might suffice, thus: We might find it comparatively easy to put ourselves in the mindset of a culture which measures land by perimeter and not by area, or a culture which does not value money — or other social values we normally support. These arguably represent other solutions within the same basic level. Such sets of tacit solution are likely to be based on subconscious well-rehearsed "concrete operations" skills, though we may find it a bit harder to share the "quaint" notions of naive children (as easily found in real life, or in Piaget's many works on infants).

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[26] Regarding this stringlike organization, see also the note on page 22, just before the subheading "Is this all a waste...".

[27] This notion of Piagetian stages is sometimes regarded as controversial, though that seems to presuppose that any such stage-diagnosis must *apply to the whole of an individual's ability-repertoire simultaneously*. If we drop that simultaneity assumption, and look at particular abilities in relative isolation, then the stages of ability become more obvious, and the misunderstanding may perhaps be allayed.

Eventually we could come down two or three stages from our usual comfort zone — maybe down to Piaget's "sensorimotor" stage where the basis of "thought" (if you can call it that) is the repertoire of basic actions. "In the beginning was the *deed*" as Piagetians sometimes say — quoting from Goethe's *Faust* — and that is as far down as Piaget takes the scale, attributing ability to "schemes" of action; and the infant has the task of learning how to organize, control, and mutate these inborn schemes.

I happen to believe that Piaget did not go far enough,[28] but that need not concern us here, and indeed I have also skipped through the concept of Piaget's stages with indecent haste. However I hope I have said enough to demonstrate the vast hidden substructure which underlies our conscious thinking.

This has several important implications, but I shall mention just two here:
(i) That logical thought does not just happen, and that the rules of logic themselves are ultimately just the result of "illogical" trial-and-error (through Darwinian coherence testing?).[29] Piaget (1949), writing about "logisticians" (formal logic-system theoreticians), put it like this: *"... all logistics depends on intuitive presuppositions: to read the principle logisticians, such as Russell, von Wittgenstein, Carnap, etc., one quickly comes to realize that they all refer to certain intuitions held by them ..."*. This awkward point made positivism inconsistent, and unintentionally hypocritical — and that includes Popperians.

(ii) Other formal systems such as Thagard's may have awkward hidden aspects too, as we shall see:

5.4. Thagard, the ECHO software, and wider issues

Outline of the ECHO approach — evaluating historical developments in science

Unlike Piaget whose background was in biology, Thagard's approach is via computers and his interest in thought-processes is centred on AI (Artificial Intelligence). Nevertheless their notions on the practical mechanics of knowledge-acquisition do have a formal similarity.

The ECHO program is devised to accept a list of propositions about rival theories, and assess their relative merits on this basis, (Thagard, 1992, espec. Ch.4).[30] He applies this analysis to various historic scientific revolutions: Lavoisier (oxygen, Ch.3), Darwin (evolution, Ch.6), Wegener (continental drift, Ch.7), various revolutions in physics (Ch.8), and in psychology (Ch.9). Let us first look briefly at the Darwin case, and apply such thoughts in *re-considering the insect-and-infrared case* of §3-§4.

In each case the book provides (i) a list of propositions including: • Hypotheses (including any known rivals), • Facts, and • Evidence bearing on the topic; but also (ii) a connectionist diagram plotting the explanatory and other logical connections between the propositions. Although this book does not offer it, one can readily see that the same link-and-list information could also be presented as a square matrix table — and such a table is offered here on the next page, for the Darwin-analysis case.

The ECHO data in an alternative tabular format (with 28 items in the Darwinian case)

For our present *methodological* purposes, the specific details are only incidental so I will barely discuss them though such information is largely available in Thagard's book and website anyhow. The first point to note is rather that, by judicious reshuffling the rows-and-columns (whilst restoring the self-references into a straight diagonal line during each change-session) one can get a feel for which

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[28] See Traill (1999, Ch.8, espec.§8.4) regarding possible sub-sensorimotor stages. Moreover there is a close analogy here to the hierarchical subprogramming of computers, when the supposedly basic "machine-language" level *actually depends on an even lower level* which usually includes some intricate "driver" software to control peripherals such as disk-drives — something the normal machine-language programmer can simply take for granted as if it had never been a problem.
Then again, Ernst Mach (in about 1895) said similar things about the forgotten "scaffolding" of maths.

[29] Small wonder then that some people use "ideosyncratic" logic!

[30] ECHO software is available online at http://cogsci.uwaterloo.ca/JavaECHO/jecho.html
(now re-written in Java language, whereas the book refers to it as being in LISP).

items cluster with which — as indicated here by the patches of shading, and other added clues. Just how useful a tool might this be? — and would it be worth the effort to construct such tables anyhow?

