THE STATUS OF COGNITIVE SCIENCE

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by

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DECLARATION

I, **NAZEER, A.**, do hereby declare that this work reported in the thesis entitled, "**THE STATUS OF COGNITIVE SCIENCE**" is original and carried out by me in the Department of Philosophy, University of Calicut, under the guidance and supervision of **Prof. (Dr.) A. KANTHAMANI.** I further declare that this thesis or any part of this has not been submitted for any degree, diploma, recognition or title in this or any other University or Institution.

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Certificate

This is to certify that the thesis entitled "**THE STATUS OF COGNITIVE SCIENCE**", submitted by **Mr. NAZEER, A.**, to the Department of Philosophy, University of Calicut, is a record of bonafide research work carried out by him under my supervision and guidance. The results embodied in the thesis have not been submitted to any other University or Institution for the award of any degree or diploma.

A K 28/9/10

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28.09.2010

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Dedicated to

Beloved

My Father and Mother

PREFACE

The thesis about challenges to the very enterprise called 'scientific rationality' (i.e., Scientific *theory* – does theory *explain all* phenomena, scientific *method* – is DN the only, *viable* method?; scientific *truth* – truth or empirical adequacy?, and scientific *progress* – miracles or not?.) and the way all these *challenges* are met within, not only the domain of philosophy of science and *philosophy of cognitive science* (philosophy of cognitive science is supposedly inherit *all* the problems germane to philosophy of science), but also in *philosophy of mind* (can *a priori* be excluded by *fiat*?), and also philosophy of language (foundational?, mutual influence? non-foundational?). Scientific challenges and there *meeting points* provide the main *bulwark* of the thesis (**CHAPTER 1**). For example, Nancy Cartwright (1983) calls physical laws as *false* and Giere (1988) disputes the *sanctify* of science (Calling it as a 'model'). Now, can cognitive science *earn* its scientific credentials by overcoming all these challenges?. This is what is being attempted in the following *pages*.

The answers to the question involves taking all these challenges on board such as Reductionism, Realism, Functionalism, and Eliminativism. Can Instrumentalism, or Constructivism be allowed to play a role in science? We are trying to examine the contours of this controversy.

Now reductionism claims to reduce Psychology to Neurobiology and thenceforward to Microbiology (biology of microphenomena). But then *mind* remains as an *integrated* concept of MIND-BRAIN. Our study of micro-level objects is to be *ultimately* integrated into psychology of the mental. So we can either stop with *mere* functionalist reduction or also go to the microlevel but we have to see *how* cognitive science is cutting across an entire array of phenomena (genes-to-behaviour). This we have to do without Bridge laws, Scientific method etc. Similarly, for realism: the challenge to realism *does not mean* that anti-realism/constructivism/constructivism is to be supported (**CHAPTER 1**). So we need both: but how to reconcile opposites like cognitive science with social science, philosophy of mind with microbiology. We will show Bechtel to be a new sort of reductionist (a sort of *complementary* type) and Craver an opponent (**CHAPTER 5**) (we call him an arreductionist).

Now, let us take *causation* as an illustration.

The earliest definition defines causation thus:

C = *df.* Necessary & Sufficient Condition (So., $P \supset q$ and $q \supset p$).

But this will *not* do. But we know, the universal generalization $(x)\ (Fx \supset Gx)$ is supported by counterfactuals. So other amendments follow.

Later amendments include such as the following:

Lewis = causal relation is *true* abstract relation in some *possible* world (i.e., in some possible world, $C \rightarrow E$), and *philosophy of biology* highlights a causal explanation as an *equilibrium* explnation between causal and non-causal phenomena (Sobers, 1980).

More recently, amending Lewis, Woodward-Pearl (2003) advances an *interventionist – manipulationist theory* which is currently based in experimental economics. Craver takes this as a *concrete* step about counterfactuals and applies it to explain 'causation in neural mechanism' to which Bechtel may not agree (**CHAPTER 4**). Bickle has taken yet another idea of *intervening cellularly* and *molecularly and tracking behaviourally approach*, so as to claim that a molecular-*linked* theory of mind looks plausible (**CHAPTER 5**).

Churchland is dead set against *theory* (and all linguaformal models suggested by LOTH (Language of Thought Hypothesis)) and Craver takes theory as transcending all possible evidence. So we have a *Connectionist philosophy of science* (in the form of Mechanistic philosophy of science) that searches the scientific credentials at a *deeper* level with all empirical support theory can gather. This is shown in *two* typical experimental modelling on *Memory Consolidation Research* (Bechtel is a counter example to Bickle). This is portrayed in all its nuances in Circadian Rhythms (Craver provides a skeptical stance to this) (**CHAPTER 5**).

So we are look to metaphysics of *time and mind* through *couched* in a new idiom (Clark calls 'reciprocal causal loops').

Mind is computational; Brain computes, but we are left with what we call a 'semantic task'. We must explain what do we mean by this. Syntax is not sufficient but we should see how causal relation are *understood*. Whereas Churchland is a foundationalist, Craver opposes it (**CHAPTER 2**). Electrical conductance flow through Ion Channels but we *do not* know *what it is*. We can give it in the form of a mathematical equation like the one suggested by H-H (Hodgkin-Huxley), but that will give only *an instrument* (not real).

During the course of investigation, we will examine whether the candidate *theory semantics* for ANTCOG (Adult Normal Typical Cognition) will serve the purpose (**CHAPTER 3**). Our conclusion is that it has serious *limitation* in the light of recent experiments in Memory Consolidation Research (**CHAPTER 4**). In this context the thesis provides a continuity to my M.Phil thesis on ANTCOG (2005). My present thesis is purely a scientific document with an admixture of philosophy.

One major hurdle for the thesis is to master voluminous literature in cognitive science at the *experimental* as well as *conceptual* level. Centralizing Bechtel, we counted 75 articles (7 articles on Circadian Rhythm; 8 articles on Cognitive Science; 2 on dynamic explanation; 2 on memory Consolidation; 2 on Heuristic Identity Theory (HIT) etc., of which his contribution to Circadian Rhythm and Memory Consolidation can never be underestimated in this next few years) *plus* half a dozen books. So also, we have triangularised the experimental work done by Bechtel, Bickle, and Craver. Besides, we have enumerated a complete catalogue of *cognitive modelling* which is *not* available anywhere in the literature (*three* basic, *fourth*, the Neural Engineering, response in the form of Self-Model, and Evo-Devo, Models). The three fundamental models (Symbolicist, Connectionist and Dynamicist) *interpenetrate* into each other (Interpenetration Thesis).

We owe to Cognitive Science Group for the following sources of influence:-

(a) The modelling of cognition (**CHAPTER 2**) (around 25 models);

(b) A new *field guide* for reductionism (Bickle, Bechtel, Churchland, McCauley and Craver) in which we raise a possibility of *alternatives in lieu* of pluralistic solution (McCauley), passing from 'bumpy-to-smooth' to the other extreme of *Asymptotics* (Hooker);

(c) A primer for microbiology and several others which are equally influencing all the members of the group in our periodical meetings;

(d) Number of papers presented by the guide and students in IPC session and other fora;

(e) The access to Ms on '*Neural Limits of Plasticity*' (Prof. A. Kanthamani).

We tried to propose *constructivism* as an overarching hypothesis thinking that this meets all other ways of doing cognitive modelling (**CHAPTER 2**). But we are not sure how to choose between different *pairs* of paradigms, because all are equally supported by science. Not only science but also science has it is known today, namely Simulation-Based science rather than Information Based Science. Even if no choice is made forthrightly, which depends on future research and experiment, we can be rest assured that all these paradigms belong to science. Thus constructivism *saves* the phenomena, without letting down cognitive science- cognitive science is not becoming *Otiose* in the sense in which it is claimed by Bennett and Hacker (2003).

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Chapter 1

PHILOSOPHY OF SCIENCE/PHILOSOPHY OF MIND: ITS INTERFACE WITH COGNITIVE SCIENCE

The Cognitive Turn:

'agents are systems endowed with a materially constituted mind'

(DANIEL ANDLER)

'Mind is what Brain does'

(CHURCHLAND)

'You are your neurons'

(C. KOCH)

'It is not impossible to build a human brain, and we can do it in ten years'

(Nature Review: Neuroscience 2006 7(2) pp. 153-60 H. MARKRAM, Leader, *Blue Brain Project*)

'If we build it correctly, it should speak and have an intelligenc e and behave very much as a human does'

(MARKRAM, BBC World Service Interview, 22 July 2009)

PHILOSOPHY OF SCIENCE/PHILOSOPHY OF MIND: IT'S INTERFACE WITH COGNITIVE SCIENCE

1.1 MODELLING PHILOSOPHY OF COGNITIVE SCIENCE ON PHILOSOPHY OF SCIENCE:

We know that science represents the most rigorous attempt by humans to acquire knowledge. When science itself becomes an object of investigation, we get what is called Metascience (Science of Science). Philosophy of science swiftly moves back and forth so as to reflect on its own enterprise in order to drive home the point as to what extent science is science. Philosophy of science precipitates its results on any new science (cognitive science), so much so that it inherits all the arcane problems which it investigates (e.g., the distinction between observable and theoretical entities; theory-observation relation; the distinction between context of enquiry and context of justification etc.,). Philosophy of cognitive science, in other words, is to be modelled on philosophy of science.

According to Andler, cognitive science rests on *three* core disciplines namely, psychology, linguistics and neuroscience-and straddles *four* academic cultures- the humanities and the social sciences, life sciences, engineering and the exact sciences (physics and mathematics)[1]. The term 'cognitive science' was introduced in the 1970s. Andler's view of neuroscience comprises neurology, neuropsychology, neuroanatomy, and neurophysiology. Elsewere, Andler updates the scope of cognitive science which comprises 1, 2 and 3 (p.3) as mentioned below[2]:

1) It is *typically French* in origin (Jacques Monod, who is supposed to have invented cognitive science, and who is also responsible to bring an encounter between Noam Chomsky, who continues to be a strong critic of cognitive science and Jean Piaget who is again supposed to counter cognitive science from a 'constructivist' point of view; and the relevant disciplines are neurosciences, linguistics, anthropology, mathematics and Cybernetics (man-machine analogy but it is understood to critique the notion of representation with a positive and negative feedback mechanism; later it will be shown to be equivalent to a weak form of reductionism pursued by Bechtel).

2) Cognitive Science is a closely connected to the development of analytic philosophy (Russell-Frege, Axiomatic-System, Turing Computability, CTM (Computational Theory of Mind) is a formal system (*a la* Fodor). They all lie in a continuum (This goes contrary to the general Anglo-American understanding of cognitive science; see Thesis 1 and 2 below).

3) It is aligned to the European tradition such as a *Phenomenology* (Husserl and Merleau-Ponty) and *Existentialism* (Heidegger) and the *Ecological Theories of Perception* (Gibson). Philosophical traditions are thus richer in their scope.

(1) – (3) provide the gist for an update definition of cognitive science involving functionalism and its types, computationalism (input-output state), structural analysis of language, and intentionalism (there is mental content). The actual definition of cognitive science is the blending of psychology and functional neuroscience. (p. 38). On Andler's reading, the above definition enters into tension with reductionist procedures, whether it is *moderate* or *radical*. While the moderate *integrates*, the radical form *divides* (p. 39). Integration means that it integrates psychology with neuroscience (see Andler's broadened definition below). Division here means that we go the microlevel of molecular biology (flow of potassium, calcium through the Ion Channels in the axons and dendrites). We must see the total picture as follows: while functionalism reduced mind to the level of its functions, microlevel research takes us to a level below. There are many thinkers who feel that such a microlevel research is redundant because it does not say anything more that structure and function of the brain. Computationalism is briefly the view that the brain computes or the mental states are Turing computational states. Intentionalism is associated with the view that mind has mental objects of intention. Cognitive science cuts across all disciplines in the strict sense it reaches behavioural sciences at the top even while starting out from the genes below. We may reflect on the naturalism as the final court of appeal - a Naturalism with a Human Face[3].

It is in this informed background that the thesis is specifically conceived to *examine the erstwhile scientific credentials of cognitive science.*

The question whether cognitive science is science is pertinent in this context. The enquiry has its focus on the very question of what is to be called 'scientific explanation' in biological sciences and to evaluate it as science in this backdrop.

Traditionally, biology is regarded as merely a *descriptive* as against *normative* science[4]. It is only after the advent of cognitive science, biology has come to be regarded as an explanatory science (Are there laws in biology?). Biology extends its tentacles to computational sciences, and even so, to *Synthetic* Biology. (Brain can be duplicated in a laboratory). While examining the scientific credentials of cognitive science, the question whether there is a biological explanation of neural phenomena seems to be pertinent.

We will have to examine the question in the full understanding that

(i) There is no scientific method ('DN-model is on the wane' (Bechtel)[5];

(ii) There is *no* theory (system of statements which are deductively or axiomatically closed which is typified in Sentential Kinematics which involves sentences, truth values, inferential relations together with logic that informs it; *rationality is human decision-making* that is, common to science and values);

(iii) No truth (no correspondence, no coherence; truth is *deflationist: p is T iff p*; it is a *lazy* predicate; truth is redundant, truth is disquotational *a la* Quine);

(iv) No scientific law (no distinction between *necessary* and *accidental* laws; only *ceteris paribus* laws, or 'law-like' or 'law-cluster' statements *a la* Putnam to back up the logic of scientific method as understood in (i);

(v) No Bridge Law (interfield or intrafield relation to facilitate the logic of the DN-model). We are left only with real world casual relations (necessary and sufficient condition *vis-à-vis* counterfactual conditionals, which can be explained *not* in terms of çausal processes but in terms of 'difference-making' consequences (*df.* 'causes make a difference to their effects', how *y* changes when *x* changes; *explanandum-explanans* relation is a *causal* relation rather than a *logical* relation; causation = intervention and manipulation; so, explanation involves intervention and manipulation with overtures to social-behavioural sciences[6]. If the physical world is causally closed, then: does it 'exclude' mental causation ('causal exclusion')?

On Bechtel's *Overview* (1): Philosophy of Science thus offers a perspective from which we can examine and potentially evaluate the endeavors of cognitive science[7]. According to his *Overview (2),* Philosophy of Mind offers substantive theses about the nature of mind and of mental activity. Now we can distinguish between traditional philosophy of mind (*a priori*) and the modern philosophy of mind (*a posteriori*)[8]. Churchland's *Neurophilosophy* has attempted to do away with *a priori* in favour of *a posteriori* theories of *Mind-Brain* as embodied in the naturalistic approach to mind-brain, which is a serious contender[9]. Let us quickly sum up the *a priori* theories below, for the simple reason that we have to *negotiate a correct passage* from the *a priori* to the *a posteriori* as evidenced in Andler[10].

1. Dualism : *Presupposes two* ontologically independent substances given as *res extensa* and *res cogitans* (called *substance* dualism in contrast to *property* dualism); Panpsychism (implied by physicalism) *celebrates* Descartes[11].

2. Behaviourism : *Adds overt* behaviourism to *covert* behaviourism (and hence rejects mind/ consciousness in principle) psychophysical/ double aspect are the responses to this.

3. Identity theory : *Holds* that mental-states are *necessarily* identical with brain-states (alternatively, contingently identical) Kripke critiques this. Identity has no explanation but it survives as a 'heuristic'[12].

4. Functionalism : *Explains* what the organism by *what it does* rather than *what it is* (the function of *heart* is to pump blood); functional states are computational (causal) states.

5. Eliminativism : *Eliminates* that which is not scientific (that is, *folk psychology* of belief). As an eliminativist, Churchland advocates that all a *priori* theories are to be eliminated.

Bechtel's *Overviews* (1&2) opine that the basic issues that impact on philosophy of science are derivable from logic, metaphysics, epistemology, and even so, from *value theory.* Bechtel's recent book (2008) adds support to the cognitive-social science interface[13]. The central issue in *logic* is the evaluation of arguments. An argument is simply set of statements (deduction/ induction/ abduction/ inference to the best explanation.) The subsidiary one is *metaphysics* which seeks to determine what are the basic or fundamental kinds of things (observable or theoretical or both) that exist and to specify the nature of these entities. The metaphysical issues are quite pertinent to philosophical accounts of science. *Epistemology* is concerned with the question of what knowledge is and how it is possible. Epistemological discussion often has been prompted by skeptical doubts that what we believe might be false. Many of the other domains of philosophy, however, are even more clearly concerned with *values* or with analyzing the source of values (normativism). This is different from the way that normative questions of value theory are not far removed from the core concerns philosophy of science.

The term 'Neuroscience' can be traced to Francis Schmitt's use of the term in his Neuroscience Research Programme 1962; it includes Solid State Physics, Quantum Chemistry, Chemical Physiology, Biochemistry, ultra structure of matter (Electron Microscope and X-ray diffraction), all of which gave rise to a *mental biophysics*. Later on, this was given in terms of Molecular Electronics, Computation Science, Biomathematics and literature. Bechtel enumerates as many as 25 disciplines[14]. The term 'Cognitive Neuroscience' became vogue in the 1980's.

Three key manifestations of cognitive science are:

(1) Cognitive Neuroscience = *df.* Cognition + Neuroscience;(Computational + Neuroscience) + Evolutionism

(2) Cognitive System Science = *df.* Cognition + Neuroscience (Cellular + Molecular level) + Computation + Evolutionism (Consumer System).

(2) takes us further into regions of (3):

(3) Computational Neuroscience (Information-Theoretic Neuroscience) with Genomics (genes) and Proteomics (Protein and amino acids).

In addition, now we pass on to a more sophisticated variant (4) Simulation- Based Neuroscience which comprises the method used in Stem Cell Research and *The Blue Brain* Project (Markram claims to reverse engineer the human mammalian Brain by duplicating in the Computer 2005)[15] etc.

Let us assume that (1)-(4) take Woodward-Craver's account of 'interventionist-manipulationist-contrastive (counterfactual)- invariant account of causation', as an option for providing the gist for scientific methodology[16]. So, we quickly review the different theories of causation (C causes E) so as to assess whether it can still *survive* with other equally good options.

1. *Regularity theory* of causation (Hume, Carnap and Quine): It merely asserts a regular succession of events ('naively deterministic').
2. Causation as *Nomological Explanation* (Nagel 1961; Hempel and Oppenheim):

As given in the nomological law in the DN model of explanation.

3. Causation as *Ontic* (Salmon 1984; and Dowe 2000): It implies the existence of spatio-temporally continuous casual processes and interaction of these processes in the external world.
4. *Causation as Counterfacutal Dependencies* (Lewis): causal claims reflect counterfactual dependencies. This is to ensure that such dependencies support a causal law. Counterfactuals (similarity relations among possible worlds) play a role without being scientific.
5. *Agency theory of causation* (Von Wright, Manzies and Price): claims that causation requires a *free* agent.
6. Bechtel's Dynamical *Mechanistic* view of causation takes the *interfield* and *intrafield* view based on bridge law: DN model is to be appropriately modified to meet *weak* reductionist claims. Causation is an interaction between different mechanisms (see Section *4.2* and *4.3* below).
7. Interventionist-Manipulationist Theory[17]: Is the most recent theory of causation which claims that causal relation is *not* a relation between two events but it is a relation between *variables*. This theory is supported by an analysis of counterfactuals (what if things had been different? e.g., synthesis of enzymes that would otherwise prevent synthesis). That is, the similarity relations among possible worlds can be legitimized in an *a posteriori* way. One may say that the 'Semantics of causality is the semantics of counterfactuals'(Professor Kanthamani's remark in a Seminar), as schematised below:

(1)		(2)
Explanans Bridge Law ——————— ∴ Explanandum	Factual + Counterfactual	Explanans ? ——————— ∴ Explanandum

8. Causation as *competitive* account of explanation operating on multi-levels[18]: this depends on the combination of mechanism as *non-reductionism* i.e., what Craver calls *constructivist* (a new word *arreductionism* is also advanced in this connection). We will evolve a classification of constructivism (Neurons *construct* the world *via construction* of a theory) so as to show its direct bearings on cognitive science (see Section: 4.5 below.) We must demonstrate that there must be compelling invariant connection between C and E.

Now we shall formulate our hypothesis: In lieu of (2), we *either* choose (6) *or* (8) that is squarely based on (7) and such constructive tendencies of the above disjuncts (which are competing theories) can *save* the 'realistic' credentials of science.

Further, the project is *not* complete unless it can also be shown that it will meet the recent Bennett-Hacker's Wittgensteinean on the conceptual foundations of Cognitive Science[19]. Bennett and Hacker advance a philosophical (Wittgensteinean) critique of 'philosophical (conceptual) confusions' within contemporary cognitive neuroscience. They call it as a 'mereological fallacy' (adding *brain* to *mind*). The fallacy involves attributing to *part* (brain) which can only be attributed to *whole* (mind) (when cognitive neuroscientists called *Mind-Brain*, they are understood to commit this fallacy). They advance what is called a 'Bounds-of-Sense Argument'.

Apart from the *a priori* theories of mind, the choice is to be limited to select some combination of *realism, reductionism, phenomenalism, functionalism, computationalism, mechanism, evolutionism and constructivism* without overlooking the relevance of some variant of *Naturalism*. But, within philosophy of science, realism and reductionism have to face challenges from within cognitive science and from philosophy of science. Functionalism and computationalism (mind is an information-theoretic input-out machine) cannot work unless they are combined with mechanistic explanation and mechanism has to be reconciled with phenomenalism. Functionalism (we can distinguish varieties of functionalism) can also be taken to the micro-level of basic neuroscience. We are left with evolutionism (mind is a byproduct of Natural Selection) and the best way to do justice is to follow the path of Constructivism (Piaget holds: 'structures are constructed') which provides one of most overarching images of science.

After dividing naturalism into *naturalism* 'free-floating'(everything is at bottom natural) and 'anchored'(methodological in that one accepts or rejects ontology/metaphysics), Andler ends up with advocacy of 'minimal' naturalism (a species of methodological naturalism with philosophically wide open eyes). Andler thinks that such an intermediate position can be reached, which is the minimal naturalism one should *countenance*. This is the 'Naturalism with a Human Face' (echo of Putnam's '*Realism with a Human Face*', 1988) that raises a problem for cognitive scientists; a vast majority of them think of themselves as natural scientists[20]. Yet theirs, to a large extent, is a science of the mind. The conclusion proposes a sober appraisal of the achievements and prospects of cognitive science, one which remains positive and forward-looking while making space for a genuine connection with mainstream social science (see Section *5.5* below on Marching Forward).

The scientific credentials of cognitive science can be fully assessed if and only if all the *challenges* against realism can be *met* (See Section: *1.3* below on Hilary Putnam etc.). So, basically the view adopted here is coloured by the way the meeting points work against the odds of all the challenges. Since DN model is 'on the wane', reductionism can survive only at great cost (Bechtel is a *weak* reductionist). And functionalism can be combined with mechanism to give sustenance to Cognitive System science under conditions that it provides what is called the invariant causal relations. *Naturalism* cannot be completely eschewed (Bechtel reconciles naturalism with phenomenalism; see his Lecture *4*). On the other hand, Bickle has done away with all philosophical package including naturalism and therefore his Ruthless Reductionism offers no promise. For Bickle, *ersatz* cognitive science is the Science of Research (science of science) and reductionism is 'ruthless' (here means: this is how science is practiced) at the metalevel[21].

1.2 THE WANING OF THE OLD RECEIVED VIEW (ORV) CALLED HYPOTHETICO-DEDUCTIVE (DN) MODEL

In view of the link between social/behavioural sciences, we must see that a rudimentary view dates back at least to Aristotle. Aristotle arranged the 'Sciences' into *three* divisions; the *theoretical* sciences (metaphysics, mathematics and physics); the *practical* sciences (e.g., ethics and politics), and the *productive* sciences (e.g., poetry and rhetoric). Theoretical sciences are concerned with knowledge alone and for its own sake, practical sciences are for *doing*, and productive sciences are for *making*. Despite these divisions, however, Aristotle's image of the science was one of a *unified hierarchy*. In the metaphysics, he made clear that the theoretical sciences most particularly metaphysics or 'theology'- are at the top of the hierarchy.

Inductivism was an attempt to ground science in observation and not purely on logic. Logic is mainly applied to *three* ways (i) *Deductivism,* (ii) *Inductivism,* and (iii) *Abduction* is 'inference to the best explanation'. Logic relies on the validity of the assumptions (which in the past were invariably wrong). The idea was to derive knowledge from the facts of experience. From these facts, theories were produced which could then be tested by prediction. Clearly a step forward from relying on pure logic based on 'picture in the mind' of intelligent men such as Aristotle.

A Hypothetico-Deductive (H-D) method is scientific method whereby science set up testable hypotheses and then try to verify/falsify them, rather than trying to confirm them by directly accumulating favourable evidence.

Basically an H-D method is to be preferable to the method of *enumerative* induction, whose limitations have been decisively demonstrated by Hume. The H-D method has been viewed by many as the *ideal scientific method.*

The Covering Law Model (Hempel-Oppenheim) is schematized into a pattern (it is so called because it covers nomological or exceptionless laws):

$$\uparrow \frac{\text{Reason : Explanation}}{\text{Why? : Explanation}}$$

1. Initial Condition (C_1, C_2, C_3........)
2. Law (L_1, L_2, L_3) → Hypothesis ← (NECESSARY laws or statistical laws)
3. Therefore, E (event) to be explained.

All share the schemata: N (p⊃q) {N: nomological = exceptionless}

$$\begin{array}{l} N(p \supset q) \\ p \\ \therefore Nq \end{array}$$

Scientific explanation was conceived as deducing a particular sentence from a universal law (given some particular initial conditions about state of the world at a time).

More formally, given (H.A) → O, 'H' is the *hypothesis*, 'A' a statement of Initial Conditions; 'All lead is malleable' and 'The piece of lead is now being hammered' states the Initial Conditions, it follows deductively that 'This piece of lead will change shape'. In deductive logic, the schema:

$$\begin{array}{l} (H.A) \rightarrow O \\ \underline{\quad O \quad} \\ \therefore (H.A) \end{array}$$

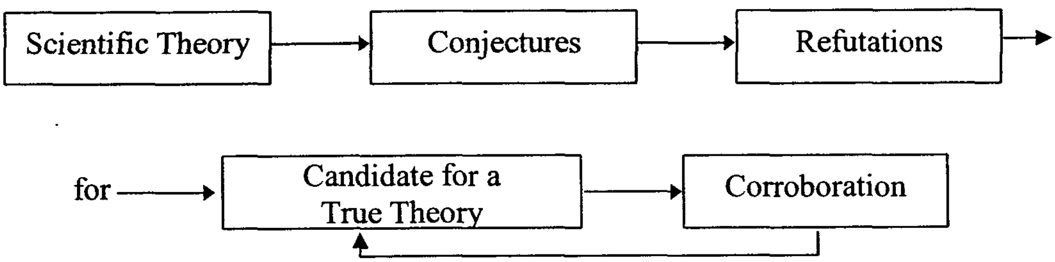
is formally invalid, committing the logical fallacy of *affirming the consequent*. But repeated occurrences of 'O' can be said to confirm the conjunction of H and A, or to render it more probable. On the other hand, the schema:

$$\frac{\begin{array}{c}(H.\ A) \rightarrow O \\ \text{not - } O\end{array}}{\text{not - } (H.\ A)}$$

is deductively valid (the argument form Modus Tollens) for this reason. Thus *falsificationism* has been advanced as a more viable model than *verificationism*. Thus the H-D was rocked both from inside and outside.

Challenge 1: The initial challenge is to verificationism of the early positivism. Popper and his followers think that the H-D method is best employed in seeking falsifications of theoretical hypotheses. Critics of the method point out the infinitely many hypotheses can explain, in the H-D mode, a given body of data. So that successful predictions are not probative, and that (following Duhem) it is impossible to test isolated singular hypotheses because they are always contained in complex theories any one of whose parts is eliminable in the face of negative evidence. Thus Holism is born: theory is more basic than observation.

Science should aim *not* to verify or confirm hypotheses – as verificationists and inductivists in general claim- but to *falsify* them. This is because science is interested in universal affirmative conclusions, of the form 'All as are Bs' and if the universe is infinite, such conclusions could never be verified. However, they could be falsified by the discovery of a counter-example. Popper rejects possibility of 'weak' confirmations, replacing it by his own notion of corroboration. So, Popper's <u>Naïve</u> Falsificationism is given in the following schema;



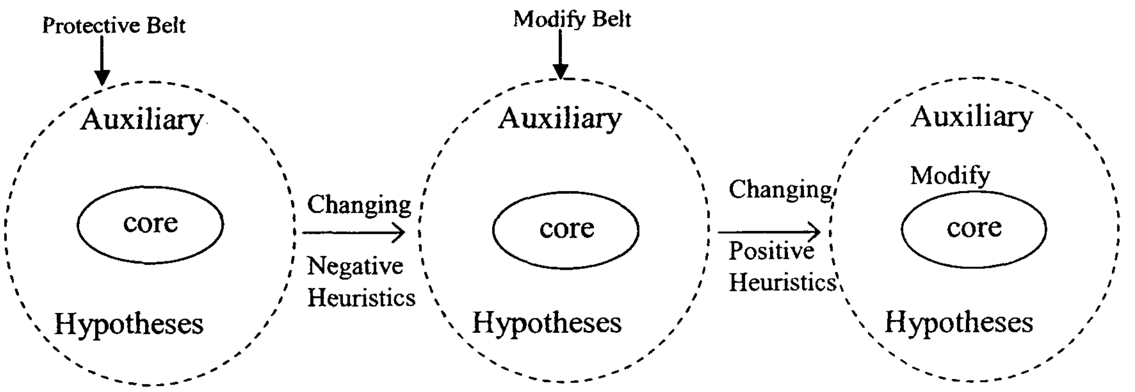
containing the following features:

1. An adequate response to the positivist's notion of verifiability (every synthetic proposition is verifiable to be true or false in relation to experience);
2. Scientific progress can be understood in terms of *conjectures* and *refutations*;
3. A theory is true if and only if it is *falsifiable*; so, falsifiability is a *special* case of criticizability;
4. That is a *line of demarcation* between science and non-science (e.g. Psychoanalysis and Astrology);
5. Truth is to be replaced by *truth-likeness* (verisimilitude);
6. All scientific theories constitute what is called '*objective*' knowledge (Third-World entities, independent of the mind). Hooker as a cognitive-reductionist critiques Popper's 'Epistemology without Subject'[22];

7. Popper makes a distinction between observational (singular existential statements) and categorical statements (Universally quantified categorical statements);

8. Popper's solves the mind-body problem with some form of interactionism between body (*First-World* entity) and mind (*Second-World* entity).

Challenge 2: Sophisticated Falsificationism: According to Lakatos's methodological account of *Research Programmes*, falsifiability does not work in the way Popper has conceived it, especially seen from theory change in mathematics. So Lakatos characterizes Popper's *falsifiability* as a *naïve* version of falsifiability. He goes on to develop a *new extended* version called *sophisticated* falsifiability programme, as heuristics which is given below:

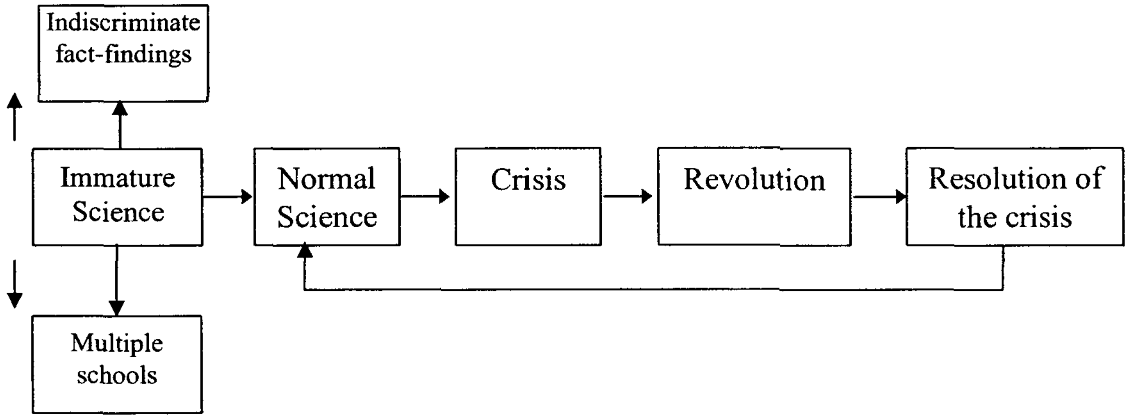


Lakatos coined the phrases *negative* and *positive heuristics*. The *negative* heuristic of a programme is a protection zone around the original world-view, that is, the new theory. Here all attempts have to be made to protect the original vision. The *positive* heuristic defines how the research programme can be developed, adding *new* theories to explain known phenomena and predict new phenomena. Turning to Lakatos, with his notion of a "hard core" of a research programme which has to be protected from falsification by deflecting criticism to other "non-core" elements of the programme, Chalmers finds that there is no satisfactory guide to the selection of theories to be protected from the rigors of criticism[23].

Within Lakatos's approach, a scientist works within a research programme that corresponds roughly with Kuhn's 'paradigm'. Whereas Popper rejected that use of *ad hoc* hypothesis as unscientific, Lakatos accepted their place in the development of new theories. Later on, we shall see how Lakatos's sophisticated variety enters into 'competition' with Lauden's own account of RT (Research Traditions)[24].

Challenge 3: Thomas Kuhn's 'Theory Change in the Wild': According to Craver, 'theory change in the wild' goes from Kuhn's account of scientific revolution in terms of Paradigms and Lakatos's methodology of scientific research programmes. We can start with Kuhn's schema and end up with Feyerabend's according of incommensurability of scientific theory.

It is schematized as follows:



Normal science is the day-to-day research activity purporting to force nature into *conceptual boxes* provided by the paradigm. Normal science is conservative, and Kuhn calls it a puzzle-solving activity[25]. In sheer temporal terms, 'normal science' occupies much larger span than does *revolutionary* science. That is to say, science is *revolutionary* or normal.

The notion of a paradigm is vague, though Kuhn describes some of its key features. A paradigm is partly defined by an exemplary scientific achievement in which some scientific puzzles have been set and solved using various conceptual and empirical techniques.

Challenge 4: 'Anything Goes': Feyerabend has a very strong view on the 'incommensurability' of different conceptual frameworks of knowledge. He takes the stance that scientific knowledge is no more valid than the other forms (so, relativism results). State has been separated from religion, but not from science. Science goes in tandem with democracy. Feyerabend wants the *state* to be neutral and allow citizens to decide for themselves what forms of knowledge are valid, or relevant for them. Knowledge based solely on observation or inductivist approaches would leave mankind the *poorer*[26].

Finally, Feyerabend argues persuasively, indeed that in the end Lakato's philosophy of science differed only inwards, not in substance, from his own more *openly irrationalist* one. And Kuhn had no difficulty in showing the very great amount of agreement that exists between himself and Popper. Lakatos and Popper, on the other hand, are at pains to magnify any distance separating them from Kuhn, and would be still less willing to acknowledge affinities with Feyerabend; and Popper is almost equally anxious to distinguish Lakatos's position from his own. Therefore Popper, Lakatos, Kuhn and Feyerabend occupy leading positions in western philosophy of science in this century. To them, we owe the prevailing view that scientific knowledge is never true (nor even probable), and never false (nor even improbable). Even the best scientific opinion, at any time, is nothing more than on unjustified conjecture, a socially-imposed dogma, or a fashionable *gestalt*.

Challenge 5: Laudan's Account of *Research Tradition* (RT) joins the bandwagon with his *empirical* confutation of realism. Laudan *counterposes* his view against *Convergent Epistemic Realism* which contains the following proposals (RC1-RC6)[27].

[RC1]. Scientific theories in mature sciences are *typically* or *approximately* true.

[RC2]. More recent theories are *closer* to the truth than the earlier ones.

[RC3]. All the terms i.e., *observational* and *theoretical* entities of the theory in mature sciences generally *refer*.

[RC4]. Successive theories in mature science '*preserve*' the theoretical relation and reference of earlier theories.

[RC5]. New theories (do and should) explain the *success* of their predecessors.

[RC6]. Claims RC1 – RC5 constitute the best if not the only explanation for success of science and their success provides *empirical* confutation for realism[28].

On Lauden's reading, RC1 and RC2 are 'not very reliable'. Laudan calls them as 'mumbo-jumbo'.

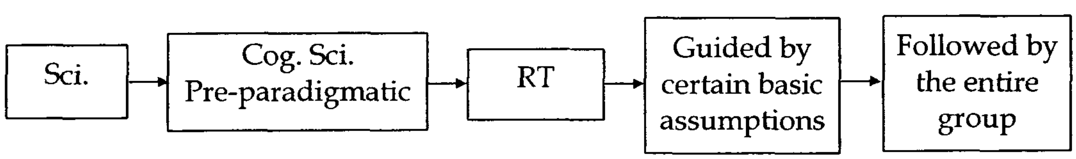
RC3-RC4 are 'vacuously true'.

RC5 is questionable.

RC6 simply stands for an *abductive* strategy.

At one point, Laudan counters *scientific realism* (especially against abductive argument for Realism) with his *pessimistic meta-induction.* He points out that there are lots of real historical cases in which scientific theories which *have been* predictively successful and have contributed positively to scientific methodology *have not been true*, so that the truth of scientific theories need not be posited in order to explain the success of scientific practice.

For Laudan, RT provides 'a set of guidelines for the development of specific theories' or a set of *general assumptions* about the entities and processes in a domain of study, and about the appropriate methods to be used for investigating the problems and constructing the theories in that domain. The schema for RT can be formulated thus:



RT may be placed *in lieu* of specific theories, each of which is designed to particularize the *ontology* of the RT and to illustrate, or satisfy, its methodology. RT is neither explanatory, nor predictive, nor directly testable. This is typical of his anti-realistic (instrumentalistic) stance against science.

In sharp contrast to the *specific* ontology of *theory*, RT, at best, specifies a *general* ontology for nature, and a general method for solving natural problems within a given natural domain.

Bechtel concedes that 'conceptual problems do not result from failure of empirical fit', for they could arise even if the theories were 'totally adequate empirically'. With reference to cognitive science, Bechtel mentions the '*tension*' created between by assuming that the mind is an 'information-processing machine' that works by *deterministic* principles and moral principles that seem to require '*free will*'. This forces Bechtel to seek Laudan's RT taking positively Laudan's stress on religious factors as 'affecting' or 'influencing' science.

But Eckardt, on the other hand, a revision of Laudan's RT, can be put into operation for his own project (called ANTCOG: Adult Normal Typical COGnition), and for understanding the scientific credentials of cognitive science[29]. But RT is unidirectional or monolithic. Bechtel does *not* approve RT as a genuine method. Bechtel thinks that, science should be unified into an integrated whole i.e., called the *unity of science*. So he does not favour Eckardt's approach over his own variant of 'inter-field theories' as one succinct form of inter-theoretic relation between theories (Churchland)). Later, turning against *unity*, Bechtel seeks a *weak* view of reductionism. Inter-theoretic account of theories are not favoured as it leads us towards a *plurality* of theories (R. McCauley 2007), but for Bechtel, the interfield theories may lead us ultimately to a recognition of '*rivalry*' between theories[30].

1.3 CONSTRUCTIVIST/INSTRUMENTALIST CHALLENGES TO SCIENTIFIC REALISM

This Section continues to look at the challenges, with a focus on the different versions of 'No Miracle Argument' of Putnam, Boyd, Hacking and Fraassen. The Realist View of Science and the theories produced are attempts to describe the reality of the world. As science progresses, knowledge approaches the truth about *Realism* defeating *Anti-Realism.*

Anti-realism is the view that the world not real or it does not exist. It is opposed to realism.

On the other hand, *Instrumentalists* admit that theories are (merely) convenient *models* which allow us to understand and predict. Theories are *instruments* for understanding and prediction represents yet another phase of the challenge to realism especially to the distinction between observable and theoretical entities. We can start quoting a number of statements about realism:

Realism assumes the metaphysical reality of the world;

Realism is only a platitude;

Our Best Theories about the world may turn out to be false.

A.F. Chalmers feels that all realists create more challenges. An instrument can be useful in certain circumstances but not in others. A realist could not tolerate this situation and would work to develop a new theory to encompass all data. Realism opens up more opportunities for advancement and creates more challenges for development than instrumentalism[31].

1. Scientific Realism, at the most general level, is the view that the world described by science is the *real* world, as it is, independent of what we might take it to be. Scientific Realism is thus the *commonsense* (or common science) conception that, subject to a recognition that scientific methods are fallible, and that most scientific knowledge is approximate, we are justified in accepting the most secure findings of scientists 'at face value'.

2. We have *no one* single descriptions for everything. But even if we had one, its idealization to different levels seems to be a requirement for our understanding. Thus, while realism claims the existence of just one single real world, scientific theories provide us with an ontological pluralism. These theories commit us to accept the ontology of each of our mature and established theories (no matter on what level) as describing the way things really are on that particular level. This tension is exacerbated by the observation, made by *Constructivists* some time ago, that the ontologies of theories on different levels are incommensurable.

3. Scientific Realism involves *two* basic positions. (a) It is a set of claims about the features of an ideal scientific theory; an ideal theory is the sort of theory science aims to produce. (b) It is the commitment that science will eventually produce theories very much like an ideal theory and that science has done pretty well thus for in some domains. Scientific Realism usually holds that science makes progress, i.e., scientific theories usually get successively better. For this reason, many people, scientific realist and

otherwise, hold that realism should make sense of the progress of science in terms of theories being successively more like the ideal theory that scientific realist describes.

4. Scientific Realism relies too much on older philosophical positions including rationalism and realism. However, it is a thesis about science developed in the twentieth century portraying Scientific Realism in terms of its ancient, medieval and early modern cousins is at best misleading.
5. Scientific Realism is developed largely as a reaction to Logical Positivism. Logical Positivism was the first philosophy of science in the twentieth century and the forerunner of scientific realism, holding that a sharp distinction can be drawn between *observational* terms and *theoretical* terms, the latter capable of semantic analysis in observational and logical terms. These difficulties for logical positivism suggest, but do not entail, Scientific Realism, and lead to the development of realism as a philosophy of science. The development of realism as an alternative to positivism also leads to arguments to support realism as a philosophy of science.
6. Scientific Realists point to the success of scientific theories in predicting and explaining a variety of phenomena, and argue that from this we can infer that our scientific theories (or at least best ones) provide true descriptions of the world, or approximately so (Putnam's 'No Miracle Argument').

Also against scientific realism, social constructivists point out that scientific realism is unable to account for the rapid change that occurs in scientific knowledge during periods of revolution. Another argument against scientific realism, deriving from the *underdetermination* problem (originates in Quine's underdetrmination of theory by data just as in inductive arguments), is not so historically motivated as the others. It claims that observational data can in principle be explained by multiple theories that are mutually incompatible. Realists counter by pointing out that there have been few actual cases of underdetermination in the history of science. Realists claim that, in addition to empirical adequacy, there are other criteria for theory choice, such as parsimony.

(i) Putnam's version of 'No Miracle Argument': Putnam passes through *three* stages. He passes from *Metaphysical Realism* to *Internal Realism* and thenceforward to *Commonsense Realism*. This is a very significant development because it shows that realism can make a natural passage to *anti-realism* and that in turn generates a kind of realism thus bringing us back not into metaphysical realism but a realism which is acceptable while at the same time it gives scope of cognitive domains. It is not unlike the passage from functionalism in philosophy of mind, to what is called post-functionalism *via* a critique of functionalism (Putnam is the founder of functionalism). Functionalism takes mental states as computational states or better, causal states. The critique denies this and the transit to post-functionalism still harbors some form of functionalism. There is a parallel dialectic in both (A. Kanthamani, 'Hilary Putnam's Post-Functionalistic Project' Paper presented in the Indian Philosophical Congress, 1996 Abstract published)[32]. Post-functionalism does not stand for a rejection of functionalism, but the resolution of the 'giant antinomy' of realism within a Wittgensteinean theory of meaning as 'use'.

Following this, Putnam, proposed what came to be known as the 'miracles' *against* Realism[33]. Putnam and Smart argued that unless the theoretical entities employed by scientific theories actually existed and the theories themselves were at least approximately true of the world at large, the evidence of success of science (in terms of its application and predictions) would surely be a 'miracle'. It appears as if it is an argument in favour of realism.

Putnam continues the discussion of scientific realism, and gives what he calls the *ultimate argument.* He begins with a formulation of realism which he says he learned from Michael Dummett. A realist holds that (1) the sentences of that theory are true or false is something external i.e., to say, it is not (in general) our sense data; actual or potential, or the structure or our minds, or our language, etc.

One major challenge each of the *four* thinkers namely Hilary Putnam, (1990); Richard Boyd, (1992); Ian Hacking, (1990) and Bas van Fraassen, (1980) puts forward is an argument against realism. The argument is called *argument against miracles*[34]. Putnam challenges the Logical Positivists' account of science which is roughly schematized below.

I. Putnam's challenge to logical positivists leads through non-realist position (identical with instrumentalism + conventionalism + relativism) towards a sort of *Cognitive Pragmatism* (Commonsense Realism).

II.

® → An overarching empirical hypothesis

1. <u>Metaphysical R</u> → God's - Eye-View (also called: Representative Realism, scientific realism and pragmatic realism)

↓ reconstructed into ↓

2. <u>Internal R</u> → (bordering on verificationist/ warranted assertibility (*anti-R*))

↓ mild rational reconstruction ↓

3. <u>Commonsense R</u> → *anti-anti-R* (Minimal Realism-in-Use. Model-theoretic problem: the problem of availability of *multiple* interpretation (*pluralism*)).

1 + 2 + 3 → 'Cognitive Pragmatism'

III. The Argument from Success: Realism is the *only* philosophy that does not make success of science a miracle.

Scientific progress is successful
———————————————— / Inference to the best explanation
∴ no miracle

The above argument itself is a case of inference to the best explanation. It is also called '*argument against miracles*'.

Finally, Putnam's own positions in which his old-fashioned story of the *Seducer* and the *Innocent* maiden was meant as a double warning: a warning against giving up commonsense realism and, simultaneously a warning against supposing that the seventeenth-century take of 'external world' and 'sense impressions', 'intrinsic properties' and 'projections', etc, was in any way a rescue of our commonsense realism. So, commonsense realism is true: there are tables and chairs as we commonly perceive them.

(ii) Boyd's Explanationist Version: Broadening the vision of Popper's attack on instrumentalism which is unable to account for his own falsificationist methodology, Boyd developed an *explanationist* version of the Miracles Argument that focused on the *methods of science.*

Boyd emphasized the human–centered (constructivist and conventionalist) aspects of science like Kuhn and Feyerabend). Boyd asked why method crafted by us on reflecting our interests and limitations lead to *instrumentally* successfully science.

Realism offers the best (indeed, the only) explanation. This is *because*, as he argues, if we begin with *truth* or near-truth, the methods we have crafted for science produce even more of the same. Since it is only realism that demands the truth of our scientific theories, the *realism wins* as giving the best explanation for the *instrumentalist* success of science. Hence, like a scientific hypothesis, realism is most likely to be true and we should believe in it.

Boyd holds that any talk about the "reality" of kinds or regarding "realism about" some kind or family of kinds is best understood as an imprecise way of addressing the question of the nature of the contributions (if any) that *reference* to those kinds makes to the satisfaction of the accommodation demands of the relevant disciplinary matrix[35].

Boyd, and occasionally Hilary Putnam, has claimed that *realism is itself already the best of both worlds.* They have claimed, more or less explicitly, that the picture of scientific change that is painted is inaccurate, and so the argument from scientific revolutions is based on a *false* premise: the history of science is not in fact marked by radical theoretical revolutions (at any rate not the history of "mature" science). On the contrary, claims Boyd: The historical progress of the nature of science is largely a matter of successively more accurate approximations to the truth about *observable* and *unobservable* phenomena. Later theories typically build upon the (observational and theoretical) knowledge embodied in previous theories.

(iii) The Experimentalist Version: Hacking produced an *experimentalist* version for Miracle Argument which he calls Entitative Realism. His theory stipulates that independent existence of theoretical entities without commitment to the truth of the theories employing them, is implausible[36].

1. Hacking tries an example of distant astronomical entities which are beyond our capacity to manipulate experimentally. Hence, *anti-realism* regarding them is more of a *live* option than it is regarding electrons. Hacking defends his antirealism about theories by emphasizing that scientists often use many, radically dissimilar "models" in connection with the some *unobservable* entitles.

2. Entity Realism = *df.* entity realism does *not* commit itself to judgments concerning the *truth* of scientific theories.

Instead, Entity Realism claims that the *theoretical entities* that feature in scientific theories, e.g., 'electrons', should be regarded as *real* if and only if they *refer* to phenomena that can be routinely used to create *effects* in domains that can be investigated independently.

Entity Realism has been an influential position partly because it coincided with a general trend in philosophy of science and science studies. More generally it downplays the role of theories and puts more emphasis on experimentation and scientific practice.

Thus *Entity* Realism is also called '*Instrumental Realism'* or '*Experimental Realism*'. While many philosophers acknowledge the intuitive pull of entity realism, it has been strongly (some would say: conclusively) criticized, both as being too restrictive (in that it ignores entities that are observable yet do not lend themselves to manipulation) and as being too permissive (to the extent that seemingly successful instances of manipulation may turn out to be spurious).

(iv) Fraassen's Version: Bas Von Fraassen's response to 'No Miracle Argument' *attentuates* anti-realism resulting in what is called *Constructive Empiricism* (CE).

Fraassen puts forward a Minimal Case for CE: Science aims to give us a *literally* true story of what the world is like; and acceptance of a scientific theory in *virtue* of the *belief* that it is true. Science aims to give us theories which are empirically adequate, and acceptance of a theory involves as belief only that it is empirically adequate.

In Fraassen's view of Constructive Empiricism, science aims to

(1) save the phenomena

(2) About observables: truth and empirical adequacy *coincide* (truth = empirical adequacy)

(3) About unobservables: truth implies empirical adequacy but *not vice versa* (may be empirically adequate, *but* false).

What the above versions show is that neither realism nor reductionism survive intact. This is not entirely the purpose for which we recall Putnam's *triple-stage* argument which is dialectical at the core. With Putnam, we have what has come to be called the Computational Theory of Mind (CTM). Now, functionalism is divided into the commonsense (or Analytical) Functionalism, Psycho-functionalism (empirical functionalism), and Machine (Turing) Functionalism. Putnam has argued against all (his Twin Earth Arguments against the first, his critique of Chomsky in the second- we have no inner states of language or grammar, and his essential stance against the last is that Turing Computational States cannot be individuated and therefore it is a sort of I-know-not-what state). What Putnam tried to arrive at here is that CTM is essentially incomplete. Recently Oron Shagrir has read this argument as serving no damage to the cognitive science[37]. On the other hand, what they aim to show is that there is a 'semantic task' for computational theory of mind (what exactly do we mean by saying that brain computes?). The argument forces us to have a thorough review of the very idea of computational theory of mind (it will be shown that essentially the same challenge is evoked against the Fodorian CTM that is characterized as the Language of Thought Hypothesis (LOTH) which is supposed to specify CTM in a way by making use of two key notions of representation and computation (see below the discussion on Andler's views in the following section). Andler's own preference is to what he calls a Liberalized Classical Framework which includes computational states (how the concatenation of XXX with XX yields XXXXX) as well as I know-not-what-states (semantic task: how to interpret). LCF in this sense represents the architecture of the human mind. Accordingly the three models (the symbolicist, the connectionist and the dynamicist) of cognitive science are distinguished into phases as given below:

Phase 1: The linguaformal LOTH works on language-like data (logic is primary);

Phase 2: The Non-linguaformal PTC (proper treatment of connectionist networks) use numerical parameters-like data for input-output in the network.

Phase 3: The Dynamic that is interactionist.

Having reviewed the challenges to reductionism and realism as well as to functionalism, we shall now proceed to explain the interdisciplinary relationship in the following section.

1.4 THE *THREE* OVERVIEWS: PHILOSOPHY OF SCIENCE, PHILOSOPHY OF LANGUAGE, AND PHILOSOPHY OF MIND

Overview (1): We have seen that philosophy of science provides a meta-theoretical perspective on the endeavors of any scientific enterprise, analyzing such things as the goals of scientific investigations and the strategies employed in regarding those goals. Philosophy of science thus proposes a perspective from which we can examine and potentially evaluate the endeavors of cognitive science. The point here is that this is not quite independent of philosophy of mind as well as philosophy of language.

Overview (2) states that, philosophy of mind offers substantive theses about the nature of mind and of mental activity. All the existing philosophical theories of mind are termed as *a priori*; we must search *a posteriori* theories of mind-brain. This does not mean all *a priori* theories are to be dismissed out of court. We must negotiate a passage from the *a priori* to the *a posteriori* theories.

Overview (3): Philosophy of language also has figured centrally in the study of cognitive process (*Continuum Thesis 1*). Philosophy of mind is philosophy of language *and* mind in a specific sense.

The 'Cognitive' in Cognitive Science expands into its equivalents such as: philosophy of mind and language, philosophy of mind and cognition, philosophy of mind and action (mental actions constitute a subpart of physical actions according C. Peacocke). Andler cites *four* key theses covering the three overviews stated above:

T1: Continuity Thesis: Cognitive Science extends analysis of language in the direction of syntax and semantics.

T2: Semantic Thesis: Content is shared by philosophy and analysis.