Table 5.1 — Representing Thagard's (1992, pp143,145) Darwinian-Revolution propositions and their linkages.
> means "*explains* proposition described on the right" **v** means ditto for "down below"
= indicates an analogy **+** is some other positive link **–** indicates rivalry between concepts

code	CH1	E.4	E.1	E.2	E.3	E.5	E.6	E.7	E.8	E.9	E10	E12	E13	E15	DF4	DF5	DF6	E14	DF1	DF2	DF3	DF7	DH1	DH2	DH3	DH4	DH5	DH6	description	code	level in diagr	orig. seq. order
CH1	*	+	+	+	+																			-	-	-	-	-	God→SeparateSpecies	CH1	0	28
E4	+	*																											Cross(Mule...):Infertile	E4	1	4
E1	+		*																					+	+	+			Few fossil-transitions	E1	1	1
E2	+			*																				+	+		+		Complex Organs (Eye)	E2	1	2
E3	+				*																			+	+			+	Instincts in Animals	E3	1	3
E5						*																		+					Extinctions Occur	E5	1	5
E6							*																	+	+				Extinction is forever	E6	1	6
E7								*																+	+				Worldwide Change	E7	1	7
E8									*															+	+				TheExtinct ≈ Living	E8	1	8
E9										*														+	+				Barriers→Simil-but-≠	E9	1	9
E10											*													+	+				Related Species nearby	E10	1	10
E12												*												+	+				Spec:SystematicAffin.	E12	1	11
E13													*											+	+				≠Speci.:Simil.Morph	E13	1	12
E15														*										+	+				Rud+AtrophiedOrgans	E15	1	14
DF4															*									v					Natural Variation	DF4	4	24
DF5																*							v						Hi.PopulationIncrease	DF5	5	25
DF6																	*						v						Life-support Limited	DF6	5	26
E14																		*				=		+	+				≠Speci.:SimilEmbryos	E14	1	13
DF1																			*		v								Dom.Anim: variation	DF1	3	21
DF2																				*	v	v:		=					Dom.Breeders select	DF2	3	22
DF3																			>	>	*				=				Dom.varieties develop	DF3	2	23
DF7																		=		>		*							Dom:vari: ≈Embryos	DF7	2	27
DH1																>	>						*	v					Struggle for existence	DH1	4	15
DH2	-		+	+	+	+	+	+	+	+	+	+	+	+	>			+		=			>	*	v	v	v	v	Natural Selection	DH2	3	16
DH3	-		+	+	+		+	+	+	+	+	+	+	+				+			=			>	*	+		+	Species have Evolved	DH3	1	17
DH4	-		+																					>	+	*			Imperfect Geol.Record	DH4	2	18
DH5	-			+																				>			*		Transitional Eye etc	DH5	2	19
DH6	-				+																			>	+			*	MentalQual.Inherited	DH6	2	20
description	God→SeparateSpecies	Cross(Mule...):Infertile	Few fossil-transitions	Complex Organs (Eye)	Instincts in Animals	Extinctions Occur	Extinction is forever	Worldwide Change	TheExtinct ≈ Living	Barriers→Simil-but-≠	Related Species nearby	Spec:SystematicAffin.	≠Speci.:Simil.Morph	Rud+AtrophiedOrgans	Natural Variation	Hi.PopulationIncrease	Life-support Limited	≠Speci.:SimilEmbryos	Dom.Anim: variation	Dom.Breeders select	Dom.varieties develop	Dom:vari: ≈Embryos	Struggle for existence	Natural Selection	Species have Evolved	Imperfect Geol.Record	Transitional Eye etc	MentalQual.Inherited	↑ ←description			
code	CH1	E.4	E.1	E.2	E.3	E.5	E.6	E.7	E.8	E.9	E10	E12	E13	E15	DF4	DF5	DF6	E14	DF1	DF2	DF3	DF7	DH1	DH2	DH3	DH4	DH5	DH6		code		
level in diagr	0	1	1	1	1	1	1	1	1	1	1	1	1	1	4	5	5	1	3	3	2	2	4	3	1	2	2	2			level in diagr	
orig. seq. order	28	4	1	2	3	5	6	7	8	9	10	11	12	14	24	25	26	13	21	22	23	27	15	16	17	18	19	20				orig. seq. order

One trouble is that there are already 28 propositions, and at some stage such an approach might seem to be unworkable.

The second point is more positive: As the table duplicates the information of the original connection diagram, one could conveniently use it to feed the propositions in to Thagard's ECHO software.

ECHO considered for analysing the Insect-and-IR debate — Problems of Hidden Concepts, etc.