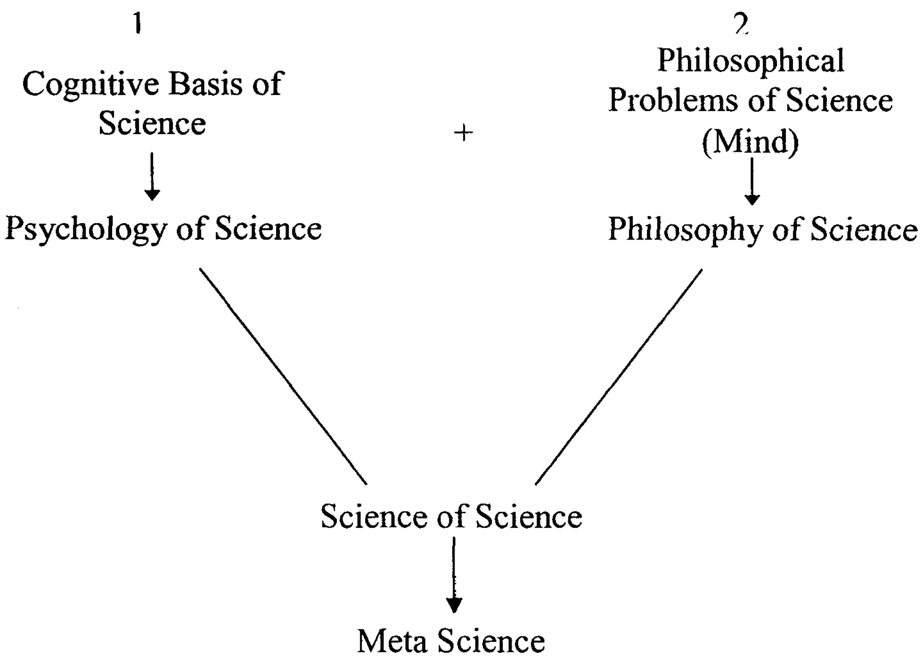
T3: The Technical Thesis: Cognitive Science is a just an outcome of the special branch of philosophy of science.

T4: The Sceptical Thesis: Cognitive Science is far from having reached stability.

Philosophical analyses of language have also had considerable influence on work in other disciplines of cognitive science, including linguistics and cognitive psychology. Philosophers, however, have not been the only investigators who have tried to analyze language; and so, to set the framework for discussing philosophy of language, it is useful to indicate how philosophical analyses of language differ from those advanced in other cognitive science disciplines. In this respect, philosophy of language is closer to linguistics. But philosophical analyses also differ from those of linguistics. Linguistics has been principally interested in developing abstract characterizations of either the *syntax* or *semantics* of a language, and often has produced generative accounts that try to predict the infinite set of sentences that can arise in a language from a finite number of principles.

Philosophers, on the other hand, have attempted to provide general accounts of what constitutes the meaning of linguistic expressions without trying to develop detailed theories to account for the types of utterances that appear in *actual* languages. A great deal of philosophical theorizing has focused on language and on the ability to language to carry meaning. The *referential* analysis of language was further developed by a group of philosophers commonly referred to as the logical positivists.

Within Cognitive Science we can combine cognition with philosophy of science as shown below:



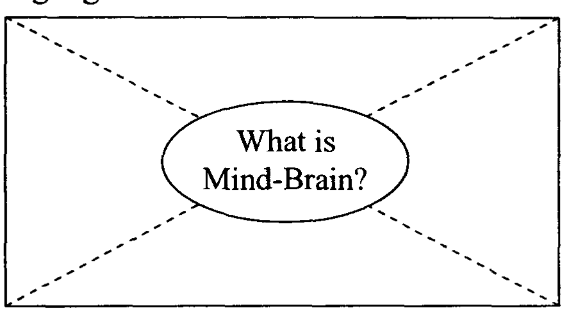
1) claims that Science is *innately* channelled

2) claims that Science is *externally* channelled

Philosophy of science thus offers a perspective from which we can examine and potentially evaluate the endeavors of cognitive science. On the other hand, *philosophy of mind* offers substantive theses about the nature of mind and of mental activity. Although these theses typically have not resulted from empirical investigation, they often have subsequently figured in actual empirical investigations in cognitive science, or its predecessors. Even in its unsettled state, however, philosophy of science can be useful to cognitive science. It offers a variety of perspectives from which we can examine the investigations being pursued in cognitive science in an attempt to understand these investigations. These perspectives can be useful to cognitive scientists as they try to chart future paths for their investigations. The perspective offered by philosophy of science lack apodictic certainty.

A roughly presented schematic figure will be formulated as below:

1. Philosophy of Language 3. Philosophy of Science



2. Philosophy of Mind 4. Philosophy of Cognitive Science

1. For Davidson (his anomalous monism), (1) and (2) are to be conjoined. He is arguing that unless a creature is able to make the sort of distinctions that can be represented in language, it lacks thought. Philosophy of language and philosophy of mind may also be conjoined with philosophy of Mathematics, Physics etc (Thagard's *seventh* challenge to be discussed below);

2. For Dummett (1) is primary. Dummett claims that theory of meaning is basic;

Following Frege, Dummett believes that a theory of meaning or semantics is more fundamental than metaphysics to which all other branches of philosophy are reduced. This is the best way of *systematizing* analytical philosophy.

3. For Searle, claim (2) is first to which (1) is reduced. i.e., mind and cognitive science is *more* basic than language (opposing 2);

Searle believes that philosophy of mind is more basic than philosophy of language and the latter can be reduced to the former. For Andler, the relation is one of 'mutual dependence'. Problems in philosophy of mind (such as the mind-body problem, and the problem of mental causation) provide the 'enabling factors' to the 'naturalistic' foundations of cognitive science.

Andler's definition of cognitive science arises essentially out of the above considerations:

'Cognitive science corrals a variety of disciplines and approaches with the aim of providing an integrated account of the mind, its stages, processes and functions'. As such, 'it draws on any potentially relevant disciplines such as neuroscience, computational science, physics, mathematics, linguistics, philosophy, parts of social science', and in a sense, 'broadened far beyond the once perceived epochs of psychology'.

Naturalism is defined as the naturalization of the mental realm (we will discuss Andler's naturalism with a human face below).

4. For many thinkers, (4) is modelled in (3);

5. For some thinkers, (2) is redundant in the light of (4);

6. For a few, (3) is redundant[38] .

Researchers first began to investigate how mental processes were supported by the brain, one of the first capacities they sought to localize in the brain was *language*. Moreover, some of the first successes in relating mental abilities to the brain involved language. Bechtel discusses in more detail, the localizationist claims, as developed by either Broca or Wernicke, that fell into disrepute in the earlier decades of the twentieth century, before being received by Norman Geschwind in the 1960s and 1970s. Geschwind defended the view that Wernicke's area was a *comprehension* centre while Broca's was a *production* centre[39]. Since then, there have been multiple reinterpretations of the contributions of different areas involved in language processing. One prominent view has been Broca's area is involved in *syntactic* analysis while Wernicke's involved in *semantic* analysis. Most of this research has relied on analysis of deficits following lesions to Broca's or Wernicke's areas, but more recently, researchers have started to employ neuroimaging of normal individuals performing language tasks.

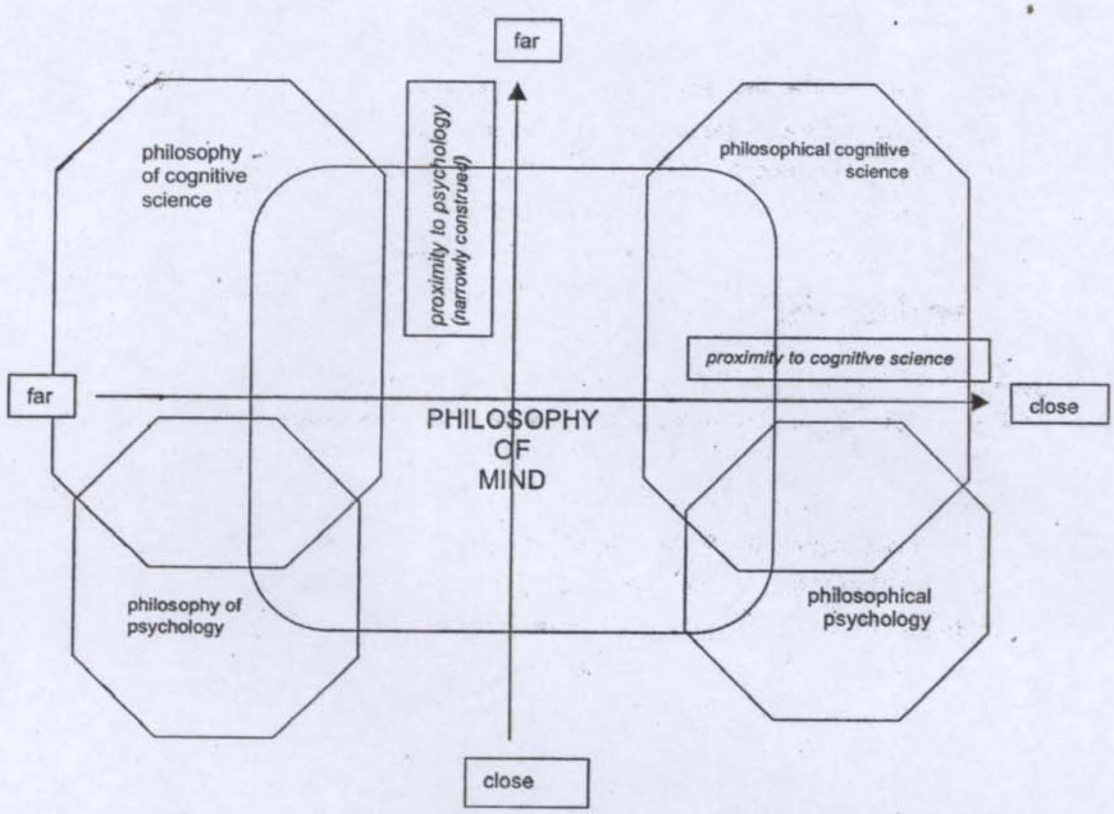
Language remains our most fascinating cognitive capacity. It becomes a computational analysis of language. The early promise of determining what specific brain areas contribute to language has not yet bean fulfilled, but the near future promises to be exciting. New tools, including neuroimaging, are pointing to more brain areas involved in language processing. The challenge is to determine how the different processing contributions each makes continuing progress in this effort will also likely reduce the differences on such polarizing issues as the uniqueness, modularity, and nativism of language.

William Bechtel has tried to provide a broad introduction to the issues of philosophy of mind and the positions philosophers have taken on these issues. Bechtel presented several different attempts of philosophers to say what is distinctive about intentionality that rendered scientific accounts of mental states impossible. He had presented a variety of proposals philosophers have advanced to explain intentionality within a framework of natural science. He began with the computational theory of mind, which seeks to use the propositional attitude formulate for describing mental states as the basis for generating an account of internal processing.

He discussed *three* ways philosophers have tried to explain the representational capacities of mind, Dretske's information theoretic approach, Searle's biological reduction, and Dennett's intentional stance approach. Dretske's approach used the mathematical theory of information to explain how one state (representation) could be about another (misrepresentation). Searle's approach linked intentionality to our biological constitution, but it seemed to make intentionality mysterious. It claimed that intentionality was biological phenomenon, but denied that we could explain what makes certain biological states intentional. Dennett's intentional stance perspective made the intentional perspective something we adopt with respect to certain systems. Bechtel suggested that how we might develop a vision of Dennett's approach that views intentional states realistically. It does this by treating them as states of the system that are adaptive to features of the system's environment[40].

We began with readings concerning the foundations of neuroscience, then explored several of the most absorbing and challenging topics at the intersection of philosophy and neuroscience[41]. Although McCauley and Churchland disagree about the precise nature of the relation between psychology and neuroscience they at least agree that there is a *relation*, and so share a commitment to some form of reductionism, or the view that psychology is reducible to neuroscience. Mark. H. Johnson has introduced as to the newly merging field of developmental cognitive neuroscience[42]. Finally, the short-term future of developmental cognitive neuroscience is dependent on successful collaboration between developmental neurobiologists, cognitive developmentalists, and computational modelers.

The cognitive approach is heir to the philosophical tradition of using principles of rationality to explain the acceptance of scientific theories, but goes far beyond it in both resource and application. Computational ideas developed in the last thirty years have made it possible to give much richer and more detailed account of the structure of science.



Nuances of the relationship between the different disciplines can be portrayed in yet a different way according to Andler, who takes cognitive science as having a root in the European traditions.

Along the *first axis*, one can plot *proximity* to (cognitive) science, as it involves either collaboration, or sympathy, or both. Near one end of the line, one finds research programs in which philosophers and scientists from one or another discipline, or sometimes several, attempts to provide a solution to some specific problem concerning a cognitive phenomenon. Cognitive science as an enterprise situated at *some distance*, somewhat like philosophy of art stands (for the most part) outside, or general philosophy of science stands outside science (by necessity, as there is no such thing as 'general science'), or philosophy of chemistry, in all but exceptional cases, stands outside chemistry. Philosophers who operate in such a framework typically do not attempt to directly contribute to the enterprise they are appraising.

The *second axis* measures distance from psychology in the traditional sense. At the *near* end, there is psychology itself; at the *far* end, cognitive science in its widest sense, where psychology as traditionally construed, no longer occupies a privileged, central position. One of the main duties of philosophy of cognitive science is to critically examine and compare these opposing views of the essential nature of the field.

We need to introduce *two* complications in order to get a realistic picture with familiar labels. The *first* is to replace the discrete positions by a continuum along both dimensions. This creates a *middle* zone straddling all *four* positions. The only available label for this middle zone is *philosophy of mind*. It intersects with *philosophical psychology* and *philosophical cognitive science*, on the *right*, and with *philosophy of psychology* and *philosophy of cognitive science*, on the *left*. However, philosophy of mind extend beyond the entire space, as some philosophers working on the mind raise metaphysical issues quite independently of any science of the mind, past, present or future.

Thus there is a part of philosophy of mind which resolutely straddles both cognitive science and its philosophy (this part is sometimes called cognitive philosophy, or again philosophy of cognition). Similarly, one may be tempted to take philosophy of psychology to be a proper part of philosophy of cognitive science, and philosophical psychology a proper part of philosophical cognitive science. But that would be to ignore or preclude the possibility of a non-cognitive form of psychology, together with a philosophy of non-cognitive psychology, or rather, a philosophical examination of the claim that psychology is not, and should never become, entirely immersed in cognitive science.

As for the philosophy of cognitive science, its fate has been closely connected to the development of analytic philosophy, which was all but barred from France after WW II[43]. Only in the 1960's were a small number of young philosophers able to cultivate it, and it took another 20 years or so for analytic philosophy to gain acceptance. But next to them, there are a small number of philosophers who learn on Kantianism or on phenomenology (mostly in Husserl's Merleau-Ponty's traditions) to approach cognition from an angle unfamiliar to most analytic philosophers. Thus there occurs continuity between analytical philosophy and cognitive science (*Continuum Thesis 2).*

Finally, cognitive science is one of the most exciting intellectual and scientific developments of the second half of the 20th century, integrating insight from psychology, linguistics, artificial intelligence, neuroscience, philosophy and other disciplines in an attempt to understand human cognition. It also has a rapidly transforming domain of inquiry. The companion presents a deep and varied account of what one need to know about cognitive science, what it has accomplished, and where it will be going at the start of the 21st

century. Cognitive science becomes a *niche* subject. It becomes so as one of the subject that enters into every subject, whether it is economics or other subjects. These explorations take as their point of departure the question what happens when humans produce new technologies? The aim of the cognitive technologies, and in particular, the interactive computer-based technologies, are humane with respect to the cognitive development and evolutionary adaption of their and users. Later on, we shall show how the term 'Neurophilosophy' is used to combine neuroscience and erstwhile philosophical theories of mind and it has gained a reputation for a cutting-edge area of research. As Churchlands use the term, Neurophilosophy is a discipline that has a 'surview' (Uberfield) of all the other branches of philosophy. For the present, we shall provide the first glimpse of what is known as ANTCOG that is advanced as a viable project in cognitive science. This will enable us to widen the area of inquiry into cognitive neuroscience as well as cognitive systemscience so as to see how cognitive science earns its scientific credentials in the wake of more interesting developments in these areas.

1.5 TOWARDS EVALUATING ECKARDT'S ANTCOG AS A METALEVEL COGNITIVE SCIENCE

Eckardt proposes to put to use Laudan's Scientific Tradition, to bolster up a viable project of Cognitive Science, which she calls the ANTCOG Project. In order to evaluate ANTCOG as a metalevel cognitive project, *two* requirements are to be fulfilled:

a) It is an adequate *conceptual* level investigation;

b) It is *empirically supported* by experimental work in some domain of Cognitive Science. In this section, we present (a) and later on, in Section 3.4, we shall back it up with her account of Kosslyn's experimental work on *Imaging*.

Eckardt's ANTCOG project, which stands for *Adult Normal Typical Cognition* is itself presented as an *empirical project* (knowledge is shared by among various individuals *normatively*, and *descriptively*). By *Epistemic Project*, she means that it is a *normative* or *canonical* project within epistemology. Presented thus, if is a project that lies at the interface between Cognitive Science and Cognitive Social Science. One of the central claims of Eckardt is that we have to use the *two* notions of *representation* and *computation*. These two concepts are factored out of the two leading paradigms called the Symbolicist and the Connectionist types (see Section below). In fact, Eckardt's project takes these two notions as making a *substantive* assumption and this can be *ramified* into *supplementary* assumptions, as it were (see the schematic picture).

SA_1

(a) Representation: Propositional: syntax, semantics and pragmatics.

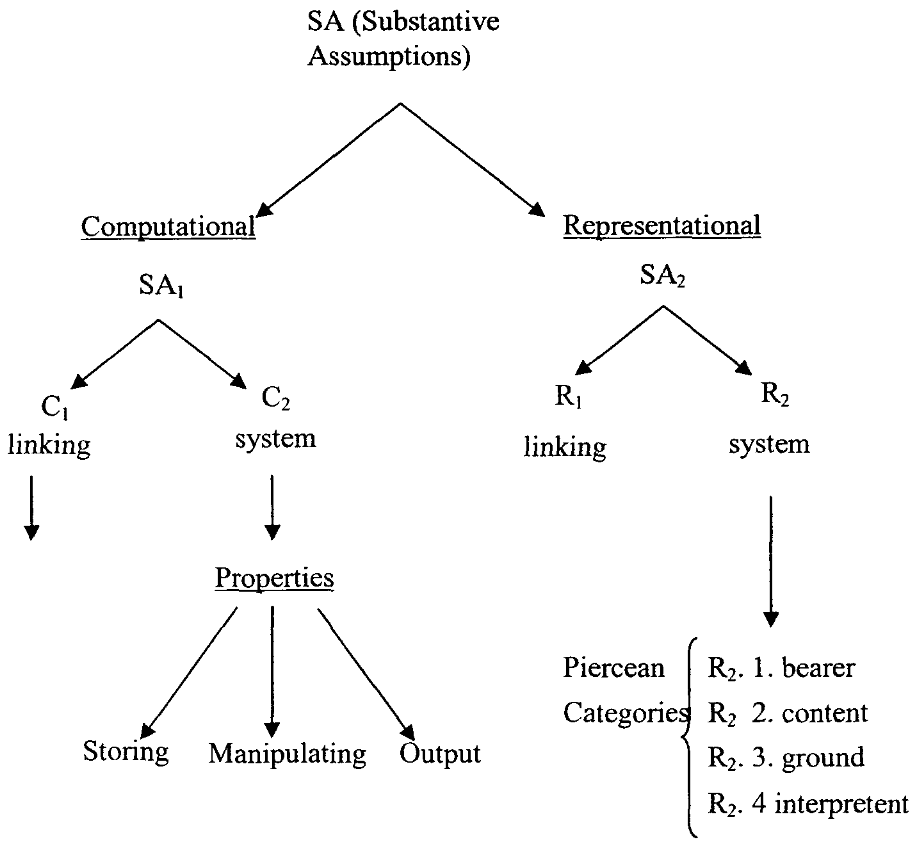
(b) Computational: Input-internal states-manipulating-transition function-output.

Plus the way (a) and (b) carry semiotical implication requires *supplementation* of the above with Peircean categories.

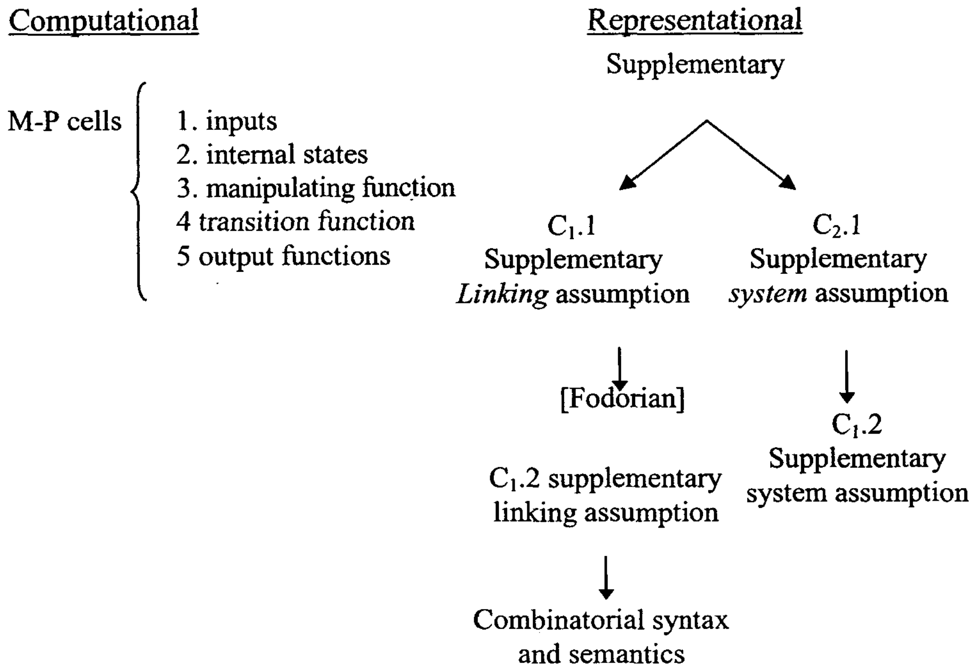
In addition to this, she also has keen interest to include *semantics*-(Pierce and then Millikan)-*pragmatic* interface into the fold of cognitive science. For this purpose, she gives a passing remark about Millikan's Teleological Semantics or Biosemantics (semantic theory + biological consideration like evolution) which is proposed to provide a *bridge* between syntactical and semantic phenomena. It is hoped that once a candidate theory of semantics is in the offing, we have a viable agenda for Cognitive Science.

A *computation assumption* is defined to be a system of computational capacity (c_1) which has the storing, manipulating and output properties (c_2).

What she calls representational assumption requires a set of Piercean categories such as bearer, content, ground and interpretent (R_2). This is shown in the following schematic figure:



What he calls *supplimentary* assumption include the five cells of MuCulloch-Pitt (M-P) theory namely inputs, internal states, outputs, transition function and output function. This is shown in the following schematic figure:



Von Eckardt tries to characterize his epistemic project as a transdisciplinary *framework of shared commitment* (FSC) and *substantive assumptions* (SA) for cognitive science[44]. While FSC come closely to Kuhn's idea of scientific revolution, SA represents a Kuhn-Laudan *mode*. Accordingly, FSC can be split into FSC-*guided* science (Normal) and FSC-choosing science (Revolutionary). Kuhn's idea of *paradigms* is taken as a philosophy of science units of analysis (PS units). From this, Eckardt proceeds to lay down *five* desiderata of research work (such as soundness, immaturity, applicability, coherence and assessment) in cognitive science.

According to Eckardt's assessment, while Kuhn-Feyrabend and Popper-Lakatos models do not apply to *immature science*, Kuhn does not meet the soundness requirement. By elimination, we can choose Laudan, though it cannot adequately meet the others. One of the most important facts about cognitive science is that it is an *immature* field. The problem is to develop a general meta-scientific schema for characterizing the *shared commitments of an immature science*. Then the *immature* science is best characterized in terms of a schema consisting of *four* components, presented as essential for a pre-paradigmatic science:

(1) a set of domain – specifying assumptions

(2) a set of basic questions

(3) a set of *substantive* assumptions which constrain answers to those questions and

(4) a set of methodological assumptions.

Eckardt called any realization of this schema a *Research Framework* (RF).

Eckardt is concerned to defend cognitive as a million dollars academic pursuit against skeptics who deny that there is no cognitive science[45]. One only hopes that the does so. But more to the point, the evaluation of cognitive science *can* bear the shocks of such caricatural account of cognitive science, let loose by these authors. It may be correct to characterize cognitive science (psychology, AI research, linguistic, philosophy, neuroscience and anthropology). But there is no such thing as cognitive science. This is echoed in Howard Gardners[46] : It propagates the thesis that "there is as yet no agreed upon research paradigm, no consensual set of assumptions or methods. A similar opinion is voiced by Miller, Polson and Kintsch in their lead paper:

"This is very *little*, if any, *consensus* concerning a set of more specific goals and meta-theoretical assumptions that could define a coherent field of inquiry" (p.16). Eckardt goes on to 'reconstruct' coherent transdisciplinary shared commitments for cognitive sciences, and claims that this would be substantially in accord with what everyone calls in cognitive science research. He cites *four* reasons for such a reconstruction:

1) Cognitive science is a coherent, intellectual enterprise;
2) Cognitive science has a multidisciplinary character;
3) There is a community of cognitive scientists who are committed to certain *foundational* assumptions;
4) We can reconstruct the *fundamental* consensus for cognitive science, which are *not* unscientific.

(1) to (4) are supported by an *epistemological point of view*.

It is necessary to see how this works against the *strong* sociological programme in philosophy of science advanced by others (Barnes, 1977; Bloor, 1976, 1981). In fact, Laudan advances a *weaker* programme which has significant bearings on cognitive science.

According to Bechtel's view, what is called RT is the broadening of the scope of philosophy of science to obtain a finer-grained analysis of both *empirical* as well as *conceptual* problems within philosophy of science. Laudan takes the merit of Kuhn and Lakatos into consideration even while overcoming the shortcomings both. While his understanding of Kuhn can be used for attacking the *empirical* problems, Lakatos gives us a new dimension of understanding *conceptual* problems.

One important facet of this conceptual problem is found in the way *competition* arises between two theories, even within cognitive science between *cognitivism* and *behaviourism*. Behaviourism has gone out of in a regressive fashion, but still it returns as a progressive programme. So in between Lakatos and Kuhn we can prefer Lakatos programme which is far more compatible with cognitive science. So what follows from the above is that there is a particular argument in favour of Laudan's research programme[47]. According to Bechtel, Laudan's Research Tradition (RT) provides a large scale unit for analysing the sequence of theories, some of *which are alternative to the others*, and hence revisability can in some sense, be accounted for within RT.

So an appropriate definition of what is called RT would tell us that there must be deciding factor when there is a logical inconsistency between two accepted theories.

This *cluster account of theory* provides an *important leverage* for understanding cognitive science. Besides it can also contribute towards understanding learning theory on the one hand and empirical factors in psychology on the other.

Moreover, the distinct possibility of bringing in non-scientific factors looms large in RT. Bechtel mentions how Laudan recognizes religious factors as influencing-enlightening methodological programmes within cognitive science. Bechtel concludes that connectionism provides a more biologically realistic model of cognition than a digital computer from this point of view[48].

Now, we must address ourselves to the question how RT provides a more '*explanatory strategy of cognitive science*', namely, with the strategy of substantive assumptions etc. And Eckardt discusses a number of methodological assumptions including above-mentioned *three* controversial assumptions about the role of neuroscience in cognitive science. In the *epilogue*, she offers her *own list* of foundational challenges that cognitive science must meet if it is to remain viable.

What ultimately emerges from the above Research Framework (RF) are the following questions for Kosslyn's experimental work on Mental Imagery, which provides the necessary experimental back up for Eckardt's endorsement of RT[49].

The experimental work carried out in the *first* phase of his research revealed numerous things about what the human capacity to image, in fact, consist in- about what people can and cannot, typically do on imagery tasks. It has addressed on instantiation of what precisely is the cognitive capacity to visually image? The relevant question is answered in Kosslyn's general theory of mental claims that certain kinds of representation structures and certain kinds of computational process underlie the human ability to image. The relevant question is addressed by Kosslyn's specific dynamic models of the human imaging capacities. Kosslyn has begun to investigate *two* questions about imaging that fall under:

1) How do people typically use visual images to answer questions?
2) How does our capacity to image interact with our capacity to visually perceive? In particular, it seeks to answer these questions in accordance with the substantive assumptions.

As seen in the schema, the linking assumption uses the computer metaphor which entails that it is a system of computational device.

The nature of computer *metaphor* is understood to be more like a 'substitution view', that is more creative than 'interaction view'[50]. This is a point that is probably derived from Boyd's account of realism. As Boyd emphasizes, it is a sort of theory- constitutive metaphor that can become the property of an entire scientific community. Part of Boyd's realism thus, Boyd regards the computational metaphors of cognitive science as paradigmatic instance of theory- constitutive metaphors[51].

Under representational assumption, the *linking* and the system assumptions are subjected to further *supplementary linking assumption* and *supplementary system assumption,* under each one of the *two* categories. As Eckardt shows the above schema will go contrary to the major approaches namely, the Searlean and the Fodorian approaches.

a) Searle's approach has shortcomings on account of his initial resistance to *strong Artificial Intelligence* (AI) programme. So the lesson is we have see the *computer* metaphor in a more ramifying way like the one that includes memory, manipulation, and transition functions.

b) Fodor's approach is defective because it divides the prepositional content into *atomistic* constituents and breaks its head on semantics. His choice of semantics may not altogether he appropriate. So the lesson is that we need a more interesting candidate theory for semantics.

Now, when this is linked Kosslyn's actual experiment gives rise to an *alternative* theory of content determination (TCD). The TCD is a shown to *be a species of possible world semantics* with respect to natural language. This is what that underlies Eckardt's thinking in relating this to the teleological semantics (Millikan).

In Chapter *three* (sec *3.2*), we shall evaluate ANTCOG as a Cognitive Science project. Now, we will proceed to distinguish the interpenetration of three fundamental paradigms *inter alia* other paradigms in the *second* Chapter.

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Chapter 2

COGNITIVE SCIENCE: PARADIGMS AND PROSPECTS

'One of the most promising roles for connectionist modelling is to serve as an explicit medium for pursuing an interactionist. constructivist perspective'

(W. BECHTEL, 2005 Nature and Nurture Controversy)

'Dynamical models without mechanistic grounding are empty, while mechanical models without complex dynamics are blind'

(C.A. HOOKER)

COGNITIVE SCIENCE: PARADIGMS AND PROSPECTS

2.1 FROM COGNITIVE NEUROSCIENCE TO CELLULAR NEUROSCIENCE

The second half of the twentieth century has witnessed not just on explosion of research at the behavioural end of neuroscience, but also extra-ordinary advances in understanding the basic *cellular, synaptic, and molecular processes* in the brain. The idea that neurons constitute the basic functional, cellular units of the brain was not widely accepted until the beginning of the twentieth century, but this provided the foundation for subsequent micro-level research. This research, in turn, has increasingly been integrated with research into higher brain functions. More recently, new tools for manipulating genetic material have extended the inquiry even further. These advances have required the collaboration of scientists trained in a number of specialities, including *neuro-anatomy, neurochemistry,* and *neurophysiology.* Today, cognitive neuroscientists routinely integrate both psychological processes and neural activity, and since the 1990s, cognitive neuroscience has taken off as one of the fastest-developing and most exciting areas of scientific study. The tools of cognitive neuroscience, such as neuroimaging and single-cell recording, are examples of this, since they require both a focus on the physiological processes and a focus on the behavioural activities these processes are subserving.

Perhaps the feature that most clearly distinguished the cognitivism of cognitive psychology, cognitive science, and cognitive neuroscience from the behaviorism that dominated psychology and even neuroscience in the half of the twentieth century was the information processing metaphor. Although this conception of *computation* and *representation* was quite popular in artificial intelligence research of the 1980s, the language-like character of the representations made it seem very uncompromising for characterizing brain-based cognitive processing[1]. It is also the appeal to representations and to computational analyses of the processing of such representations in the brain that has helped spawn the collaboration of cognitive scientists and neuroscientists in the enterprise of cognitive neurosciences. If the appeals to representation and computation in analyses of the brain turn out to be *viable*, then this integration may have a secure foundation. If not, then alternative bases may need to be sought if the integration is to be successful. In any case, the analysis of representations, or any replacement notion, is a key issue in the foundation of neuroscience and cognitive neuroscience. This Section is devoted to the *state-of-the-art in cognitive neuroscience.*

Neurophilosophy arises out of the recognition that at long last, the brain sciences and their adjunct technology are sufficiently advanced that real progress can be made in understanding the mind-brain. More broadly, it predicts that philosophy of mind conducted with no understanding of neurons and the brain is likely to be sterile. Neurophilosophy, as a result, is to focus on problems at the intersection of a *greening* neuroscience and a *graying* philosophy.

Neurophilosophy becomes an *Uberfield*:

Uberfield = *df.* a field that provides a vantage point to survey all other branches of philosophy

Neurophilosophy (Updated) = *df.* {Philosophy-[*a priori* (Metaphysics + Epistemology + Ethics + Religion + Semantics)] ⇒ *a posteriori* Cellular and Molecular Neuroscience}

Neurophilosophy = *df.* Neural Explanation of the World (Metaphysics without theory) + Neuroepistemology + Neuroethics + Neurosemantics.

Phenomenology = *df.* Neurophenomenology

Molecular Neuroscience (Voltage-Gated Ion flow) = *df.* [Cognition (Brain States) + Electrical Conductance (resting → depolarized state (Na^+) + Repolarized states (K^+) ⇒ Molecular cascade (spiking at the axon hillock)]

Neurophilosophy = *df.* Neuroscience + *a posteriori* philosophical theories of mind

The standard diagram of levels here is due to Churchland and Sejnowski, as shown in *Figure* 2.1 rank entities from molecules measured in Angstrom units to organisms measured in meters. Organized structures are found at many spatial scales in nervous systems. Functional levels become even more fine-grained. Thus dendrites are a smaller computational unit than neurons, and networks may come in many sizes, including local networks and long-range networks. Networks may also be classed according to distinct dynamical properties. Icons on the right depict distinct areas in the visual system (top), a network (middle), and a synapse (bottom)[2].

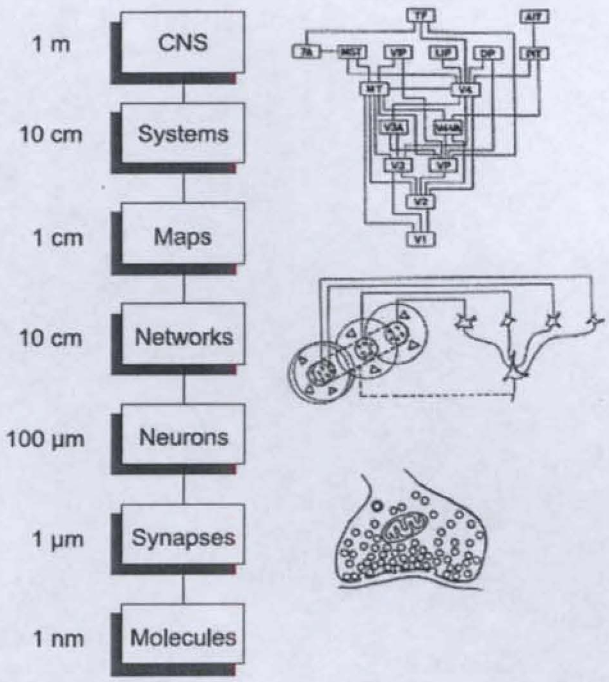


Figure 2.1: Shows that the classical picture of the levels in Neuroscience:

Icons on the right depict the layered (6 layers) {V_1, V_2, V_3, V_4, V_5, V_6 + striate cortex} areas in the visual system (top).

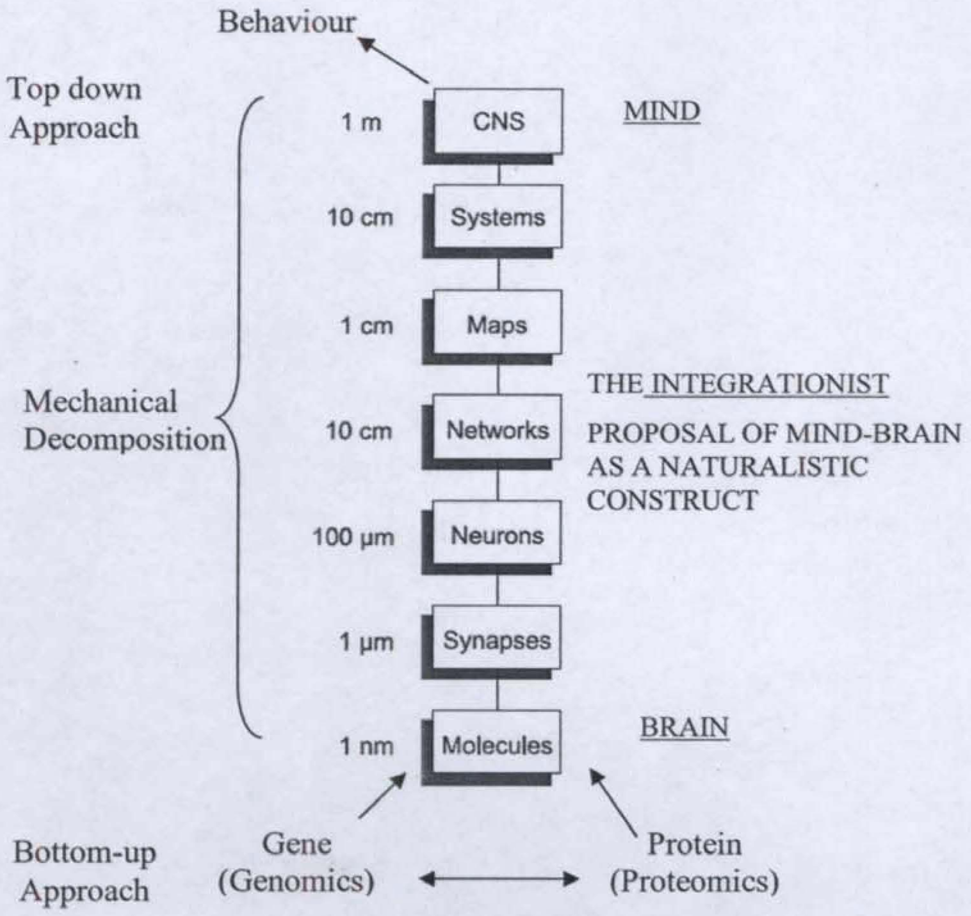
A network (middle), stereo vision: Light rays fall on the Retina are processed by Rods and Cons → Optic Nerve → Optic Chiasm – LGN → Occipital Lobe.

A synapse (bottom), with Neurotransmitters:

Synapse = {Pre → Neurotransmitter → (Electro-Chemical Modulation-Ion Channels) → Post-Synapse}

(Based on Churchland and Sejnowski, 1988).

The picture of the Neuronal Man illustrates more as shown below:



Figuring out how neurons do what they do requires very high-level technology. To have a prayer of understanding nervous system, it is essential to understand how neurons network, and that was a great challenge technically. The most important conceptual tool for making early progress on nervous system was the theory of electricity. What makes brain cells special is their capacity to signal one another by causing fast microchanges in each others' electrical states. Movement of ions, such as Na^+, across the cell membrane is the key factor in neuronal signaling, and hence in neuronal function. As for neuronal membranes and ions and their role in signaling, understanding these took much longer (Figure 2.2). The Ion Channel at the cellular level is schematised below:

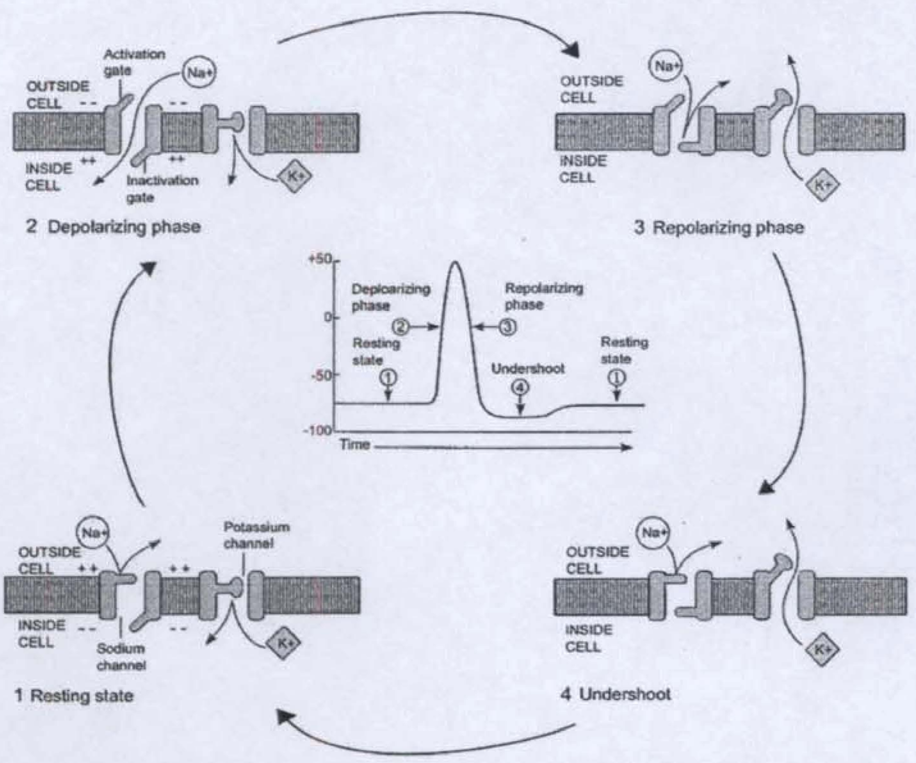


Figure 2.2: Shows that the neuron is in the resting state (*1*): both the sodium (Na^+) and potassium (K^+) Channels are closed, and the outside of the cell membrane is *positively* charged with respect to the inside. Hence there is a voltage drop across the membrane.

The membrane is *depolarized* (*2*): Sodium Ions enter the cell until the cell's polarity is reversed; that is, the inside of the cell is positively charged with respect to the outside.

In the repolarization Phase (*3*): the potassium channel then opens to allow efflux of Potassium Ions, the sodium gate closes, and Sodium Ions are actively pumped out of the cell. All of these activities help bring the membrane back to its resting potential.

Because the potassium gate does not close as soon as the resting potential is reached (*4*): the voltage drop across the membrane briefly drops a little below the resting voltage. Equilibrium is reached once the resting potential is restored[3].

The Neurophilosophy (as updated) inaugurates an outlook that seeks to *link* the known neurophysiology and functional neuro-anatomy of basic neuroscience with higher neurofunctional kinds. As such it flagged off a typical *integrationist* outlook taking the cue from the celebrated '*Constructionist Manifesto*' *a la*[4]. Thus Patricia, along with his collaborator, Sejnowski, appropriates a *Neurocomputational Brain* with a chain of reductions that will ultimately *link* minds-molecules-in the only manner of *linkage* possible, given the multiple intermediate structure[5]. The Churchlands failed to find more fundamental levels of linkage which could possibly bridge the gaps between molecular description and molar (system-based) descriptions. Thus they showed their vulnerability to a criticism which tries to push their contributions into the 'realm of *abstractia*', taking their own account of *intertheoretic*(Bickle) *reduction* into a *ersatz* inter-theoretic approximation to an exclusively molecular-linked theory of mind thus sponsoring the idea of *explanation in a single bound* within the broad framework CREB-molecular biology (Cellular-Molecular level)[6].

Churchlands remained faithful to the following *three* hypotheses: (1) reductionist identity of mental actions and brain (2) cognitive science, as the science of mental activity (Neuroscience); and (3) a 'canonical' understanding of the brain at all levels of organization (explanatory understanding). Throughout Churchland waged a war against functionalism (see his review)[7].

Although there are many proposals for making progress experimentally, for convenience, the strategies targeting the brain can roughly be grouped as one of two kinds: a *direct* approach or an *indirect* approach. Churchland prefers complementary of both, and so, they are not mutually incompatible.

The *direct* approach is to correlate of phenomenal awareness, then eventually to get a reductive explanation of conscious states in neurobiological terms. The direct approach is equal to change phenomenology into neurophenomenology (neural correlates of consciousness (NCC project). Direct approach is adopted by Francis Crick (testable hypothesis) two features *first* one is give neural correlates of consciousness (NCC project) and *secondly*, a property of visual system known as binocular rivalry.

The *indirect* approach is Attention, Short-term memory, auto-biographical memory, self-representation, perception, imagery, thought, meaning, being awake, self-referencing-all seem to be connected in some way with being conscious of something. The indirect approach proposes that once we understand the neuro-biological mechanisms of each of these diverse functions and the relations between them, the story of consciousness will more or less come together on its own.

Neurodevelopment and neurobiology have essentially laid waste to the very simple *nature* or *nature dichotomy*. Biology turns out to be vastly more complicated than the simple dichotomy implies. This *two-bins assumption* is overturned by a number of considerations, prominent among which is the fact that normal development, right from the earliest stages, relies on both genes and epigenetic conditions. Moreover, paradigmatic examples of long-term learning rely on both gene expression and *epigenetic* conditions. We can begin by addressing the neural basis for postnatal plasticity, and more narrowly, for postnatal plasticity that is uncontroversially experience-dependent. Hence we shall consider what is more commonly called learning, remembering, forgetting, and adapting.

The crux of Donald Hebb's insight, slightly reconstructed, is this: *correlated activity* of pre- and post- synaptic cells should *increase* the strength of the synaptic connection; *anti-correlation* should *decrease* the strength of the connection. The actual mechanism for modifying synaptic weights were not specified in Hebb's proposal, however, since neuroscience had not yet began to catalogue the assorted structural changes that could yield a strengthening of synaptic connections. In particular, it can be modified to get a powerful reinforcement-learning algorithm, which updates the weights as a function of a Hebbian correlation between a sensory reward (such as nectar) detected now and a representation of whether there is an error in predicting what that reword would be[8]. To qualify as *Hebbian plasticity* they have to satisfy two criteria: (1) it is specific to the synapse where the pre-and post- synaptic activity occurs, and (2) it depends conjointly on both the pre- and post- synaptic cells, but not on the activity of other (connected) cells. *Non-Hebbian Plasticity* will include changes that fail to satisfy either of these *two* criteria. To a *first* approximation, early development is characterized by mainly non-Hebbian plasticity, whereas Hebbian plasticity probably characterizes much of postnatal plasticity, including classical examples of learning. In early child development, both kinds of plasticity probably have an important role.

The NMDA receptor, a complex transmembrane protein, plays a crucial role in the cascades to the synaptic strengthening in certain forms of learning. But the very same protein, NMDA, also plays a crucial, if quite different, role in development. The other protein channel, the NMDA receptor, plays the key role in plasticity. This receptor is voltage sensitive, which means that it will not open unless two primary conditions are satisfied: (1) the Neuro-transmitter glutamate binds to it, and (2) the membrane must already be a bit depolarized typically from a second source. When these two events happen within a brief time window, the NMDA channel at the "innocuous connection" opens and stays open or about 100-200 Msec. The opening is actually a change in shape of the protein that sets free a magnesium ion and permits calcium ions to enter the cell[9]. [Figure 2.3]. The NMDA receptor in the induction of a form of neuronal plasticity of the LTP is shown in below:-

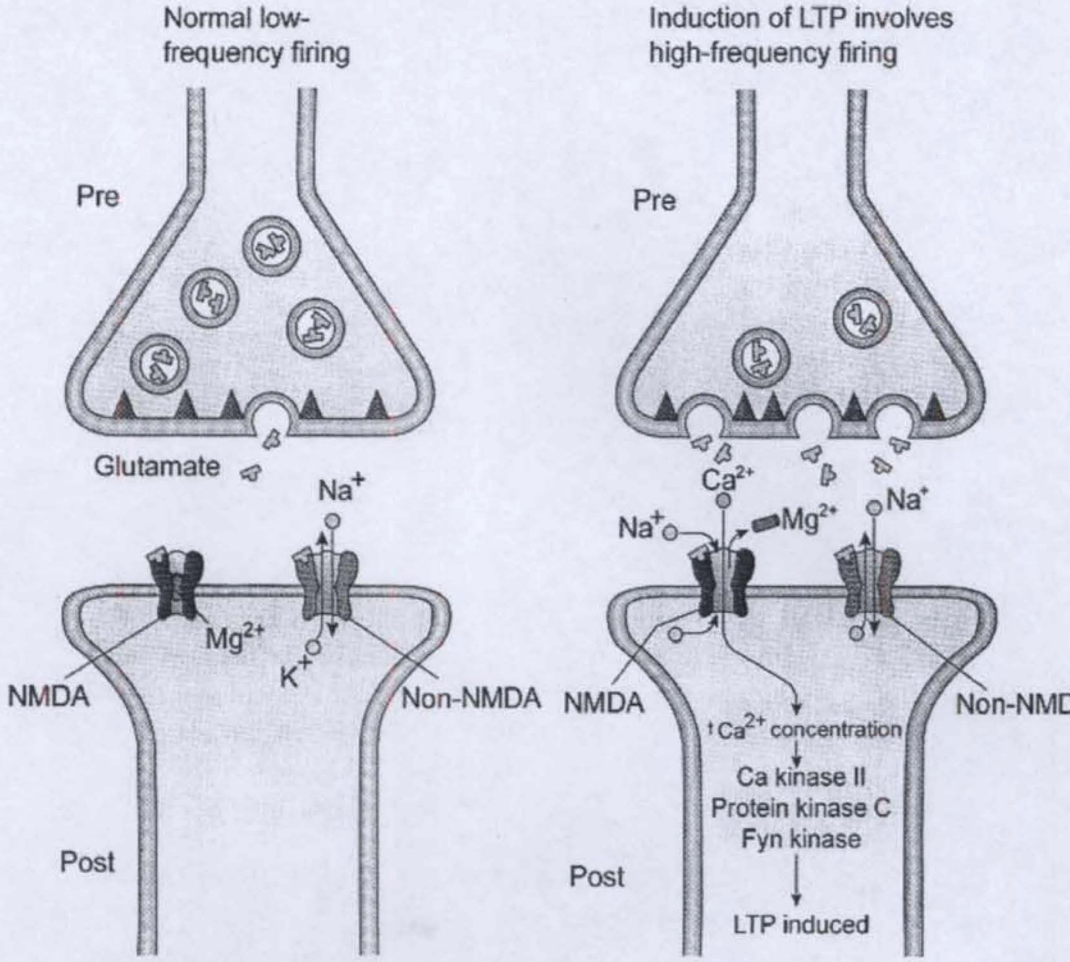


Figure 2.3: Figure shows that the role of the NMDA (N-methyl-D-aspartate) receptor in the induction of a form of neuronal plasticity known as Long-Term Potentiation (LTP). *Left*: During normal synaptic transmission, when the presynaptic neuron fires at low frequency, the NMDA channels remain blocked by $Mg2^+$ ions. Na^+ and K^+ ions can still enter through non-NMDA channels to mediate ordinary synaptic transmission. *Right*: LTP is induced when the presynaptic neuron fires at a high-frequency (a tetanus) and depolarizes the membrane of the postsynaptic cell sufficiently to unblock the NMDA receptor channel, which allows calcium to enter the cell[10].

Let us close the technical discussion that shows how the Cellular and Molecular Neuroscience handles the themes at hand and proceed now to the next section to describe the major cognitive paradigms in cognitive science.

2.2 A CLASSIFICATION OF ALL/MANY/ONE? COGNITIVE MODELS

Taking the *three* models, (namely the *symbolicist, connectionist and dynamicist*) as *fundamental*, Eliasmith-Anderson combines the merits of each one of these excluding their demerits to develop a *Neural Engineering Model* (*NE*- Model) as tabulated below[11]:

(1)	(2)	(3)	(4)
Nature of theory	Metaphor	Features	Components
1. Symbolicist Symbolic Rep. + Symbolic Compu.- Propositionalism	Mind as a computer (Turing) Mind as software	No temporality added	Language of Thought hypothesis (Sentence-Crunching)
2. Connectionist Vector Rep. + Vector Compu.- Vectorialism	Mind as a Brain	No temporality	Non-linguistic (Number-Crunching)
3. Dynamicist no representation and no computation (Interactionism: Radical/Moderate).	Mind as Watt-Governor	Add temporality	Mind + Body + Language + World

What is called propositionalism is related to the classical account of cognition which makes a *bipartite* distinction between mind and consciousness.

The rough distinction is reinforced by the way Fodor distinguishes between the *informationally – encapsulated modules* and the *informationally-unencapsulated* non-modular aspect of consciousness[12]. A *module* is an *input-out machine*. The *modest* account of modularity was soon to be overtaken by *massive* modularity thesis advanced by Peter Carruthers in many of his books[13]. This provides the stepping stone for the later development of computational theory of mind (this was originally formulated as the Computational Representational Understanding of the Mind (CRUM) in the sense in which it is shared by Fodor-Carruthers and more recently endorsed by Schneider[14]. But Fodor is well-known as the 'arch-enemy' of connectionism[15]. This is what drew the comment from recent critics: 'vectorialism is to connectionism, what propositionalism is to computationalism', thus bringing out a close (Churchland's view) analogy between symbolicist and connectionist approaches[16].