Thagard does warn that ECHO is a historical tool and that it is probably unhelpful during actual ongoing research. It is perhaps not too difficult to see why. The problem is not primarily in the much longer list (95 items compared to 28 for Darwin, but they there are ways of trimming that down, as we have seen). The real difficulty is a bit more elusive, though it seems to centre on the need to tidy up the mass of unrehearsed subconscious *knowledge-and-belief-etc* which goes along with these propositions — the hidden commonsense insights and distinctions within a new field which we would normally use-*or-discount* uncritically.

(In fact this latter problem of knowing how much weight to allot to various barely-distinguished items which is probably at the root of much naivité here and elsewhere. For instance, a Westerner trying to do business in Japan, has much to learn about the altered priorities-and-details of various seemingly-trivial social acts like exchanging business cards or shaking hands — items which one might normally have come to perform in a certain way without even being conscious of them.)

In real-life such massed-tables of simultaneously-introduced novelty are comparatively rare, since the ideas are likely to reach us in small doses. That may have the disadvantage that, without their network of potentially-coherent support, we may just reject or overdistort them one-by-one as the various small clusters of ideas reach us — a failure to accomodate.[31] On the other hand the slow-scan may give us time to assimilate[31] parts piecemeal into our pre-existing world-view, come to terms with their perhaps-subconscious implications, and eventually re-assemble them into a now-tidier form — assimilating them again, but now to the new collective.

Be that as it may, the processing which I actually adopted in the first half of this paper did perhaps follow some of these trends, largely without any great premeditation. It just seemed "natural" • to group, distinguish, promote-or-demote the deemed relevance, and also • to "divide-and-conquor" by treating the subsets (e)-to-(k) separately. In the process, some further subgrouping seemed sensible, for instance the "(#24,#25,#26)" within the (h) section; — also some further elimination in some cases (no trace shown here); — and the reverse of that, as the late addition of two unlisted items: "(#Extra)" in the (g) and (h) sections — not to mention the key decision, prompted by Laithwaite himself "(#1)" to remove the whole topic of "short-range only" away from all the rest, thus making the messy main topic much more tractable.

If we are looking for serious studies of epistemological methodology, this was perhaps no more than an anecdotal pilot-study, yet it might help to set the agenda for future work. Such work would take at least two forms: • The social/scientific question of SCIENTIFIC METHOD, of which Thagard's approach is a notable example; and • The workings of the NATURAL BRAIN, and here Piaget's lead still seems to me to offer the best approach if we really want to find the actual mechanisms and processes (Traill, 2005b). Thus it might be interesting to construct models which treat propositions (and perhaps their hidden basic assumptions) as Piagetian schemes with multiple coordinated-but-mutatable copies, each capable of coherence-seeking — and of suffering Darwinian elimination if they fail to find it. But here we must make sure that we count practical success in the outside world as *one form of coherence* with its own feedback loops (Traill, 1999, §2.4).

The traditional actual neuron shows no sign of the stringlike organization which would seem to be necessary if the brain really does operate on the basis of Piagetian schemes. So, without doubting the importance of the neurons-and-synapses (system [A]), there probably must also be some other basic

[31] In this context, "assimilation" and "accomodation" are standard Piagetian terms.

physical mechanism at work here — the "[R]" system, and the evidence suggests that it is based on ncRNA. See Traill (2005b)[32]

Is this all a waste of time when there are no rival theories to compete against?

Thagard concentrates on the rivalry between theories, as befits any historian studying how scientific theories become superseded. But theories come in all shades of self-coherence, and some will arguably never have any serious rivals. Doubtless the most stable is our concept of *object* (which then leads to the notion of space); (Piaget, 1949, 1952; Beth and Piaget, 1966). The very neat mathematical Piagetian-schemes which underlie this object-concept are such that even an inefficient coherence-seeking procedure could hardly fail to discover and assemble these schemes correctly, provided it is given the appropriate playtime environment — and anyone who failed to achieve this milestone would be almost completely disabled mentally. In this case, any real alternative solution is virtually impossible — and unthinkable except as an abstract exercise, or as an artefact on a computer-screen dealing with a bizarre artificial world.

At the other end of the scale there are theories about immensely complex systems like society. Here, despite what the various fundamentalists may believe, there is no way that anyone can ever capture the *full certain picture of reality* in any form — mental or otherwise. The best we can do is to try, and keep trying, but meanwhile accept that our models will always be so imperfect that we should make due allowance for that fact. In these circumstances it is particularly important to tolerate and discuss rival theories, because there simply is no infallible right anwer that we can discover.