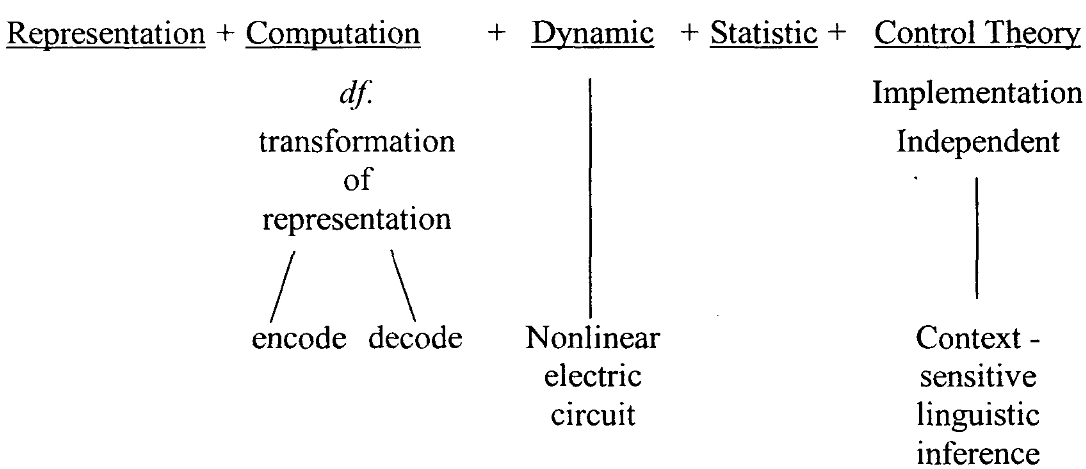
Now, let us look at the above chart to see more of the merit of combining these models. The merit of (1) + (2) + (3) is it yield a Neurally approximate Engineering Model based on *Classical Control Theory* and *Modern Control Theory*. This technical theory facilitates the above models dovetailing them into a Self-Model. Some of the features are enumerated below.

1) Eliasmith proposes and defends a theory of *Representation* and *Dynamics* in neural systems (R & D theory) relies on *Modern (as opposed to Classical) Control Theory*, Information Theory and recent results from neuroscience, to provide an account of what minds are.

2) Eliasmith and Anderson describe a model of working memory that accounts for representational phenomena not previously accounted for specifically, this model employed complex representations to demonstrate how working memory could be sensitive not only to spatial properties (that is, position) but also to other properties concurrently (for example, shape).

3) So, unlike connectionism, R & D theory, carefully relates *neural* and *psychological* characterizations of behavior to provide new insights into both. And, while it is possible that certain *hybrid* models (either symbolicist/ connectionist hybrids, or localist/distributed hybrids) may make up for some of the limitations of each of the components of the hybrid alone, there is an important price being paid for that kind of improvement.

The NE-Model vouches for *BIO-SLIE MODEL (Biologically Plausible Structure-Sensitive-Learning Inference Engine*) as noted below:



Chris Eliasmith wants to argue that each of the 'metaphors' mentioned above has some insight to offer regarding certain phenomena displayed by cognitive systems. However none of these metaphors is likely to lead us to all of the right answers. Eliasmith wants to provide a way of understanding cognitive systems that draws on the strengths of symbolicism, connectionism and dynamicism.

In a sense, the above engineering model approximates to general model which can do justice to the *three* fundamental models as well as to the self-organizing model that is to be discussed below. The Self-Model itself is to be defined as

Self-Model = *df. constructs* a model of itself

This is identifiable with a higher-order activity of the brain (e.g. consciousness); and offers the solution to the problem of consciousness.

So a few of the *Self-Representation Models* can be considered as a collective response to the *three* fundamental paradigms and they are enumerated as follows:

1) The Emulator Model (R Grush-Churchland): *df.* The self-model is constructed on the basis of emulating bodily knowledge. Taking the inner model as the coordination and control problem of the body as 'emulators', Rick Grush is justified to these models as emulators. Emulators contain both *Sensory* and *Motor* system, and they help make the *Sensory-to-Motor* transition[17].

Emulation = *df.* Construction of Self on the basis of knowledge of the body (proprioception given by motor components).

On the Grush-Emulator Hypothesis, the fundamental platform of the *sense of self*, as Churchlands have suggested, is first and foremost a matter of body regulation and body representations. Nevertheless, the capacity for self-analysis, self-reflection, and self-awareness-the capacity to know that 'I know'-has seemed to betoken something supra-biological and even supra-physical about the mind'[18]. As discussed earlier, to a first approximation, the motivation for actions is anchored in the fundamental drives for food, sex and survival. As plans develop, the imagination generates representation of plan *sequelae*. To these internally-driven scenarios, as well as to perceptually-driven representations, emotional responses are generated, *via* mediation of the Brainstem structures, Amygdala, and Hypothalamus. The central function of the emulator is to predict and evaluate consequences of proposed actions. As we saw, the emulator can be employed on-line in making immediate decisions and off-line for high-level decisions involving longer time.

2) The Homeostatic Model (Antonio Damasio): This is also called '*as if*' model that is based on neuro-anatomical features of the brain. This takes *Amygdala* (which is considered to be the seat of emotions, is the seat of the mind (reason)). This brings into coordination the *emotive* and the *rational* part of the mind (Hume said the 'Reason is the Slave of Passions'). It is based on the idea of *Homeostasis* (Homeo = Same: Stasis = State), which is important for the function of metabolism. Damasio criticises Descartes (calling it 'Descartes' Error') and prefers a position which is closed to Spinoza. We can negotiate and lend him biological credence.

Damasio has emphasized that this anatomical proximity of structures is an important clue to the coordinating role of the brainstem and its pivotal role in self-representational capacities[19]. As Damasio correctly notes such data are powerful clues that neurons in the visual cortex may not be generators of visual conscious experience (against NCC). Churchland explains at least why we cannot say Neural Correlates of Consciousness (NCC)[20]. Rather, their activities are representations that the subject might be aware of '*as if*' he were consciousness. So until the tough cases have been excluded by experiment, no conclusion can be drawn from correlations in the relatively easy cases.

His attack on the problem is launched, at the systems level rather than the neuronal level. His motivating point is that the capacity for consciousness is the outcome of high-level self-representational capacities[21]. Thus nervous systems have integrative organizations for ranking goals, making behavioral decisions, and evaluating relevant perceptual signals in the context of specific behavioral plans. We used the notion of an internal model- specifically the Grush emulator- to conceptualize self-representational capacities that deploy an inner representation of the body in relation to its environment.

3. Metzinger's Self-Model Theory of Subjectivity (SMT) represents the high watermark of Self-Models because it simultaneously operates on *phenomenological, representational, functional and neuroscientific levels* of description, using a method of interdisciplinary constraint satisfaction[22]. The self-model theory is a maximally parsimonious framework for the scientific investigation of self-consciousness: There is no such thing as a substantial self (as a distinct ontological entity, which could in principle exist by itself), but only a dynamic, ongoing process creating very specific representational and functional properties. Self-consciousness is a form of physically realized representational content.

The obvious fact that the development of our self-model has a long biological, evolutionary, and (a somewhat shorter) social history can now be accounted for by introducing a suitable version of teleo-functionalism (functionalism with a consumer state) as a background assumption. The development and activation of this computational module plays a role for the system: the functional self-model possesses true evolutionary description, metaphorically speaking, it was a weapon that was invented and continuously optimized in the course of a "cognitive arms race"[23]. The notion of consciousness has been suspected to being too vague for being a topic of scientific investigation. Recently, consciousness has become more interesting in the light of new neuroscientific imaging studies. Scientists from all over the world are searching for neural correlates of consciousness. Metzinger claims that no such thing as *'selves' exist in the world.* All that exists are phenomenal self-models, that is, continuously updated dynamic self-representational processes of biological organisms[24].

The above model suggests that we can have an additional set of cognitive modelling which are brought under 'Evo-Devo' models. These models require that we start from the gene and reach the behavioural output. Bechtel and Clark agree to *Gene-Neuronal* Model. Churchland hesitates to include Genes into his integrationist approach because of the obvious difficulty. The most important model is the *Gene-Meme Model* which is developed by Dennett (Meme is a cultural artifact which includes theories, concepts etc.,)[25]. Besides we have Global Workspace (Baars) Models and the Quantum Model)[26]. The *Gene-Neuron* and *Gene-Meme* have raised dust on many crucial issues on consciousness, freewill, etc., which are called the 'metaphysical fodders' (See Section *2.5* below). Churchland also clashed with Penrose with a howler: when a brain computes non-computationally, how can we *know* it.

Brain computes = Brain also non-computes (both we do not know; what we know is that the icon on the Left Hand Side is subjected to a '*Church-Turing Fallacy*'. The fallacy is so termed because we have no means to say that mental/brain states are Turing Computational States).

Dennett's *Pandemonium (Multiple-Draft Model*) almost agrees with Baars's theory, which also thrives on 'competitive architectures', which also has an analogous neuro-anatomical brain-model[27].

The whole point of all the above models is that such competitive architectures can only be studied from a *constructionist* point of view, which provides therefore an *overarching model* for the many of the models above (see below).

We have already seen how the NE-Model closes the differences between the three fundamental paradigms. Now generalize this to say that almost all others to some extent will interact with the constructive model.

Finally, Metzinger has developed the tools, with which he builds the core of his theory in *three* stages: the concept of the *Phenomenal Self-Model* (PSM), and the *Phenomenal Model of the Intentionality-Relation* (PMIR). The *PSM* is constituted by the ongoing phenomenal self-representational, self-simulational, and self-presentational process. The fact that consciousness (under normal conditions) is always tied to an individual first-person perspective is then picked up again by the discussion of *PMIR*, the *third* big building block of Metzinger's theory of subjectivity. The *PMIR* is the continuously dynamical representation of the system interacting with an object.

The consideration of too many models is just to help us to formulate an *overarching* hypothesis which stipulates that either all of them or some of them, in one way other, is related to the *constructivistic mode* of thinking (we can equally claim that some one model *implies* constructivism *vice versa*). As the pervading *constructivistic* strain overlaps all those models, we need a rough and ready classification of constructivism in this context, which is supposed to save scientific realism in a well-intentioned sense. The constructivist strain in different models can be roughly characterized as follows:

Churchland : Intertheoretic-Integrationist-Constructivist

Bechtel : Reductionist-Integrationist- Constructivist

Clark : Cognitivist-Incrementalist- Constructivist

Hooker : Cognitivist -Interactionist- Constructivist

While Churchland integrates mind and brain, Bechtel conflates it with a dynamic interaction with external world (constructivist). So also, Clark also derives the constructivist strain from his incrementalism that stands for incremental accumulation of knowledge systems. Hooker introduces the cognitivist strain into reduction (Reduction as a Cognitive Strategy) sharing the interactionist trait with Bechtel[28]. More of it below.

2.3 RESPONSES TO SYMBOLIC-CONNECTIONIST AND DYNAMIC SYSTEMS

In this section, we shall consider at least the following *four* key responses to the above:

1. Harmonization (Smolensky)- HARMONY-Phase (HA-Phase)
2. Hybridization (Clark) – HYBRID-Phase (HY- Phase)
3. Non-Classical Response (Tienson and Horgan)– Non-Classical- Phase
4. Mechanistic Response (Bechtel and Waskan) – Mechanistic- Phase

Let us start with the *HA-phase* with Smolensky, we reach the zenith of the 'Proper Treatment of Connectionism' (PTC)[29]. The integrationist picture of symbolic and connectionist this is called 'Harmony Theory' ('Harmonic Grammar' as it bases itself on Chomsky's Transformational Grammar). The schema for this is given below:

Connectionist | **Symbolic**
↓ | ↓
PDP + Grammar (units of grammar)
(1) | (2)

The system (1) and (2) are *isomorphic* to each other. Generative grammar + connectionism yield, according to Smolensky an *Optimality Theory* of Harmonic Grammar.

The following schema explains more about the Harmony theory.

	Symbolic		**Connectionist**
1. Higher level symbolic (whole) roughly corresponds to *competence*	Syntactically structured ↑	Can be extended to cultural knowledge	Not symbolically structured ↓
2. Lower level subsymbolic (parts) roughly corresponds to *performance*	Conscious Rule Interpreter (Performance)	Intuitive Processor (Competence) ↓ Neural level	Micro level ↓ Neural level (rep. + compu.)

As against Rumelhart and McClelland who prefer to identify (1) and (2) *competitive* (2 is more accurate), Bechtel identifies them as '*symbiotic*' because neither is rule-based. But his quest is to fit this into a 'reduction' model where (1) and (2) are roughly analogous to 'reduced' theory and 'reducing' theory respectively[30]. Bechtel's response (along with Waskan) to this and the 'Non-Classical Response' (3) is articulated below[31].

Incidentally, it may be noted that Bechtel clarifies the real challenge for connectionists will *not* be to defeat symbolic theorists, but rather to *come to terms* with the ongoing relevance of the symbolic level of analysis. Referring to the *two* competing approaches to *past-tense formation* he thinks that they might be given *complementary* roles.

According to Smolensky, connectionist models operate between the classical conceptual level (e.g., frames) and the neural level[32]. He calls this the "*sub-conceptual* level. This is the level of "*intuitive processor*". The symbolic level is called *Conscious Rule Interpreter* which gives you what is called the *virtual* machine, which is to perform the semantic interpretation of the units. According to Smolensky, since what is called the *proper treatment of connectionism* (PTC) places connectionist between neurological models and traditional symbolic models it involves subsymbolic modelling. The fundamental level of the *subsymbolic* paradigm, the subconceptual level, lies between the neural and conceptual levels. In the symbolic paradigm, the above levels of cognition are analogized to the level of computer systems and, as with computer systems, it is not a part of the symbolic paradigm to say exactly how the symbolic level is implemented at the neural level.

Smolensky's focus is on *intuitive* processor such as "perception, practiced motor behavior, fluent linguistic behavior...... in short, practically all skilled performance". Connectionist models, construed on the subsymbolic paradigm, are precise and accurate descriptions of these processes, whereas symbolic models are not. As Smolensky notes later, this feature precludes subconceptual models from implementing conceptual models-assuming that implementation carries with it the properties of being complete, formal and precise. Smolensky rejects the idea that connectionist models are neural models. He propounds the neural architecture hypothesis: The intuitive processor for a particular task uses the same architecture that the brain uses for that task. According to PTC (Proper Treatment of Connectionism), brain structure and functioning is (in principle of course) exactly characterized by the neural level of description. *Intuitive processing* is (again, in principle) exactly characterized by connectionist models at the sub-conceptual level of description-the level of nodes, vectors of nodes, and weighted connections. Smolensky says that "only complexity" distinguishes a cognitive system from a thermostat or a river.

Now we proceed to the *HY-phase*, following closely on Smolensky Harmony theory, Andy Clark develops his idea of *Micro Cognition* (MC):

MC = *df.* the inner rules do not map onto rules determined by everyday, contentful, purposive characterization of the mental (Clark)

Symbolic	Connectionist
Rule Following	Rule 'Kludge-ing'
↓	↓
'semantically transparent'	'semantically opaque'
(MIND'S-EYE VIEW)	(BRAINS-EYE VIEW)

Base neural model: Micro level cognition

Microcognition

↓

leads to cultural knowledge
(CYBORG KNOWLEDGE)

Cognitive science is the 'gold rush' of the mind[33]. Although connectionists such as Smolensky claim that their models are more abstract than neurons, and so the models might be realizable in other abstract than neurons, and so the models must be realizable in other material, they are free to agree with Searle that only certain kinds of stuff will duplicate cognition. This is an *important difference* between classical and connectionist theories: connectionist model of cognitive activity, and it is natural for them to insist that real brains (or their equivalent) are necessary for there to be cognitive activity.

Andy Clark's strategy is to show that analogs of beliefs (and other propositional attitudes) exist in connectionist network, but at higher levels of description[34]. Clark argues that "distributed, subsymbolic, superpositional connectionist models are actually more structured than Ramsey *et al.* think, and hence visibly compatible with the requirements of propositional modularity. Clark takes NET-talk as his example, and in particular *Sejnowski and Rosenberg's* Hierarchical Cluster Analysis (HCA) of the activation of the hidden layers which yielded a coherent semantic interpretation of the weight space in terms of *vowels* and *consonants*[35]. Clark favors this response, and proposes "to reject outright the idea that folk psychology in necessarily committed to beliefs and desires being straightforwardly causally potent ...... there are other ways .... in which a construct can have explanatory value, ways which do not require that it to be identified with any specific underlying scientific essence"[36]. His strategy here is to replace causal demands on networks with "explanatory" demands, than to argue that connectionist explanations of behavior in terms of propositional attitudes can be given which satisfy the equipotency condition.

Now, we shall briefly review, the Non-Classical Phase Tienson and Horgan's Non-Classical response to the picture integrates symbolic, connectionistic, and dynamic models[37]. We shall review here both the Tienson-Horgan (T&H view) and Bechtel-Waskan (B&W view) debate on what is called the '*Tractability Argument*' below.

When connectionism re-emerged as a framework for modelling cognitive processes in the 1980s, it was a relatively well-defined approach. With the emphasis on Recurrent Network (feedbackward net as opposed to feedforward net) or 'back propagation of error learning algorithm' (Rumelhart, Hinton and Williams) as illustrated in the network governing the phonemes employed in past-tense formation with the suffixes (*d/ed/or/t/*used on regular verbs) and it was thought to explain *non-linear* (*parallel* = the output is greater than the inputs, as opposed to *serial,* the output is the sum of the inputs) modelling of cognition.

The crucial argument here can be called *Tractability* Argument. It lies in the question: what makes a computation *non-tractable*? In part, H&T illustrate what non-tractable computation would be in terms of a huge (possibly infinite) list of functions for which there is no more compact representation. So we 'give up' the tractably non-computable by suitably modifying the net within a dynamic systems theory (DST) so as to *zero in* on tractability (as it is in the net called RAAM or Elman's). We start with the differences that are roughly captured as follows:-

T-H Model

	Symbolicism	Connectionism
1.	rules symbolic structure-sensitive ∴ tractable But the Frame Problem will block this. So, Non-tractable	no rules non-tractable Modify it as Tractable via Dynamic model
2.	sentential sentences have syntax and semantics	non-sentential modulating weight in the vector space.
3.	No back propagation	back propagation of error.

Assumption (1) rules → tractably computable → changed into cognitive transition function (weight adjustments)

Assumption (2) no rules → *not* computably tractable. The above assumptions inform (3) and (4) below:

3. **Sentential** (1) Symbolic/structured + cognitive transition function. (rep. + compu.)

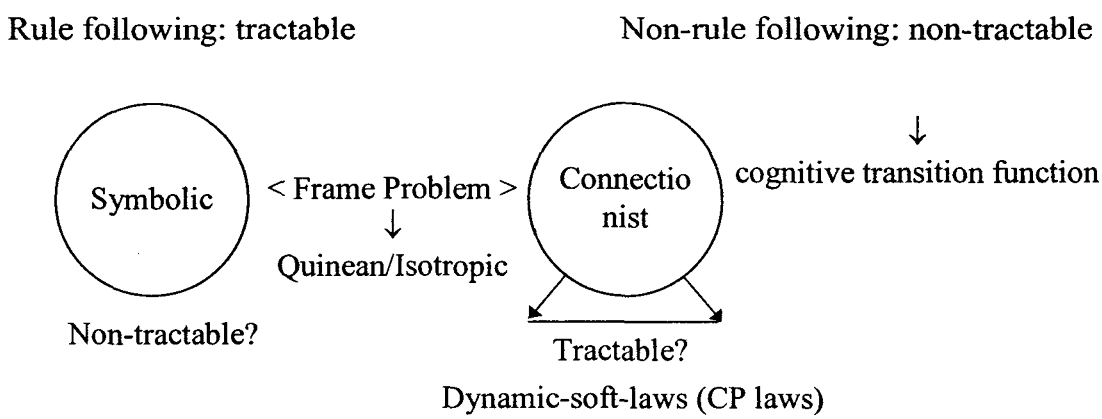
4. **Connectionist** (2) not structured; so, reject (1). That is, change the syntax (non-sentential) into one that is closer to semantics. This is T-H's view.

The question is whether T&H can '*give up*' non-tractable transition function: consider the following schema. In other words, how to *save* the '*Brittle Model*'? T&H make the following numbered moves:-

1. 'The Frame Problem': how to put a new belief? (Isotropic way by considering the relevance to other already existing beliefs or Quinean way by absorbing into the existing 'web of belief')

2. So we modify: representation + computation, by adding transition function (computational transitional function) and by bringing in Dynamic system model, we can build a system with *soft constraints* (including *ceteris paribus* laws (CP laws)), resulting in what is called *Representation Without Rules*. Both models reach a stage at which they are now tractable in a sense.

The following schema explains the above move:-



In criticisms of the above, B&W argue that T&H model is a "*mistake*"[38]. They suggest that we should (1) retain the assumptions, and (2) eschews one powerful way to introduce semantic coherence and representation level computation. They also say that 'T&H made a wrong call', to reject the non-tractable representational level computational processes[39]. There is no reason why they should not take it as it might also characterize symbolicist model as well. On the other hand, their approach seems to favour tractably computational view.

For some critics such as Fodor and Pylyshyn (1988), this has represented a shortcoming of connectionist models. Without syntactically structured representations, they claimed the connectionist would be unable to explain such features as the *productivity* and systematicity (x loves y → y loves x) of thought. Although H&T defend the use of syntactically structured representations, their portrayal of them differs significantly from that endorsed in classicism.

T&H cite *two famous models:* 1. Pollack's RAAM (Recursive Auto Associative memory) networks are easier to provide an interesting way to represent syntactically structured information in a manner that is only functionally, *not* explicitly, compositional. RAAM's compressed representations preserve functionally *syntactic* information[40]. 2. Again, in Elman's model, networks are *trained* to predict the next word in a linguistic corpus. It grows tree-like. Now we can see that both preserve syntactic structures, and the question whether tractably computable or tractably non-computable can be compromised without rejecting the latter.

Finally, B&W argue that the strongest case for connectionism as a basis for cognitive modelling involves construing it as rejecting "tractably computable cognitive transition functions" but yet employing syntactically structured representation. B&W say that, these features of connectionism are (by nature) *ex hypothesi*.

B&W suggest *three* moves:

(1) As against the assumption of 'total cognitive state', suggested by the hypothesis which holds that weight changes *alter* the system by virtue of inhibitory connection between two possible responses, B&W take it as a *single* cognitive state; but with '*modular structures*' (the given cognitive task is divided into *subtasks*) and hence *decompose* them into component parts. This is the basis of his dynamic mechanistic explanation.

(2) Whether they perform tractable computations or not depends on contextual factors.

(3) As against *total* states, B&W prefers *single* cognitive state.

(1), (2) and (3) will preserve tractably non-computational, by conceding that even that occurs in classical systems.

So, from W&B's point of view what is called computationally non-tractable need not be exchanged for computationally tractable, even while the Isotropic-Quinean traits hardly matter. The point about structure-sensitive syntax is less bothersome in the light of other connectionist network models (e.g. Elman's Net). How to read then the debate between the two pair of thinkers? One interesting way we can read is to see them to as talking past one another, because both agree to maintain a *combinatorial notion of computationally tractable and computationally non-tractable*, which is purported to explain the linear-nonlinear combinatorial power of networks. There is no warrant to project this as a hypothesis but a considered understanding will convince that this is not far from truth.

What follows from the above, on B&W's view is that the components may be performing the non-tractable without affecting the 'wholes'. This is what we need for developing a dynamic mechanistic explanation'.

So connectionism also can argue that they are tractable from a mechanistic point of view where symbolicist as well as semantic features are *decomposed* into components together with *memory*. So T-H picture is not agreeable. The lesson from the debate is that there is more than one way of integration the symbolic-connectionist models into a synergic one, of which the *Tractability Argument* provides one legitimate avenue.

Finally, we have also emphasized that cognitive science, despite its many disputes, has progressed by continually combining and recombining a variety of influences. When combined with other influences and commitments, the outcomes discussed here have ranged from information processing models with quantified operations to connectionist networks to both global and mechanistic dynamical accounts. Each of these approaches has provides different answer to the question of whether the mind processes language- like representations according to formal rules, and we have argued that the overall answer need not be limited to just one of these cognitive science takes multiple shapes at a given time, and is protean across time.

2.4 THE SCIENTIFIC STATUS OF COGNITIVE MODELLING

Cognitive modelling means devising an engineering design. An advanced application of cognitive modelling is the creation of cognitive machines, which are AI programs that can be said to think for themselves. A cognitive architecture, whose models can account for both traditional behavioral data and, more interestingly, the results of neuroimaging studies in this sense, it is a neuroarchitecture. Cognitive speaking, it is a hybrid-architecture that combines *symbolic* and *connectionist* mechanisms in a resource-constrained environment. Critically speaking, it moves beyond the localism of most neuroscience accounts, proposing that thinking is a network phenomenon.

What gives a better theme of cognition in connectionism is given in the PDP features below[41]:

1. a set of processing units (u_i)
2. a state of activation (a) at a given time (t) (Vector of real numbers $a(t)$).
3. pattern of connectivity: (connection between *unit I* and *unit j* can be represented by a matrix w of weight value wij).
4. rules for propagating activation : WX $x(t) = \sum \mathrm{wij\,aj}$
5. activation rule: $a_i(\mathrm{t}+1) = \mathrm{F}\ [\mathrm{net}\ i(t)]$
6. algorithm for modifying pattern of activity
7. environment (exogeneous factors)

The advantage of connectionism is that it provides a *better theme of cognition.*

Thagard mentions the following challenges to symbolic and connectionist systems. The above models are challenged on the following grounds:

1.	The Emotion Challenge	: Cognitive science neglects the important role of emotions in human thinking
2.	The Conscious Challenge	: Cognitive science ignores the important of consciousness in human thinking

3. The World Challenge	:	Cognitive science disregards the significant role of physical environments in human thinking
4. The Body Challenge	:	Cognitive science neglects the contribution of embodiment to human thought and action.
5. The Social Challenge	:	Human thought is inherently social in ways that cognitive science ignores.
6. The Dynamical System Challenge	:	The mind is a dynamical system, not a computational system.
7. The Mathematical Challenge	:	Mathematical results show that human thinking cannot be computational in the standard sense, so the brain must operate differently, perhaps as a quantum computer.

Thagard's *supplementary view* argues that all these challenges can best be met by expanding and *supplementing* the computational-representational approach, not by abandoning it[42].

Reduction is deduction as far as theory (sentential kinematics) is concerned. For Churchland, it is *Inter-Theoretic Relation* which undergoes many phases as discussed below.

(1) *Eliminativism entails* that T_1 is eliminated and absorbed into T_2 when it is scientifically matured.

(2) Co-evolution of theories: Both T_1 and T_2 evolve simultaneously upto a point of time where the less scientific is a disposed of T_1 is in favour of T_2.

(3) *Replacement*: T_1 is replaced by T_2. Churchland depends on Kuhn's model of theory change for obtaining the inter-theorectic relations. During the second phase Churchland fully endorses the Cellular-Molecular view which advocates the changes takes place through *Voltage-Gated Ion Channels* (conductance of electric pulses). Here he agrees with Bickle.

During the *3rd phase,* he adopts an *Evo-Devo* approach (gene-neuronal model) and enters into controversy with Churchland. Both Churchland are somewhat reluctant to include Genome into their research programme. Add count status of cognitive science includes Genomics (genes: first sense of information-theoretic), Proteomics (Protein and Amino acids: second sense of information-theoretic) and Connectomics (a '*connectome*' is an aggregate of part of network of neurons: a third sense of information-theoretic), where connectionism (all the above three share similar traits) becomes the mainstay of cognitive science research.

The *First* phase of Bechtel appears in the article which he has co-authored with Hamilton[43]. The *Second* phase of Bechtel advocates a (dynamical) mechanical explanation seeks an integrated picture of the intertheoretic relation as given by:

M = *df.* Decompose (parts) + Localize + Integration (whole) (*pace* unity view).

The *third* phase of Bechtel modifies the above to yield a formula like

M = *df.* Decomposition + Localization+ Recomposition (of parts) (functional + structural.)

Opposing the exemplar of Memory Consolidation, Bechtel moves to the 3rd phase of connectionism in which he formulates the *dynamic mechanistic explanation* as follows.

M = *df.* Decomposition + Recomposing + Emplacement (due to *exogenous* factors; emplacement means '*situated*').

The above formula leads to *weak reductionism*. This enduring phase occurs in the context of his experiments on Circadian Rhythms (fourth phase).

Bechtel's last phase endorses pluralism of theories following McCauley. He also shares *Heuristic Identity Theory* (HIT) with the following features such as[44].

1. HIT theory favours Indiscernability of Identity rather than the Identity of Indiscernibles (both laws are due to Leibnitz).
2. Alternatives are not mirrored perfectly, and so, equivalent but rivals;
3. More coevolutionary and less hypothesized.
4. They depend on Correlated adjustments.
5. They could endorse Kim's idea of confirmability.
6. They can vindicate cognitive science.
7. Identity is neither a conjecture, nor brute.

The above seven points explain the heuristic of identity. This is the solution suggested by Bechtel. The significance is far-reaching.

Bickle's model of Ruthless Reduction requires that one be able to construct "equipotent image" of the reduced theory within the structure of the reducing theory as well as "*ontological reductive links*" between the two[45]. The idea of an equipotent image is a technical notion that plays the role of the derivation requirement in the strongest formulation of the classical model, but that allows degrees of homomorphism between the *two* theories. The reduction model is focused exclusively on explanations that appeal to lower-level mechanisms, and so does not accommodate these aspects of the explanatory unity of neuroscience. Reduction models thus provide an inadequate account of the *explanatory unity of neuroscience.* Reduction survives as a model of the *unity* of scope and clarity. The *Mosaic Model of the Unity* of neuroscience encompasses these virtues but it adds precision in characterizing what one demands of explanations in sciences that seek mechanistic explanations[46].

Bickle's project can be described in the following words:

Intervening causally into increasingly lower levels of biological organization, i.e., cellular physiology, molecular path ways,

and then,

Tracking the effects of those interventions on the behaviour of organism using a variety of experimental procedures that are well accepted as measures of cognitive phenomena under investigation.

Bickle has made much of the significance of this difference in approach, citing a variety of advantages for the Churchland-Hooker's version. One important advantage has already been canvassed: release from having to find connecting bridge principles (laws or identities) to obtain any *intertheoretic reduction* relation, thus by-passing their numerous difficulties. There follows the advantage, as noted above, that where the reducing theory corrects the reduced theory, including' radically so intertheoretic relations are dealt with in the same general way as the clearly retentive cases, while the Schaffner's model will have difficulty in providing coherent bridge principles. Since the reduced and reducing theories are logically incompatible, a further advantage is its amenability to a semantic model theoretic formulation, inherently more powerful than the Schaffner-style syntactic formulation. This provides a richer structure to the 'analog relation' and thus can provide a finer set of distinctions with which to theorize intertheretic relations. This extension of Hooker was developed by Bickle and labeled "*New Wave*" reduction theory[47]. Bickle's model theoretic apparatus does formalize some useful distinctions, ones that help to flesh out the account in Hooker both in respect of the general analog relation and its application to function-to-dynamics relations in particular[48].

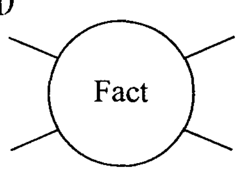
According to *early* Craver's Transtheoretic Approach, the causal formula $C \supset E$ which asserts that Cause is nomologically sufficient condition for Effect is questionable from a scientific view of mental or neural causation. This provides another form of causal exclusion problem. The causal exclusion problem assumes that physical causation and mental causation are mutually exclusive. To rectify this, Craver develops his *interventionist - manipulationist – contrastive - counterfactualist invariance* *account of causation theory of mental causation* which is based on "difference-making account'. The point of the above theory is to discover how an intervention at one level of causation makes a *difference* at the consequent level. For this Craver takes 'C' and 'E' are as *variables* rather than events. That question is whether E would *change* under some suitable experimental manipulation of 'C'. This is arrived at by excluding other confounding possibilities. This is what is captured by Craver's distinction between how-actually, how possibly and how plausibly, which is a direct derivation from H-H experiment.

More precisely,

X→ Y iff there are background circumstances suitable if some intervention that changes the value of the variable 'X' were to occur in 'B', then the variable 'Y' would change. So the exhibition of patterns of counter factual dependency between the factors cited in *explanans* and the *explanandum provide the gist for causal relevance.*

Why the fact occurs?

Declaratives (If p then q)
Explanans: IC
BL
∴ Explanandum



Counterfacutal (If it were p then q)
Explanans:
causal relevance
∴ Explanandum

Covering Law: relevant circumstances that makes *invariant* relation between C and E. This is what is called causal *relation* (law?).

This is supposed to operate at the micro-level phenomena (Synapse-Voltage Gated Ion Channels).

Why the Hodgkin and Huxley (H-H) model does *not* explain the action potential is revealed by the following features[49]:

1. This is putative exemplar of CL model of explanation.
2. There is perhaps no better example of the CL model of in all biology than the H-H model of action potential.
    a) Flux of Sodium Na+
    b) Flux of Potassium K+
    c) Leakage current for other Ions.
3. H-H concluded that the electro-physiological technique alone could not decide among *competing mechanistic* models for the conductance changes.
4. Therefore, it is incomplete because it has *no norms*.
5. Mathematical equations are analogous to Ptolemy's Planetary Models.
6. Commitments about underlying mechanisms are replaced by mathematical constructs that *save the phenomena* (a-h) as much as Ptolemy's Epicycles and differences save the apparent motion of the planets through the night sky (thus the alternative possibilities are recognized). HH is an alternativist.

Hodgkin and Huxley insist that they have no evidence whatsoever in favor of the model that they "tentatively had in mind" when formulating their equations for conductance changes. According to that model, the membranes' permeability to Na^+ is regulated by the position of *four* particles in the membrane: *three* "activation molecules" that move from the outside of the membrane to sites on the inside, and one "*inactivation molecule*" that can block either the activation molecules or the flow of Na^+ through the membrane. Craver earlier constructs his model of mechanistic explanation to serve *two* alternativist ends: (1) to distinguish *how-possibly* explanations from *how-actually* explanations, and (2) to distinguish mechanism sketches from mechanism schemata. He illustrates progress along these *two* dimensions by considering how neuroscientists moved beyond the Hodgkin and Huxley model of the action potential in order to provide a complete explanation of the conductance changes constituting the action potential. The proposed account should have resources adequate to distinguish *how-possibly* models from *how-actually models*. *How-possibly* models have *explanatory purport*, but they are only *loosely* constrained *conjectures* about the sort of mechanism that might suffice to produce the explanandum phenomenon. *How-actually models*, in constrast, describe *real* components, activities, and organizational features of the mechanism that in fact produces the phenomenon[50]. The *alternativist* model wins by default.

Later, in his reflections on multiple realizability, Craver reiterates the same point calling attention to the required cooperation between metaphysics of mind (Turing machine states of the mind) and cognitive science (mind as brain). He distinguishes *three* types of realization.

1. realization of an aggregate (mereological sum);
2. realization of a structural property (Translation/transcription of DNA molecule into RNA).
3. realization is an activity.

Craver concludes that the *total* current that is produced by the opening of the sodium channels in the *hillock* and *sum* of the currents flowing through individual sodium channels may have different values of the same variable. So multiple realizability is explainable at the cellular/molecular level[51].

Most philosophers who discuss the unity of neuroscience (for example Bickle 1998, 2003; P.S. Churchland 1986, Schaffner 1993a, 1993b) describe it using models of *Intertheoretic Reduction*. According to the "classical" model of reduction (Nagel 1949, 1961), from which each of these authors models descends, *reduction is a species of Covering Law (CL) Explanation*: One theory is reduced to another when it is possible to define the theoretical terms of the *first* with those of the *second* and to derive the *first* theory from the *second*. Schaffner's model of reduction (which Churchland adopts) requires that a corrected version of the reduced theory be derivable from a restricted version of the reducing theory with the aid of *transtheoretic identifier*[52].

Hooker's <u>Cognitivist Approach</u> provides a Non-Spectrum View that they defy understanding within our present knowledge and that Bickle's apparatus does not offer much help here. Instead, in physics it is *asymptotics* *analysis* that has provided the, insight and it will be a corresponding analysis of dynamical input/output maps in relation to neural assembly self-organization that is likely to provide neuro/psychological insight[53].

There is another way in which *asymptotics is crucial to reduction*: it grounds a dynamical account of self-organization proper and this in turns grounds principled dynamical accounts (I) of emergence, (II) of levels proper within complex systems and, on that basis, (III) of cross-level causal (more generally: dynamical) relations, leading to a principled dynamical account of causal multiple realization, and (IV) of cross-level functional to dynamical relations, leading to a principled dynamical account of functional multiple realization, and (V) of context-dependent laws, and hence of the so-called 'special sciences', such as biology and social theory. On this score, the consideration of *asymptotics*, and self-organized constraints in particular, begins to provide a scaffolding for *filling out* Churchland's Spectrum Model approach. So Churchland's vision is of an unfolding scientific understanding that penetrates every area of life, from our social morality to our personal consciousness. Science itself emerges under our creation from the primordial species capacities for exploration and adaptation and is itself unfolding as at once part of, and generator of, that understanding. This is how we gain what is called the credentials of cognitive science.

All the models are only models that are approximately biological. Finally, the scientific status of cognitive modelling is raised a question: which model is the most viable? The symbolic model is vulnerable, but defensible, connectionist model is widely used paradigm, and the dynamic model is mostly acceptable to every one. These models are not real paradigm but they are partitioned from wholes.

2.5 THE CONTROVERSY ABOUT EVO-DEVO MODELLING

The 'evo-devo' model entails that we look at the controversy as a specimen from the Gene-Neurons point of view. The actual controversy is between Gene-Neurons (Churchland) and Gene-Meme (Dennett) the former is meme-free 'evo-devo' account and the later is meme-bound 'evo-devo' account. The whole controversy comes to nothing if they are shown to be compatible with other. This what Dennett does but Churchland refuses to believe that the controversy is silenced. The main points of the controversy are captured below.

As part of the 'evo-devo' response, we shall unfold the controversy between Churchland and Dennett the question of consciousness capturing the essentials of the debate that lasted for the whole decades, since starting from 1991[54].

The debate between Churchland's connectionism (PDP recurrent network) and Dennett's-Densmore, Von Neumannesque Meme Machine (a combination of connectionist (functionalist)- symbolicist-dynamicist account) is the controversy between two paradigms which form a 'mutually coherent family'. So there is no sharp contrast between them as Churchland interprets it. On Dennett's view, such a contrast is mistaken because the opposition almost dissolved on closer inspection. Hence the debate represents a 'division of labour'. Churchland terms the virtues of virtual machine as a 'failed prototype'[55] for which Dennett responds by saying that it is an 'oversimplification'[56].

The controversy was sparked off from the time Dennett's book on *Consciousness Explained* (CE)[57] was in print and it drew a response in the *Engine of Reason*, the *Seat of the Soul* (ER)[58].

Now, Dennett attempts to take *two* steps more closer on consciousness as he winds up the debate.

The *whole controversy* starts with the distinction between *hardware* and *software*. Dennett's picture is schematized as follows.

Virtual machine	Software	Meme	Serial
	Hardware	PDP	

Von Neumannesque Meme

whereas Churchland offers the following schema:

PDP	Recurrent	Dynamic	Parallel
	Feed forward	Static	

PDP Recurrent

Patricia Churchland is *not* in favour of the analogy between hardware and software (See *Brainwise* for details)[59]. None of the following:

Protein Channels in Membrane/Neurons/Microcircuits/Macrocircuits-Subsystems/ Systems is to be identified with *hardware* and so the analogy is 'wrong-headed' (for Dennett and Densmore (DD) the disanalogy is acceptable for a different point of view)[60]. The 'contrast' is to be evaluated in terms of what is called the 'magnificent seven' (see section 2 p:751) which are enumerated in *Engine of Reason* (ER).

(1) It displays steerable attention; (2) It is independent of sensory inputs; (3) It has the capacity for alternative interpretations; (4) It involves short-term memory; (5) It disappears in deep sleep; (6) It reappears in dreaming; and (7) It harbors the contents of the several basic sensory modalities within a single unified experience[61].

Churchland's criticism is *not* that Dennett accounts for this *seven* features, but he does not do so.

1. The Metaproblem: What the PDP machine is to do next? The answer is given by saying that it is 'autostimulation', it is connected with language (memes). Dennett calls as this as a 'metaproblem'. The DD view accuses Churchland as not being able to tell us how one prototype vector is activated (selected to the exclusion of others).

2. Independence of Sensory Inputs: According to Churchland, consciousness of independent of sensory inputs (*Contra* Crick). The DD view holds that consciousness is not independent but it is an interpretation and elaboration of sensory inputs and they contend that it is not a denial of Churchland's claim even though it appears to be so.

3. The Problem of Alternative Interpretations: Whereas for Churchland an ambiguous input triggers one vector rather than another, Dennett wants to look at as providing alternative interpretation.

4. Short-term memory: Churchland's can be charged for their negligence of long term memory, because he has not addressed to this question. Churchland holds that short term memory can be understood in terms of hidden layers (nodes) but for DD it conveys a limitation and the short term memory can be overwritten by latter contents.

5. Dreams, Sleep and Unity: 5, 6, 7 deals with two issues. (1) Dreams are mundane (not transcendental) and (2) dreams experiences are also prototypical in character. Churchland thinks that there is an intralaminar nucleus of the thalamus which provides an information bottleneck. That is, representations in that *recurrent network* or *polymodal* (plurality of modalities), and they are processed in multimodal representation. For Churchland, this can explain absence of consciousness in deep sleep (contrary to Indian traditions). This can also explain the reappearance of consciousness in dream states. Dennett does not offer an explanation of either the absence of consciousness or it reappearance in dreaming in his book[62]. For DD such hallucinatory experiences are the outcome of 'epistemic hunger' whereas takes this to be a 'metaphorical theory sketch'. Churchland cannot identify the intralaminar nucleus as a *sina qua non* of consciousness. So the debate leaves much to be desired.

Whereas for Churchland, the emphasis should be laid on the neuroanatomical details, for Dennett it should be handled as a higher-level explanation, thus postponing speculations about neuroanatomy. For Dennett, there is no Cartesian theater where everything comes together and hence no intralaminar nucleus. The DD further contends that Churchland makes no distinction between the time of arrival and the time of concepts of consciousness.

With regard to the distinction between the *animal* and *human* consciousness, Dennett is not favourable to identify animal and human consciousness, whereas Churchland is willing to grant that there is no distinction between them. In sum, both offer over-simplified sketches of the theories of consciousness and it needs much more further elaboration before they can be counted as confirmable theories.

In response to DD, Churchland criticizes the virtues of virtual machine as follows. Churchland's main charge is that functionalists are obliged to tell us how the program is implemented. In this connection, Churchland calls attention to the 'flawed' character of functionalist research in the last 40 years. Churchland takes the way software programs are to be installed upon the parallel network of the brain, as 'metaphors' and they are self-deceptive and uncomprehending. They provide the wrong model for the cognitive activity of biological brains.

They are also wrong on the following *five* counts.

1. It is wrong in its story of our basic computational mechanisms.
2. It is wrong in its account of how occurrent information is coded and manipulated,
3. It is wrong in its account of how skills are embodied and how "regular" behavior is typically produced.
4. It is wrong about the nature of learning.
5. They are even wrong about language.

Incidentally, it may be noted that the last criticism cannot be sustained except on ideological (non-linguaformal) grounds.

Now, while for Churchland, we can move from '*implastic*' character of the brain towards the '*plastic*' character, in the recurrent network, for Dennett they can be considered from a 'functional' point of view. There is a great deal of discussion about 'rule' and 'rule-following' in this context, but the exact significance is a rather obscure. For Churchland, '*rules play no causal rule*' at all (and neither the 'virtual rules' as envisaged in the virtual machine view).

Churchland contends that he is not blind to non-linear dynamical features of large recurrent network. Similarly he is not averse to how the 10^{14} neurons can function in real time. That takes the discussion to the subsequent response given by Churchland in his *Catching Consciousness in a Recurrent*

Net. Here he develops more points about the dynamical signature of the cognitive activities, and proceeds to criticize Dawkins' 'virus analogy to theories as sterile'. He also points out at least *two* major shortcomings for taking consciousness as 'self-representation'[63].

The *first* is that it fails, at least on all outstanding versions, to give a clear and adequate account of the inescapable distinction between those of our self-representation that are conscious and those that are not.

The special subject matter, then, seems not to be the essential feature that would seem that a conscious representations from all others. On the contrary, it would seem that a conscious representation could have any content or subject matter at all. The proposal under discussion would seem to be confusing self-consciousness with *consciousness in general.*

The self-representation view has a *second* major failing, which emerges as follows: consider a creature, who has a battery of distinct sensory modalities-a visual system, and auditory system, an olfactory system-for constructing representations of various aspects of the physical world. Our original problem attends the inward-looking modality no less than the various out-ward looking modalities with which we began, and adding the inward modalities does nothing obvious to transform the outward on in any case. Once again, learning on the content of the representations at issue-on the focus, target, or subject matter of the epistemic modality in question fails to provide the explanatory factors that we seek.

Churchland's picture takes the feed-forward network as *static* while the recurrent as *dynamic*. The recurrent model adds a completely new universe of functional and dynamical possibilities. It adds a '*context-fixed*' at the second layer of the network. It also includes a discussion on the temporal as well as spatial structures of the networks. Churchland counterposes this model to Dennett's Heglian type of raising consciousness that is backed up by his views on 'reverse engineering' (a retrospective account of explanation for are evolutionary point of view) and the Joycean machine (stream of consciousness).

In the *final* run, both of the above pictures are *not so incompatible* as the respective authors claim.

Dennett's counterclaim is that 'the opposition almost dissolves on closer inspection'. In other words, the virtual machines, Dennett likes to talk about, are implemented by the massively recurrent networks. Churchland agrees that there are massively recurrent neural networks, but virtual machine is active at a somewhat higher level. There are *three* questions to be answered from Dennett's points of view:

1. Should we take virtual machines in the brain seriously?
2. Should we take *meme* seriously?
3. Is human consciousness a virtual machine?

The answer to first question is that we have to take seriously what is called virtual machine. (From Dennett's point of view).

The answer to the second question depends on whether we accept meme. Dennett accepts it where as Churchland has reservation.

The answer to the third question follows from (1) and (2) above. For Dennett, the conclusion is that we are *virtual machines made of memes*. But for Churchland, we are Parallel Data Processing Machines (Our brains are massively parallel machines). Dennett comments that the first two questions could get positive answers, and yet his starting and revolutionarily claim answering 'yes' to the third may be rejected. So Churchland is inclined to deny the third, with which Dennett is in general agreement.

So the conclusion is that they are not taking the divergent view points after all. Because both accept dynamic systems, the controversy takes us in the direction of how to close on the *two* steps to consciousness.

Now, Dennett wants to take second step to finally end of the controversy by pointing out that they are *compatible* positions.

Churchland claims that *Rules* play no causal role in the circuits. Once you compile the source code, the rules evaporate and all the *causal* work it has done at the level of flip flops and logic gates. "It is no more following rules than is the water of the Mississipi following rules in order to meander its way down a literal landscape from the northwest plains to the Gulf"[64].

There is *no rule-following* in the hardware either neural or silicon; but he does not mean that there is *no rule-following*. They *alter* the rules just as the icons on the desktop changes Colour and becomes somewhat translucent when it's being moved, and reverts to its original Colour when the cursor lets go of it. This it gives us the sense of a virtual machine.

Thus, from Dennett's points of view "there would be only a terminological preference separating Churchland from his positions". He is at one with self-modelling advocated by Metzinger, which in a sense agrees with the neural implementation of language at the virtual machine level as envisaged by Ray Jackendoff[65] .

Thus while Churchland insists a *hardware* level, Dennett insists on a *software* level (see above the picture array).

MEMES: Dennett does not agree with Churchland's mistrust of memes. The first point is that gene is the information while neuron is the vehicle of information and thus a gene meme parallel can be taken seriously. Churchland tries to cast aspersions on this idea. A meme according to him is just like a virus, invading a body and getting it copied again and again in the brain. This is what Churchland denies.

For Dennett, whole theories are *unwieldy* memes. The differential replication of memes within an individual brain is the underlying competitive mechanism of learning. Just as there are well-known trade-offs in the evolution of microbial and virtual parasites famously, the explanation of the evolution of virulence and a-virulence as a trade-off between intra-host and inter-host replication strategies. There are parallel principles to explore in the evolution of memes.

The Joycean Machine: While Churchland thinks that the hardware structure that are widely shared by animals, are '*Meme-Free*' and '*Von-Neumann-Innocent*' (a parallel machine), Dennett suspects the grounds, and defends a '*minimalist*' view of functionalism. In the end, the disagreement between Churchland and Dennett as to whether the recurrent neural network is a serial architecture boils down to this: while Churchland says 'yes' and Dennett denies it because the settings of the connections make all the difference.

In saying this, Dennett is not supposing anything like a stream if consciousness, but still it counts as a stream of consciousness. The difference between animals and human beings depends on the "family of microhabits of self stimulation that have to be installed by culture".

Later we will unfold the full story with reference to experimental work in chapter *4* and *5*. As seen in the two major paradigms of memory consolidation experiment *via* their consequences, we will reevaluate the ANTCOG and the experimental support it receives from Kosslyn's Study on Imaging.

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Chapter 3

AN EVALUATION OF THE SCIENTIFIC STATUS OF COGNITIVE SCIENCE FROM WITHIN

'Reduction is a priceless tactic in science, but that is not the same thing as a metaphysical programme and it engenders no reason to anticipate the dispensability, let alone the eradication of success'

(R.C. McCAULEY)

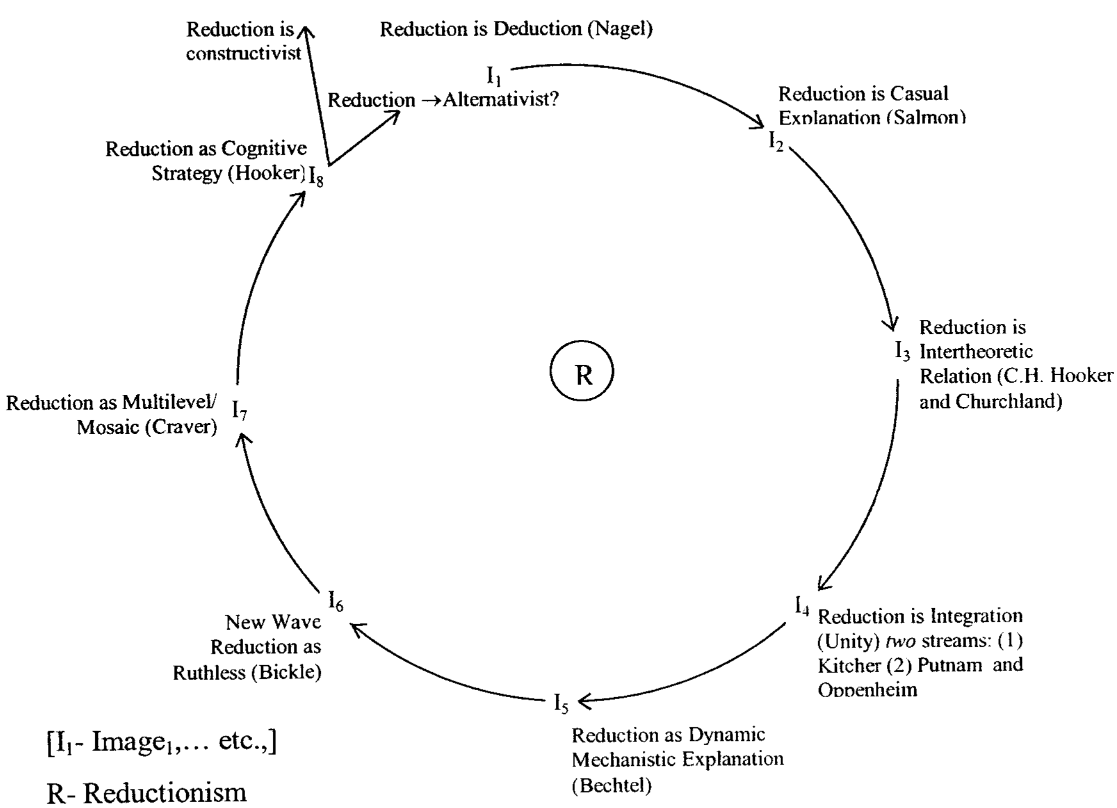
'Reduction is a relative matter'

(ANDLER)

AN EVALUATION OF THE SCIENTIFIC STATUS OF COGNITIVE SCIENCE FROM WITHIN

3.1 REDUCTIVE STRATEGIES IN COGNITIVE SCIENCE: IMAGES OF REDUCTION

Philosophers have been concerned almost exclusively within the rationality of theory choice; cognitive scientists primarily with the effectiveness of various decision process and strategies. In the 20th Century, claims about unity of science were commonly tied to claims about theory reduction. In particular, the strategy was to reduce the theories of higher-level sciences such as physics and chemistry. Claims about reduction were, in turn, treated as claims about deductive relations between the theories. The following picture illustrates the several stages of development:



[I_1- $Image_1$,... etc.,]

R- Reductionism

A summary view reveals the following strata of reasoning about reduction:

a) Reduction is *heterogeneous* but disguised as *homogeneous* (Nagel); it is *theoretical.*

b) If reduction is not deduction, then it is Intertheoretical Reduction (Churchland-Hooker).

c) If reduction is not both (a) and (b), then it is unity (Kitcher, Putnam Oppenheim).

d) If it is not unity, it is *decomposed* into mechanical components (Bechtel).

e) If it is not mechanical, it may be *ruthless* (Bickle); if it is not theoretical, it is *non*-theoretical.

f) If it is not canonical, then it is non-canonical (multi-level); if it is not parts, it is greater than wholes (Mosaic).

g) If they change is also wild, then theory-change is a system with appropriate feedback loops (Hooker).

h) The last option which is not tried, but bears scope: theories are alternative mechanisms without falling into relativism.