Trouble can arise when we cannot (or will not) distinguish the two instances, such as when we are dealing with a borderline case between the *obviously-true* and the *very uncertain*. Trouble can also come when there is a history of acrimony or extraneous-association which means there is disturbing reperoire of those hidden factors discussed above — in which case there may be a tendency to accept a phantom rival (the *non-explanation* of an ignorance-tolerant status quo) and reject the only candidate which might have offered a solution. Sometimes such subconscious baggage will be too strong, and then there may be nothing but to wait for fashions to change. However if one can achieve something approaching perfect self-consistency (full coherence), then one might hope for the theory to gain at least provisional acceptance — in the fullness of time perhaps!

Darwin managed to get close enough to full self-consistency, despite some minor difficulties (which were largely resolved eventually). The Laithwaite-Callahan explanation of IR, when tidied up, can also be seen as having nearly perfect coherence *provided that* we confine our attention to the long-range problem. There is perhaps still the difficulty of no direct evidence that IR can cause action-potentials in the insect nervous system, but then there turns out to be an explanatory argument that this "essential" may not actually be essential at all; (see § 4.1(i)(#86) on page 14).

In short then, even if there is no rival theory, arguably we are seldom wasting our time in trying to improve overall coherence. It may even be worthwhile aiming for perfect absolute coherence — but only in cases which are simple enough for this to be feasible. If nothing else, there may at least be a certain aesthetic satisfaction in these tasks since such coherence-seeking is probably something which evolution has ensured that our species would find enjoyable — either as a "mere" game, or as a real-life undertaking.

[32] and also see perhaps — the brief mention in "(#39)" on page 14, above — and the "(Incidentally...)" paragraph of section 5.2 on page 17.

6. Conclusions

6.1. Conclusion 1 — the Scientific issue of Insects-and-Infrared

On the evidence presented here, it seems hard to avoid the conclusion:
that for long-range communication at least, some insects do depend on infrared as the medium for "seeing" a modulation-encoded message from their target — that this IR message is emitted by fluorescence (probably enhanced by weak laser-like properties of stimulated emission) from the "cloud" of pheromone-or-scent eminating from the target — and that the causal-energy comes mostly from higher frequency ambient radiation, often at night despite the comparative lack of visible light.

The question of short-range communication has been deliberately left open here, though evidence arising in connection with the 1977 debate will be found listed in the top of the Main Table, on page 8. However we might confidently expect that any navigation method which is feasible to insects, will have been used by at least some species. Thus one might expect to find a mixed usage of both the long-range method *and* various chemical concentration-gradient olfactory methods as well — singly or in combination — in one species or another.

This partly vindicates Callahan, but his accounts often tend to be misleading and to contain unhelpful errors. Diesendorf correctly identified many of the errors, but he missed an opportunity for a constructive synthesis.

6.2. Conclusion 2 — the Epistemological issue of Coherence-seeking

Damage from Popperian policy

One purpose of this paper was to illustrate the folly of rigid Popperian policies, which can easily "throw the baby out with the bathwater" — and I hope I have contributed helpfully to that point. After all, Diesendorf did what would have been expected of a Popperian critic at that time, effectively: "Try to find at least one significant breakdown in the case so that we can establish a Popperian disproof. After that you might as well let your hair down and say rude things *ad libitum*, since the theory already has its death certificate."

It would have been helpful however if either Diesendorf or the editorial board had analysed the logic of the situation a bit more carefully (dispite the sometimes erratic original presentation) and focused on the Laithwaite distinction between long- and short-range. That way they might have come to a more useful conclusion even despite their Popperian orientation.

Thagard's ECHO software and approach

As Thagard tells us, ECHO is intended for assessing the issues within a recognized conceptual revolution of the past; *i.e.* not as a tool during the actual investigaion. I nevertheless looked into the feasibility of such usage in the Callahan case. This might conceivably be made to work, but as the concepts were "somewhat more ragged and untried" than those of established debates such as evolution, the task seemed unpromising. Instead I did find it useful to play round manually with the propositions which had been prepared — group and re-group them (a process which could also apply to schemes within the brain) — and deal with the subgroups thus obtained. This was useful, but once again the main progress was in first applying the Laithwaite distinction — thus greatly simplifying the problem.

Meanwhile it was instructive to note the formal similarity between Thagard's approach and Piaget's theoretical account of how the mind/brain must be operating.

Darwin's own Support for Coherence-seeking

Thagard (1992, p149) quotes from Darwin's *Origin of Species*:
"It can hardly be supposed that a false theory would explain, in so satisfactory a manner as does the theory of natural selection, the several large classes of facts above specified. It has recently been

objected that this is an unsafe method of arguing; but it is a method used in judging of the common events of life, and has often been used by the greatest natural philosophers."

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[33] Callahan (/3\p114.2) tells us that this was his first paper dealing with infrared.

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