One major reason for the strong support for (h) is that we have alternative world models in physics (wave-particle theories), in genetics (Mendelian-Genetics in biology) and even so, in mathematics. In a sense, they are equivalent systems, but rival to one another; so they are *prima facie alternatives*. We can project this conclusion in support of the alternativist picture we have touched on in the case of Craver and to some extent in Bechtel also (we called attention to the combinatorial alternatives of tractably computational and tractably non-computational).

Now, it is time to review the different *images*:

Image 1. Reduction is Deduction (Nagel): The logical positivists advanced the theory-reduction as part of their effort to provide an account of science that avoided entanglement with metaphysical issues. Nagel identified an intermediate category of experimental laws, which provide an empirical summary of the phenomena observed[1]. These experimental laws are contrasted with theoretical laws, such as Newton's, which go beyond the observed phenomena by positing theoretical entities like forces and masses to account for the experimental laws. This is the well-known Deductive-Nomological (D-N) or Covering Law Model of Explanation (i.e., *reduction is deduction*). To account for the relations between the laws or theories of different sciences, the logical empiricists proposed simply generalizing this account, and argued that it should be possible to derive the laws or theories of one discipline or science from those of another.

This ORV (Once Received View) gives rise to a sense of unity which positivist calls as method of unity, unity of all sciences. Now the D-N model is on the wane, euphemistically called the '*Theories in the Wild*'(Craver)[2].

Image 2. Reduction is Causal Explanation: Wesley Salmon's classification of scientific explanation falls in to *four* types[3]. They are called *logical, causal, mechanistic* and *teleological.* Salmon's reduction is *causal* (empirical explanation). This is *causal* explanation at empirical/mechanical level. These norms of explanation have been pursued by defenders of the causal-mechanical account to challenge the sufficiency of alternative models of scientific explanation[4]. In Salmon's sense, in the last two i.e., mechanistic and *teleological* somewhat oppose to each other. But in the context of cognitive science, we cannot think of the opposition sometimes teleological (example, Millikan's Teleosemantics).

Image 3. Hooker-Churchland Model: The reduction is intertheoretic relation i.e., the plurality of theories. The idea that *lower-level* theories need to be enriched to account for what is learned at the *higher-level* leads to a view that *reduced* and *reducing theories co-evolve,* a view that Patricia Churchland espouses for the relation between psychology and neuroscience. Intertheoretic Reduction which involves two theories may be given as involving identity[5].

Theory $_1$	=	Theory $_2$
↓		↓
Folk Psychology	=	Scientific Psychology

We also used co-evolution etc. It displacement/replacement occurs then the left side is eliminated. This is called *eliminativism* (ultimately it leads to plurality of theories)[6].

Image 4. Reduction is Integration: Recently, strong dissent has been raised on both scores, with some philosophers rejecting both reduction and unity of science. Other philosophers, more sanguine about unity, have advanced alternative conceptions that emphasize integration more than unity and detach these issues from questions of theory reduction. In addition, accounts of reduction that do not tie it to deductive relations between theories have been advanced i.e., integration without reduction. It falls into two streams (1) Kitchers *moderate* version and (2) Putnam – Oppenheim's account of explanatory unity.

Philip Kitcher has argued for more than two decades that we should be interested in the *unity of science* because of the tight connection between *unification* and *explanation*. Kitcher defends this view as a means of offering an account of explanation that both builds on the work of some of the logical empiricists (Particularly, Hempel and Fiegl) and overcome some shortcomings of the Covering Law (D-N) model of explanation[7]. Kitcher's emphasis on unification is meant to be a way to retain the logical empiricists' commitment to explanation as derivation. So reduction is not reduction but unity of all sciences.

On the other hand, Oppenheim and Putnam argue that the unity of science consists in a chain of reductive explanations that link phenomena at the highest levels (for example, the behaviors of societies) to phenomena at the lowest levels (for example, elementary particles). Most philosophers of neuroscience have followed Oppenheim and Putnam in using reduction models to describe the multi-level structure of neuroscientific *explanation*. Although these later models differ in details, each descends from Nagel's classical reduction model[8]. According to this model, reduction is achieved by identifying the kind of terms in higher-level theories with those of lower-level theories and deriving the higher-level theories from the lower-level theories. On the assumption that different fields of science have their own theories and on the assumption that their theories describe different levels, the reduction model then provides a view of the unity of neuroscience.

Image 5. Reduction as Dynamic Mechanistic Explanation (Bechtel): Although philosophers have generally construed reduction as theory reduction, this notion fits poorly with what is scientists typically call "reduction"[9]. A mechanism is a structure performing a function virtue of its components parts, component operations, and their organization. The orchestrated functioning of the mechanism is responsible for one or more phenomena. A central feature of mechanistic explanation, and the one that makes them reductive is that they involve *decomposing* the system responsible for a phenomena into *component parts* and *component operations*. While the study of *mechanism is reductionsitic* and can promote integration of knowledge from various disciplines, it does not promote a ground for any unificationist vision. It has undergone many changes during its career.

Mehanism =Decomposition + Localization + Integration (in Carnaps' Sense). This is modified into one that is stated as follows:-

Mechanism = Decomposition + Recomposition + Situating Circadian Mechanisms (with feedback loops), called Dynamic Mechanistic Explanation and it is found applicable in the context of the neurobiological mechanisms (Suprachiasmatic Nucleus (SCN)) governing *Circadian Rhythm.* Bechtel reaches his variant of reduction which is termed as Reduction + System (contextualisation) approach with feedback loops. The mammalian researchers traced the maintenance of these rhythms to a specific region of the brain – the Suprachiasmatic Nucleus (SCN)- which is regarded as the central clock[10]. It is located on both sides of the hypothalamus.

Image 6. Reduction as Ruthless (New Wave Reductionism, Bickle): Bickle (2006) characterizes the project of the ruthless reductionism with the proposal to "intervene cellularly/molecularly and track behaviourally"[11]. Bickle contrasts his ruthless reduction approach to that of philosophers who have appealed to cognitive neuroscience as the appropriate locus in neuroscience for explaining cognitive functions.

Having identified differences between ruthless reduction and mechanistic reduction, Bechtel has to import that difference to the practice of neuroscience. There is no doubt that the research that Bickle cites as exemplar of *ruthless reduction* has provided important information about processes at work at some level of decomposition within the mechanism of memory consolidation.

Bickle has made much of the significance of this difference in approach, citing a variety of advantages than the Chruchland – Hooker version. One important advantage has already been canvassed: release from having to find connecting bridge principles (laws or identities) to obtain any inter-theoretic reduction relation, thus by-passing their numerous difficulties. There follows the advantage, noted above, that where the reducing theory corrects the reduced theory, including radically so, inter-theoretic relations are dealt with in the same general way as the clearly *retentive* cases, while the Schaffner model will have difficulty providing coherent bridge principles since the reduced theories are logically incompatible. This extension of Hooker was developed by Bickle and labeled "New Wave" reduction theory. So Bickle in his valuable has turned in a similar direction for further neuroscientific explanation at the Cellular and Molecular level[12].

Image 7. Interventionist-Manipulationist Idea of Causation: Mosaic unity of neuroscience is achieved both through interfield integration at a given level and through integration across levels in a hierarchy of mechanisms. Craver develops this model using a putative exemplar of reduction in contemporary neuroscience: the relationship between the psychological phenomena of learning and memory and the electrophysiological phenomenon, Long-Term Potentiation(LTP)[13]. Craver thereby demonstrates that the Mosaic View is far superior to reduction as a model of the unity of neuroscience.

The mosaic unity of neuroscience is often integrated when researchers in different fields, identify constraints on different levels in a multi-level mechanism or collaborate to link levels in mechanism. Craver believes that the unity of science serves an epistemic function, one that captures at least much of distinction between *good* (neuro) science and *bad*. Oppenheim and Putnam characterize the unity of science reductively in terms of the ability to explain the phenomena of higher-level science in terms of the laws of some fundamental science[14].

Image 8. Cognitive Strategy (Hooker): While Churchland's 'Spectrum View' ('bumpy'-to-'smooth' reductionism) is understood as a process akin to reductionism, Hooker's Non-Spectrum treatment of reduction (two theories meet asymptotically) is set with his larger vision of 'cognition' and 'cognitive strategy'. One dimension of this concerns the nature of the relations between relevant theories, as we actually find it in science. In the most thoroughly worked out cases those of physics, the relevant inter-theory relations are all specified as *asymptotic* relations (Theories meet at ∞); it is given in the formula such as

$$\underset{p\to 0}{\text{Limit}}\ (T_n) = T_o \text{ for some parameter p.}$$

(tends to zero)

$$\text{Limit}\ (T_n) \quad = \quad T_0$$

(Relativity theory velocity$\to$0) (Classical Mechanism)

This is ultimately a dynamically specified relationship, and one that shows rich variety and complexity[15].

In thus focusing on T_n imaging of T_o rather than on deducing T_o from T_n, Churchland takes a position that unorthodoxy plays down the role of the bridge laws that establish the correlations or identities between the two theoretical domains. It is certainly undeniable that the deduction of T_o laws from T_n logically requires bridging laws or identities, as Nagel made clear when developing the deductive model of reduction[16]. Since, then the standard position has been that the 'bridge laws' (Identities) lie at the heart of a reduction.

But they do not lie at the heart of real reductive practice in science. By considering how scientists actually treat the reduction of scientific laws, for example, the reduction of the Boyle-Charles' law to statistical mechanics, Nagel himself shows how scientists arrive at reduction of a law L_o or property P_o of theory T_o respectively to a law L_n or property P_n of theory T_n by first showing how to choose conditions (real or idealized) under which it is possible to construct the imaging (here mirroring) relation and from that deducing that the reduction is shown achievable through the postulation of the relevant laws or identities.

There is another way in which *asymptotics* is crucial to reduction: it grounds a dynamical account of self-organization proper and this in turns grounds principled dynamical accounts (I) of emergence, (II) of levels proper with complex systems and, on that basis, (III) of cross-level causal (more generally: dynamical) relations, leading to a principled dynamical account of casual multiple realization, and (IV) of cross-level functional–to–dynamical relations, leading to a principled dynamical account of functional multiple realization, and (V) of context- dependent laws, and hence of the so-called 'Special Sciences' such as biology and social theory.

Finally, Churchland's primary legacy lies in the rich sense of cognitive strategy he has been able to convey. Churchland's vision is of an unfolding scientific understanding that penetrates every area of life, from our social morality to our personal consciousness. Science itself emerges under our creation from the primordial species capacities for exploration and adaptation and is itself unfolding as at once part of, and generator of, that understanding.

We are not poised to select any one form of reduction, nor are we anywhere nearer to propose alterity *in lieu of* reduction. But when we say that mechanism is plurality writ small, we wonder whether pluralism is mechanism, or better alternativism, writ large, we are inevitably led to a position of alternatives. Thus we can pitch alternativism against pluralism which looks like a simplistic solution. Any other explanation of pluralism is welcome but may prove costly. The exact reason why we are motivated in this direction cannot be spelt out at once. We have to wait till the time what we have termed as the semantic task of reduction, is completed. Meanwhile we shall devote the next section to an analysis and evaluation of ANTCOG as a viable project in cognitive science. There is no reason to believe that it will be pronounced as such for the simple reason that much water has flown under the bridge. Thus we should not lose sight of the pragmatic constraints on mechanistic explanation (Daniel Strites 2010). So, what we call alternatives is still normative as well as inclusive of alternative models of decision-making.

3.2 EVALUATION OF *ANTCOG* AS A VIABLE PROJECT

A rough sketch of Eckardt's main lines of the complex argument is given below:

Step 1 : Mental Representative Semantics (MRS) needs a *ramified* set of assumption such as, '*supplementary*' and '*linking assumption*' which are *three-layered* and symbolic to Kosslyn's work on Mental Imagery.

Step 2 : MRS is shown to be *symbiotic* to Biosemantics

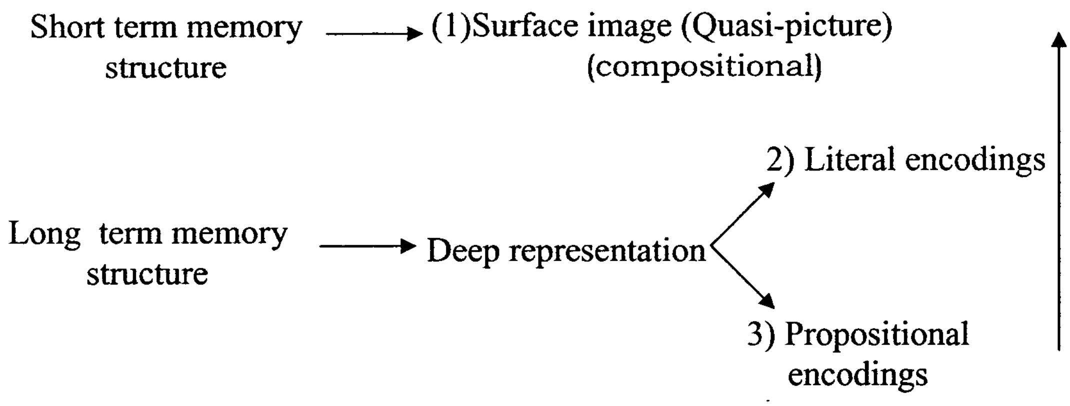
Step 3 : MRS is shown to be a species of Natural Language Semantics.

In order to achieve this, she needs a further assumption claiming that, we require *a candidate theory of semantics*. She suggests Millikan's '*biosemantics*', or what is called '*teleosemantics*', as suitable enough to serve the purpose for a Natural Language Semantics (Step 2 →Step 3). This is what she actually does not probably execute however. It is left to us to address this question afresh in the sequel.

The above argument is supported by *two* important assumptions:

1) Semantics is a wider part of Semiotics of the Peicean type.
2) The whole procedure requires a Smolensky-like model of symbolic/ subsymbolic levels.

So, the viability is determined by the substantive assumptions of a three-tier of representation that may be schematized as shown in figure 2:



On the one hand, the above proposal continues to inspire the latest paradigm in 'hardcore' neuroscience, where memory consolidation research is preponderant, and informs the experiment on mental imagery on the other. However, the specific dynamics of her project requires that an image is

(i) semantically selective

(ii) semantically complex

(iii) semantically evaluable

(i)-(iii) allow a certain semantic diversity which is augmented by propositional encodings before yielding a particular 'semantics' of mental representation. The whole enterprise of the semantics provides an important link between the classical connectionism and modern variants. We will be able to realize this while studying closely the assumptions. Now, the question is how to build up a viable semantics. We require further assumptions like (SA_1).

SA_1:The Computational Assumption

C_1:(linking assumption): The human cognitive mind/brain is a computational device (computer);hence, the human cognitive capacities consists to a large extent, of a system of computational device.

The nature of computer metaphor is understood to be more like a 'substitution view', that is more creative than interaction view[17]. As Boyd emphasizes, it is a sort of Theory- Constitutive Metaphor that can become the property of an entire scientific community[18]. Thus, Boyd regards the computational metaphors of cognitive science as paradigmatic instance of theory- constitutive metaphors.

It is a sort of mapping from source to the 'target' representation expressed in terms of Holyok and Thagard's. In their terminology, it states that[19]:

If predicate 'P' and subject 'O' (source) maps onto 'P' and 'O' (target), than of P(O) holds in the *source* can yield an inference like P(O) in *target*[20].

More specifically, there are at least *five* ways in which C_1 functions like a Boydian Theory Constitutive Metaphor.

a) No other theoretical terminology for describing the mind/brain at a functional level is fruitful.
b) The attribute that the mind/brain is a computer is clearly open-ended.
c) In order to determine the points of similarity between mind/brain and computers, they must be experimentally determined.
d) C_1 is also theory – constitutive in Boyd's sense in that it is a property of group (namely, scientific, community of cognitive scientists) rather than of a single individual.
e) The force of C_1 is certainly not lost upon repeated within that group.

Now C_1 (linking assumption) gives what is called the cognitive science concept of computer. The uniqueness of this is the understood in terms of the distinction between

1. A mathematical theory of computability.
2. A data – processing or information – processing device.

Eckardt stipulates that (2) is more appropriate on the following consideration:

1) it is analogous to mind and

2) it is broad enough to include both conventional (Von Neumann) and connectionist devices

3) it valourizes a computation modelling and

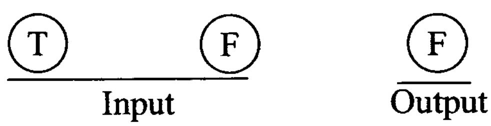
4) it provides a theoretical base for ANTCOG Subsidiary Research Programme.

The point that is to be borne in mind here is that (1) - (4) do not convey a Finite Automaton nor a Turing Machine. But it is essentially a device capable of accepting, storing, manipulating, and outputting data or information in accordance with a set of effective rules, but the ambiguity here is on 'data' and 'information'.

The ambiguity forces us to pass on to a close study C_2 (system assumption).

<u>C_2 (system assumption)</u>: A computer is a device capable of automatically inputting, storing, manipulating and outputting information in virtue of

inputting, storing, manipulating and outputting representative of that information. These information processes occur in accordance with a finite set of rules that are effective and that are in some sense, in the machine itself. Thus C_2 includes both conventional (Von Neumann Architecture) and Connectionist Devices (PDP) as that of McCulloch-Pitts (M-P) essentially because of the manipulation of information. We sense a sort of *Neurologic* given as a *logic-neural* interface it comes to this. Look at the logical rule for *conjunction*:



The term 'neurologic' has been swamped by a maze of networks that have been developed over the years. No one can recover this idea today.

Together with 'pattern of connectivity' they justify a need to distinguish between low-level and high-level representations. This is what is illustrated in the case of NET talk (Churchland and Sejnowski, 1989) where a network learns over a period of time[21].

Now, we add a supplemental (SA_2) which is stated in terms of R_1 and R_2 is follows:

R_1 (Linking assumption): The human, cognitive mind/brain is a representational device, hence the human cognitive capacities consists of a system of representational capacities.

The least promising semiotic dimension is to be explained as follows:

R_2 (System Assumption): A representational device is a device that has states or that contains within it entities that are representations. Any representations will have *four* (the bearer, the content, the ground and the interpretant) aspects essential to its being a representation expressed in formal terms.

Now, in order for research framework to evolve, at least one of its components must consist of a *revisable* element. Cognitive scientists interested in architecturally specific research assumed that the mind/brain was something like a general-purpose conventional machine. To be more precise, in the first stage C_1 and C_2 were supplemented by something like this:

$C_1.1$ (SUPPLEMENTARY LINKING ASSUMPTION): More specifically, the human mind/brain is a general- purpose, stored program, conventional computer.

$C_2. 1$ (SUPPLEMENTARY SYSTEM ASSUMPTION): A general purpose, stored program, conventional computer is a described as a conventional machine.

$C_1.2$ (SUPPLEMENTARY LINKING ASSUMPTION): More specifically, the human mind/ brain is either a general purpose, stored, program, conventional computer or special purpose, wired program, conventional computer or connectionist, or some combination of these.

$C_2.2$ (SUPPLEMENTARY SYSTEM ASSUMPTION): A general purpose, stored program, conventional computer is... (as described in conventionalism). A special-purpose, wired program, conventional computer is... (as described in conventionalism). A connectionist computer is... (as described in connectionism).

The current conception of the end state of this capacity among psycholinguistics is that to understand a sentence of some natural language is to recover and represent the meaning of that sentence. That is, the semantics of MRS (Mental Representative Semantics) must be at least as rich as the semantics of natural language. The assumptions to be discussed then follow from certain theoretical assumptions embraced by most semantic theories of natural language.

MRS requires representations to be *selective, diverse, complex* and *evaluable*. MRS could be counterposed to Fodor's Semantic Atomism (she calls it as '*Isolationism*'). The main argument is given as follows:[22]

1) There are firm data for only gross psychoneural correlations.
2) Therefore, it is likely that there is multiple neural realizability
3) Therefore, cognitive science should adopt an isolationist stance.

The fact that there are no firm data for the existence of detailed psychoneural correlations is consistent with *two* epistemic states of affairs: (a) there are firm data that there are no such detailed correlations; (b) there are no firm data either for or against the existence of such correlations.

Neuropsychologists have only recently began to appreciate that the attribution of functions to parts of the brain cannot occur in a state-of-the-art way but must proceed in concert with sophisticated scientific psychological theorizing[23].

Even if cognitive functions are multiply realized in human brains, neuroscience may still be able to provide important evidence about the nature of human information processing. Two sorts of findings come to mind. When neuropsychological techniques are used to provide evidence for functional localization, they are, at the same time, providing evidence of the existence of a certain psychological function. If the best explanation for a patient's pattern of behaviour is the hypothesis that there is selective impairment in a particular component or subcapacity, then that pattern of behaviour is evidence for the existence of that component or subcapacity in normal individuals.

Another class of findings whose utility is independent of the degree of multiple neural machinery. These sorts of considerations have become especially important for cognitive scientists interested in developing connectionist models, since one of the virtues of these models is supposed to be their greater biological plausibility.

Von Eckardt is not happy about the multiple realizability argument and so it is wrong to use this in support of an isolationist methodology for cognitive science. According Eckardt, the mere fact that information-processing functions are multiply realizable does not mean that a particular kind of stuff is not constrained by the structure and organization of that stuff. The fact that thus far only gross psychoneural correlations have been discovered does not mean that there are no detailed correlations to be had furthermore. Even if detailed correlations are not forthcoming, there are still ways neuroscience can constrain the construction of information processing models. With this, we close our discussion cutting off other details and pass on to consider biosemantics as a worthy candidate theory of semantics.

Against P.S Churchland who has argued that some neuroscientists are just as much in the business of developing computational/ representational accounts of cognition as workers in psychology and artificial intelligence are, Eckardt proposes the co-evolutionary tag[24]. The argument here is that, if neuroscientists are going to venture into computational and representational territory, it would be foolish of them not to make use of the results of previous and concerned explorations by their non-neural cognitive science brethren. So, Eckardt concludes that the only reasonable strategy is a co-evolutionary one:

The optimal strategy for developing an adequate theory of the cognitive mind/brain to adopt a *co-evolutionary approach*, that is, to develop information processing answers to the basic questions of cognitive science on the basis of empirical findings from *both the non-neural cognitive sciences and the neurosciences*.

According to the substantive linking assumptions, the cognitive capacities consist, to a large extent, of a system of computational and representational capacities. These assumptions constrain what counts as a possible answer to each of the basic questions.Thus in endorsing the substantive assumptions, cognitive scientists limit themselves to entertaining only answers to the basic questions that are roughly speaking, formulated in information processing terms.

Cognitive science seeks to explain the human cognitive capacities by re-conceptualizing them as a system of computational and representational capacities. Von Eckardt turns the above into one about 'information processing capacity' to refer to a capacity that is both computational and representational, by mean of the substantive linking assumption. Thus the force of the linking assumptions, C_1 and R_1 together amount to this:

CLA (THE COMBINED LINKING ASSUMPTIONS): The human cognitive capacities, to a large extent, of a system of information processing capacities.

Many of its assumptions are inherited from its parent framework. The first *two* methodological assumptions, M_1 and M_2, claim that cognitive science's focus on individual cognition- *individual* as opposed to *social* and cognitive as opposed to non cognitive- is warranted in this sense.

Von Eckardt attempts to justify the choice of commitments selected to be part of the characterization and she attempts to clarify the meaning or significance of the included assumptions. The *first* task is necessary because not every one agrees on what the fundamental commitments of cognitive science are. The *second* is necessary because it turns out that even where there is near- unanimous agreement that some particular assumptions constitutes a commitment of the field, it is not always clear what that commitment comes to.

Although there is near- unanimous agreement that these are the two fundamental assumptions of cognitive science, i.e., *computation* and *representation.* Von Eckardt tries to do the best thing and say something about how cognitive scientists conceive of the computer at the present moment in the history of cognitive science. Eckardt's attempts to characterize cognitive science's concept a computer in general takes into consideration which she describes as *two* kinds of computational devices–called conventional and connectionist machines.

Eckardt attempts to sort out what assumptions cognitive science makes about how these *four* aspects are manifested in mental representation. In general, her position is that working out a detailed theory of the *representation bearer, the content, the ground, and the interpreting of our mental representation* is a task for future cognitive science research. With this much limitation in mind, she tries to fit this into the available empirical evidence from the experimental work as mental imagery.

Eckardt's succeeds if he can demonstrate that MRS is also a species of *natural language* semantics. Whether he succeeds will form the content of the *next* section.

3.3 ECKARDT'S SOLUTION MR SEMANTICS AS A SPECIES OF BIOSEMANTICS

Eckardt's solution to semantics involves acceptance of the Peircean semantics, partially or fully and eschewing both Fodrian and Searlean approaches to semantics, so as to preserve the *semiotic function of natural language*. This invites a type of semantics that Millikan has developed within the parameters of language as a biological category and it is called 'teleosemantics'[25]. The broad features of this semantics will be captured below.

Millikan's *teleosemantics* is suggested as a candidate theory of semantics. So we have to enquire to what extent the features of this semantics will automatically support Eckardt's way of looking at an alternative theory of semantics. In the end, we will find that since it subsumes Peirces semiotics, it can be serving a purpose.

Currently, there are two important approaches in contemporary philosophy of language.

(1) The *formal* approach, is mainly concerned with those semantic properties of a given language that help us to understand the reference of its individual expressions and the *truth-conditions* of its sentences. This is semantics in its *purest* form.

(2) The other let's call it the *cognitive or psychological* approach is likewise concerned with the semantic properties of expressions of a language, but those semantic properties are now filtered through the psychological/ biological features of the user of the language.

A teleological theory of content is mainly concerned with the problem of content-fixing from a naturalist point of view. 'Teleosemantics', is a theory only of *how* representations can be *false* or *mistaken*.

They take it that mistaken representations are "representations", in the sense that the biological functions of the cognitive systems that made them represent things. Falsehood is thus explained by the fact that the purpose often goes unfulfilled. The teleosemanticist, in order to speak most clearly, should refuse to equivocate in this way.

The following features of *Biosemantics* are prominent:

1. Biosemantics is a naturalistic, teleological theory of mental content, which appeals to the teleological notion of function.
2. The notion of function is defined as follows:

   Function = *df.* What a mental state represents depends on the function of the state in the system that uses/produces it, where the notion of function is the notion of *what something* was *selected* for by natural selection or some other natural process of selection. This function is anchored in *natural* selection.
3. There are *three* different kinds of representation

(1)	descriptive rep.	(2)	Directive rep.	(3)	pushme/pullyou rep.
	↓		↓		↓
(1)	represents facts	(2)	tells us what to do	(3)	is the most primitive and functional kind of representation

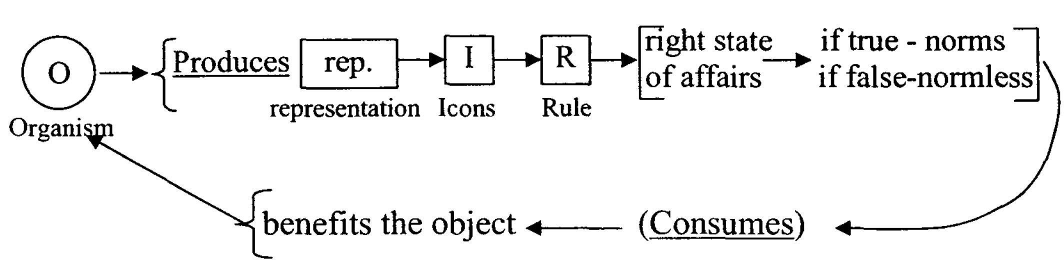
As a naturalistic theory of representation, it displaces the following features.

1. It is a theory of mental representation
2. It is a theory of mental content.

Some how (1) and (2) are disjoint because they do not say what representation is (it says when representation occurs, and it says when representation does not occur). Millikan illustrates this with the dancing of the Honeybee and the semantic rate of *Beemese.*

3. It is a theory of information
4. It is a theory of function

How this theory anchors the notion of function to selection is explained by the producer – consumer model; as schematized below:-



The *teleoltogist* adds that for your true representation to be an intentional representation, it must be a function or purpose of the system that produced it to make *true* representations. Otherwise, though it may indeed be a true representation, it is not an *intentional representation.* Then the teleosemanticist proceeds to explain what a *false representation* is given your view. That is all teleosemanticist amounts to. A common way of glossing teleosemantic theories of representation has been to say that they claim that "*the function*" of an intentional representation is "*to represent*" or to indicate something. But that way of expressing the teleosemantic idea invites serious confusion. The teleologist might claim that when the systems that produce and/or use intentional representations perform the tasks they were designed to perform and these tasks by means of their normal mechanisms-let us just say "in a normal way" – then the intentional representations or basic representations-whatever "basic representations" are taken to be.

A further reason for doubting the teleological account derives from the character of psychological explanations themselves. If we opt for a teleological characterization of content, we commit ourselves to the idea that the environmental properties that count for the explanation of an agent's behavior are always 'real' properties of the world. Like Millikan, we must invoke a 'rule of correspondence' that reflects some 'actual condition in the world' and a condition that affects the individual, not only as an individual, but as a member of one particular species. Such commitments, however, go against the usual explanatory strategy in psychology[26].

The rest of the "just-so story" tells us how all these assumptions (main and subsidiary) give rise to a theory of mental representation. An essential step here consists in making it to conform to Fodorian semantics of *mentalese* (language of thought). For Eckardt, this is done by means of an inference to the propositional attitudes that is to be stored in long term memory. Basically there are *two* approaches:

a) The Searlean approach

b) The Fodorian approach

Eckardt does not favour any one of the above for the obvious reason that they aspire to gain explanatory power by considering 'propositional attitude *explanandum*' and 'propositional attitude *explanans*'. Then both generate difficulties on account of *equivocalism* between 'propositional attitude' (*explanandum*) and mental representations (*explanans*).

On the other hand, Eckardt recommends the need to introduce the *four* Peircean categories to gain explanatory power. i.e., bearer, semantic, ground and interpretant.

Now we shall explore the close analogy to Kosslyn. Kosslyn also believes that the *three* kinds of corresponding representations are involved in our capacity to image[27].

a) The *surface* representation: surface representation depict the appearances of objects from a "viewer-centered" point of view. Their semantic are such that parts of the representation represent parts of the imaged object. The medium of the surface representation is called the '*the visual buffer*'.

b) The *literal* encodings: the literal encodings contain the information necessary for generating the surface representation. There are literal encodings for whole objects and for their parts. The literal encoding for whole objects represents only its global shape.

c) The *propositional* encodings: The propositional encodings represent various facts about the imageable objects. Those facts are represented in a sentence - like way and organized in terms of a list which is stored in long term memory. The medium of the propositional encodings simply consists in the types of data structures appropriate for containing all this factual information.

The conventionalist Fodor and Pylyshyn have recently mounted an argument that constituent structure is necessary of MRS to account for the *productivity* and the *systematicity* of our cognitive capacities[28].

The human cognitive capacities are *productive* in the sense that once a capacity has been mastered, it can be exercised in a practically unlimited number of novel ways.

The *systematicity* of the human cognitive capacities amounts to the fact that the sub-capacities that constitute those larger capacities are typically mastered in "clumps" that are systematically related. According to Fodor and Pylyshyn, an analogous sort of systematicity exists in thought.

A working assumption of psycholinguistics is that anything that is uttered will first be mentally represented. Since Fodor and Pylyshyn ultimately use these arguments to support the very controversial conclusion that the human cognitive architecture cannot be connectionist. Eckardt suspects that there may be well be a significant number of cognitive scientists who will want to 'halt' the march toward anti-connectionism at this point. Fodor and Pylyshyn are right to hold that structured representation are needed in order to account for the '*productivity*' and '*systematicity*' of human cognitive capacities; they are holding it only in the strong sense.

As a conventionalist, Fodor and Pylyshyn put forward the argument that our cognition depends upon a constituent structure which accounts for *productivity* and *systematicity*.

Systematicity Phenomenon:

The angry Jay chases the Cat

The angry Cat chases the Jay

Productivity Phenomenon

The angry Jay chases the cat *and* the angry cat chases the Jay

These phenomena are combinatorial and recursive and this is what is required of a syntax and semantics. It is presumed that there is a strict analogy between systematicity and productivity in language and thought. But this is not provable by empirical investigation. These phenomena are sensitive to structure and they can be handled better in the symbolicist paradigm. But contrary evidences show that language is syntactically structures even in connectionist paradigms but with different motivation (need not be compositional). This gives support to the interpretation like the one we have discussed in the context of Bechtel-Waskan critique of Horgan-Tienson view (see Section 2.3 above). It is only from some such reflection that the critique advanced by Fodor and Pylyshyn want to derive an anti-connectionist conclusion.

Eckardt tries to halt the above argument, along with the cognitive scientist (especially Smolensky) with the use of constituent structure but in a *weak* sense. So Fodor and Pylyshyn anti-connectionist conclusion is not only prevented but also there is a direct endorsement of Smolensky's model of connectionism. If this is the only proper form of connectionism as Smolensky himself terms it, then the proper form of connectionism, that is cognitive scientific, can only take this form. Eckardt can very well support the synergy between different cognitive models (Symbolicist and Connectionist). The strong presence of the synergy thesis supports our demand for the unique way of linking the symbolicist and connectionist paradigms.

In talking about the semantic properties of representations, Eckardt has used a rather restricted vocabulary. To this he adds some feature of Peirce's theory of representation, a representation and its object or content: semantic relations of representing and ground relations in virtue of which these semantic relations are supposed to hold. There is an unfortunate tendency in the literature to refer to theories of both sorts of relations as "semantic" theories. A similar ambiguity can be found in the realm of mental representations. The structure-content relations of MRS have yet to be studied seriously, but when they are studied, this study will undoubtedly be called a "semantics" of MRS.

Again, Eckardt concludes that an alternative "Theory of Content Determination (TCD)" is what is needed to complete the project[29].According to this theory, a genuine semantics for MRS would stand with respect to truth – conditional semantics as Fregean semantics, and possible – world semantics stand with respect to natural language.

Start with the Truth Conditional Theory which defines Meaning as follows:

Meaning = *df.* Truth Condition (as given by truth-table)

Plus Tarski's Semantic Theory (Listiform Theory).

Frege was a 'semanticist without a semantics' of natural language (as Hintikka derides him in the context of his variant of possible world semantics). Incidentally we must note that this point alone speaks against inclusion of Fregean semantics among possible-world semantics. Hintikka's point is that

Fregean Semantics is not a species of Possible world semantics;

The possible world semantics is the only viable way of doing semantics;

Hence Fregean semantics is not a viable system of semantics

But this need not be true of Eckhart who takes Frege's definition of meaning at its face value:

Meaning = *df.* {Sense and Reference}

A theory of *content* minimally backs up Fregean Semantics and so it can be okayed. The presumption here is that Frege cases of sense and reference must serve as a base for any viable semantics. The only way this could be executed is to take account of what is called the most primitive form of biosemantics namely that pushme/pullyou representations. The reason why it is called primitive is that it is prior to any viable semantics. This suggests that some form of Kripkean semantics will serve the purpose. This is endorsed in Dr A. Kanthamani's 'Does Neurobiology of Mind Matter?'[30]. Accordingly the pushme/pullyou is in such a combinatorial protoform as the one Kripke would have endorsed as rule-following and rule-violation. This looks the alternativist solution we have been pursuing. We have to show that this will be a candidate for natural language semantics. The prospects are not as dim as one believes. Not much can be claimed over this but in the face of the inherent difficulties of building up a model for philosophy of language and mind, this stands one such model and that too, a prospective one at that.

The shortcomings of ANTCOG become obvious once we recognize that no existing semantics can be suggested as a substitute for a candidate theory. But Frege's theory of content can stand in relation to Biosemantics. But that is what that has not been shown. So we conclude that the conceptual grounds are weak. But that excludes the pragmatic grounds which are still needed. The question that is not very clear is that to what extent a mixture of Fregean semantics at the possible world level and Biosemantics will do the trick. Probably she thinks that a teleosemantics, that is inclusive of semiotics, and a complementary Fregean semantics of content (sense and reference) will be ultimately available for carrying out the semantic task. But she fails to realize that the semantic task is much more complicated than this. One point that is clear is that there is a 'semantic task' that has to be completed. At what level? We can attack the problem in the way it is suggested by Eckardt. The other way is what we have characterized as the 'semantic task' that looks more promising. We conclude that there are better ways of looking at the scientific credentials than the ones suggested by ANTCOG. Meanwhile, let us now review the empirical grounds which stand a chance for fulfilling a viable project of cognitive science.

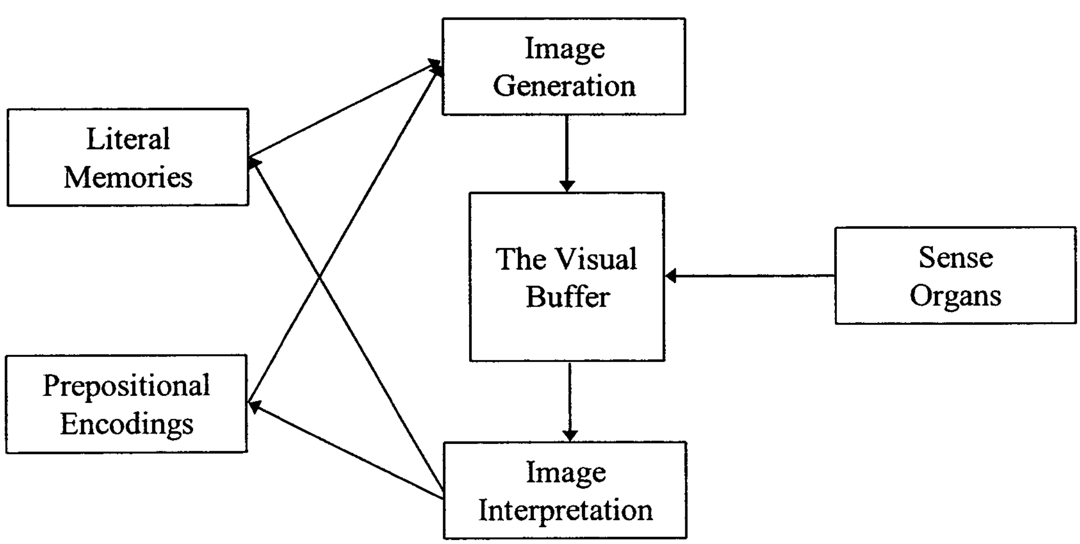
3.4 EXPERIMENTAL SUPPORT FROM KOSSLYN'S WORK ON IMAGING

One central debate in cognitive science is considered to be over Imagery. Stephen Kosslyn's basic idea is to develop on illuminating initial metaphor of Imagery: a spatial display generated on Cathod Ray Tube. Visual images might be like spatial displays provided on a Cathod Ray Tube by a computer program operating on stored data. That is, we hypothesized that *images are temporary spatial displays* in *active memory* that are generated from more *abstract* representations in long term memory.

Kosslyn and his co-workers have constructed a running *simulation* of human imagery[31]. *A simulation is theory-like in proceeding at a suitable level of abstraction.* A psychologist need not be concerned with how psychological functions are realized in brain ware though he must ensure that the functions he posits can be so realized. Similarly, the programmer need not be concerned with the hardware implementation of his program. A simulation is theory-unlike in having various theory neutral characteristics, characteristics it may or may not share with the modeled domain.

The crucial feature of long-term storage is that it is divided into two components. One encodes the "literal appearances" of objects or scenes. This information specifies which points in a matrix are filled if a given image is to be activated. The other component consists of lists factual, discursive information. They play an important part in Kossyln's model, for instance in determining how the parts of an image are fitted into an *image skeleton*, and in the generation of *composite image not* corresponding to a single remembered scene.

How are images generated and transformed in this model? We sketch, the functional interrelations between long-term memory, the visual buffer and visual perception look like this:



The heart of this system is a *visual buffer*, common to visual perception and visual imagination. Representations may arise on this buffer through perception, in which case, interpretive processes make perceptual information available to the organism, and may *filter* some through to the *two* long-term memory stores. Alternatively, representations may be memory generated for cognitive use.

Kosslyn's account of the interpretation of imagery depends on part-whole relations already coded in long-term memory[32]. In other words, the only relations the imager can detect are those already coded in memory. As Pylyshyn has repeatedly argued, imaged do not require interpretation to the same extent as percepts: they came pre-interpreted. Pylyshyn has made the point in terms of examples like the "attack" relationship in chess. Typically, an image of a chess position will not need interpretation about: where is the White King what pieces are in the center, etc. Kosslyn diffuses Pylyshyn's problem through the device of *double coding*, together with the division of "appearance" memory into a main file *plus* subfiles. Thus for instance, the fact that memory loss is loss of significant rather than arbitrary elements become explicable. Memory failure is the loss, or loss of access to, subfiles.

So our central concern will be: does positing depictive representation yield a better account of mental manipulations than can be given posting only discursive representation? There is no doubt that Kosslyn's model is predictively successful. It is successful because both rotation and scanning proceed by small steps. Pylyshyn instances in this connection a principle that Kosslyn needs for the predictive success of the model: namely "mental images are transformed in small steps, so that images pass through intermediate steps of transformation"[33]. Now, Pylyshyn points out that this principle must be given a semantic interpretation: images are transformed in such a way that successive images correspond to small changes in the scene depicted.

Kosslyn argues that the criterion of cognitive penetrability of an overall process-like rotation scanning shows only that some components of this process are penetrable, not that there are no fixed, hard-wired process[34]. Kosslyn is undoubtedly right in this claim. But the predictive accuracy and power of Kosslyn's account of mental rotation and scanning do not depend on fixed and intrinsic properties of the model-properties. The model must have if it is to have a visual buffer but on cognitively penetrable and/or contingent features of the model. So, though Kosslyn's model does not seem to be predictively and heuristically valuable, it is very impressive; so impressive that it is hard to believe that he is not onto something important and right. Kosslyn claims that these results suggest that the tasks accomplished *via* the examination and manipulation of mental representation themselves have spatial properties i.e., *pictorial* representations, or images[35].

The primary function of mental imagery is to allow us to generate specific predictions based upon past experience. All imagery allows us to answer 'what if' questions by making explicit and accessible the likely consequences of being in a specific situation or performing a specific action. Imagery is also characterized by its reliance on perceptual representation and activation of perceptual brain systems. The conception of imagery is to argue that all imagery is simulation more specifically, it is a specific type of simulation in which the mental processes that 'run' the simulation, emulate those that would actually operate in the simulated scenario'.

Mental images need not be simply the recall of previously perceived objects or events; they can also be created by *combining* and *modifying* stored perceptual information in *novel* ways. Imagery has played a central role in theories of mental function at least since the time of Plato. It has fallen in and out of fashion, in large part because it is inherently a private affair by definition restricted to the confines of one's mind. Thus imagery has been difficult to study. Many researchers were not convinced that *imagery is a distinct form of thought*. Indeed, Wastson's position was echoed 60 years later by Zenon Pylyshyn, who championed the view that mental images are not "*images*" at all, but rather rely on mental descriptions no different in kind from those that *underlie language*. According to this view, images are subspecies of linguistic representations. This, together with the synergic principle referred to in the above brings together, the symbolicist, imagist and connectionist paradigms into an integral unity. The Imagist paradigm in brief is the subspecies of both the symbolicist and connectionist paradigms.

In addition, neuroimaging technologies developed in recent years, especially *Positron Emission Tomography* (PET) and Functional *Magnetic Resonance Imaging* (fMRI), allow theories of imagery to be tested objectively in human. Researchers have taken advantage of these developments to show that mental imagery draws on much of the some neural machinery as perception in the same modality, and can engage mechanisms used in memory, emotions, and motor control.

The fundamental problem of a research framework is obviously a problem consisting of many "parts". We can treat each of these "parts" as a problem in its own right. Thus, corresponding to each of the basic empirical questions of the research framework, there will be a smaller problem. How to individuate problems at a finer grain than this is not at all obvious and may well depend on the specific character of the research framework involved. Undoubtedly, however, there will be a complex interplay of hypothesis formation and hypothesis testing that will give rise to numerous derivative problems.

Kosslyn's work on mental imagery provides a nice illustration of such *derivative* problems[36]. Kosslyn began his research with the *working hypothesis* that visual mental images are like *computer-generated displays* on a Cathode Ray Tube. This working hypothesis then gave rise to a rough picture of what representational and computational resources are involved in imaging. Kosslyn posited *two* kinds of representation "*surface*" representation and "*deep*" representation- *plus* numerous distinct computational processes.

It is natural to think of a research program in the *non- technical* sense, as seeking explanations of the phenomenon in its domain. This common place claim about research programs can easily be accommodated by his technical conception of a research framework if we adopt what some philosophers have called the "erotetic" approach to explanation.

On the *erotetic* (question-answer models) view of explanation, the '*explanandum*' of all explanation consists of the *questions* itself, the *explanans* consist of the *answer*. The explanation is that in which we explain how things happen? The *explanandum* is what needs to be explained. And the *explanans* is what explains any phenomena. The Deductive Nomological (DN) Model suggests the need for a different paradigm. DN model contains the following ingredients (i) Initial Conditions and (ii) Nomological Laws (explanatory laws) which deduction implies (iii) *explanandum*.

In talking about explanations, it is useful to draw a distinction between a possible explanation and the *correct* or *actual* one. This distinction is mirrored in a straightforward way in the domain of *questions* and *answers*. A possible explanation relative to some *explanandum* is simply a possible answer to the question that constitutes the *explanans*. The correct or actual explanations, is then an answer that is both possible and true. It is also useful to talk about kinds of explanations. One can do this, on the erotetic view, by talking about kinds of questions.

How Eckardt used Kosslyn's work on mental imagery? He used it to throw light on this *erotetic* side of explanation. There are *two* reasons for his choice. *First*, Kosslyn's work is often regarded as paradigmatic example of research in this field. *Second*, as we will see, the richness and the systematicity of this research nicely illustrate many of the points that he has occasionally referred back to specific features of Kosslyn's research to illustrate particular aspects of cognitive science's research framework.

The core of Kosslyn's research concerns the *normal adult capacity* to form and use mental images. This work has *three* major components: the *experimental* study of human imaging capacities, a *general theory* of mental imaging that outlines the representational structures and processes underlying these capacities, and a number of specific, dynamic models of how our imaging capacities are exercised.

In Kosslyn's program of research, it is conceptualized as a *two*-phase strategy. In the *first* phase guided by the working hypothesis that visual mental images are like displays on a Cathode-Ray Tube (CRT) generated by a computer program from stored information, experimental data were collected to constrain the class of possible models relevant to human imaging capacities; in the *second* phase, a detailed theory and a model were proposed, to be tested and elaborated by further experimental work.

The *first* phase, the CRT metaphor suggested a number of hypotheses. The *first* was that *two* kinds of representations are involved in imaging: quasi-pictorial "*surface images*", which occur in a spatial display medium and are subject to the limitations of such a medium and "*deep*" representations, which consists of information stored in long term memory that can be converted into a surface image. A *second* hypothesis was that there were a number of different kinds of processes involved, including processes that generate the surface display once it is generated.

Kosslyn was interested in whether the surface representation underlying the experience of "having an image" had anything akin to the spatial characteristics that seem to be feature of phenomenal images (see figure below)

Figure 3.1: **The fictional map in Kosslyn's map-scanning experiment.** (From Stephen M. Kosslyn, Image and Mind, © 1980 by the President and Fellows of Harvard College. Reprinted by permission of the author and Harvard University Press.)

The graph showing the time scale is appended below

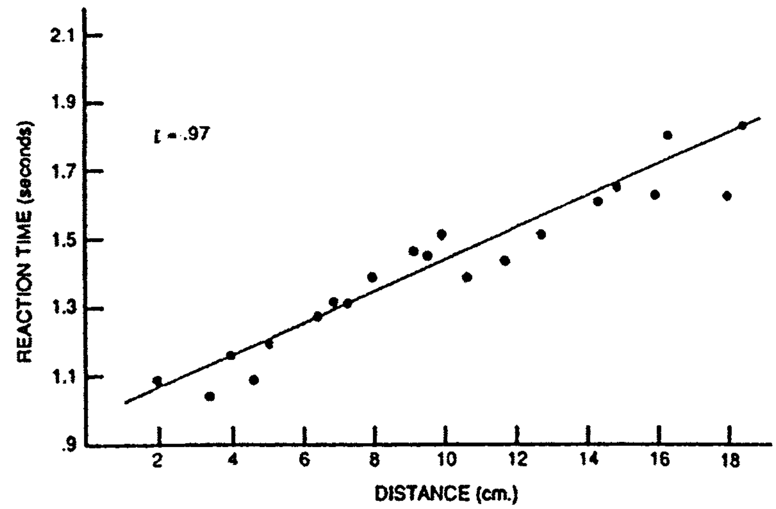


Figure 3.2: The time to scan between all pairs of locations in Kosslyn's map-scanning experiment on an image of the map illustrated in figure 3.1. (From Stephen M. Kosslyn, *Image and Mind*, © 1980 by the President and Fellows of Harvard College. Reprinted by permission of the author and Harvard University Press.)

As a general theory of mental imaging, this has the following features.

The theory posits that a number of representational structures and processes underlie the human ability to image. There are *three* kinds of representational structures. The *first* a short-term memory structure, consists of quasi-pictorial "Surface Images" which occur in a spatial display medium and are subject to the limitations of such a medium. The *second* and *third* called "deep" representations, consisting of information stored in long-term memory that can be converted into a surface image[37].

The general theory of imaging describes the various representational structures and processes that supposedly underlie the human ability to image.

In addition, because it specifies the input conditions required by each operation and the results of executing any particular operation, the general theory also, in effect specifies the ways in which these operations can be put together. It does, however, give a blow-by-blow account of how we exercise our imaging capacities or how we carry out particular imaging tasks. Kosslyn supplements his general theory with various *specific* models for these individual capacities and tasks.

Kosslyn's theory that image generation involves the PICTURE, PUT, and FIND modules is supported by *three* classes of empirical findings: the fact the image generation time is proportional both to the number of "parts" the imaged object or scene has and to its complexity, the fact that humans can construct images on the basis of descriptions of how parts are to be arranged, and the fact that image-generation time is proportional to be "subjective size" of the object being imagined[38].

In *recent years,* additional evidence for Kosslyn's theory of the imagery system in normal human has been obtained from the study of *neurological patients*. Roughly speaking, the arguments go like this: If the best explanation for a patient's pattern of behaviour is the hypothesis that there is *selective* impairment in a particular component or "*module*" of the imagery system as conceptualized by Kosslyn then that pattern of behaviour is taken to be evidence for the existence of that component or module in normal individual. So, we conclude that there is a fairly good empirical support for Kosslyn's study of Images. But the point to be borne in mind is that it can easily be surpassed by complementary developments that are evident in the current scenario. We shall choose two leading paradigms of Memory Consolidation and Circadian Rhythm to consolidate our stand as to the scientific credentials of cognitive science. The point is that we gain more by considering these interesting paradigms which are more scientific than conceptual. Bechtel himself has written nearly half a dozen papers on Circadian Rhythms which require a mastery of cognitive science at the Cellular and Molecular level. A more interesting point is that they are opposed to each other and in a way contribute towards the understanding of the scientific credentials of cognitive science. The debate is ongoing and moving onto simulation based science which is already present in these paradigms. Before we look into the future prospects let us now move on to the next Section to reinforce the commingling of at least certain fundamental paradigms with a view to establish that they stand in direct support of the thesis given as constructivism and saving the phenomena of cognitive science.

3.5 THE COMMINGLING OF THE THREE GRAND PARADIGMS IN THE CONTEXT OF 'TRADITION": (TRADITION IS PROXY FOR SCIENTIFIC THEORY?)

Now we must evaluate how, ANTCOG proves its mettle by sounding a fine-grained research project in cognitive science. That is, we have to see how in the final run, the ANTCOG project succeeds to achieve its task by advancing what it calls the semantics of mental representation. We hypothesize that one may locate the project more on the *dynamic side of cognition*. One may even hazard a hypothesis saying that Eckardt's subsidiary project is fundamentally a dynamic project of cognition. Given this understanding, it can meet dynamic model that poses the greatest challenge to static connectionist models. It is therefore necessary to see how the challenges are posed and met in the connectionist models that have become vogue in the cognitive science literature.

The classical symbolic computational theory of mind asserted that mental representations are symbolic structures and mental processes consists in the manipulation of those representations in accordance with symbolic algorithms based on symbolic rules. The dictum that asserted that mind is a sentence-crunching machine represents the high water-mark of this and it is fully articulated in Jerry Fodor's intentional realism. On the other hand there are number-crunching connectionist networks and the challenge is from the dynamicist models.

All these *three* fundamental models are not self-contained. They are equivalent in the sense they all try to explain the same phenomenon. But they are built on the ruins of one another and they pose as rivals. We can hypothesise that Connectionism is on one of the possible range of alternatives and so also, dynamic models *ditto* on connectionist models. But better put, all models are at bottom dynamicist because no model can be built without appropriately introducing time into cognition. And if so, dynamicist model is the best battleground for the viability of any one model. Other models enter into this model and this interpenetration of each into the other can very well be supported. This is one of the results we have demonstrated throughout the thesis. It is this *commingling* that is now to be foisted on the above ANTCOG approach to prove that it is successful at least in the coarse-grained sense. It is coarse-grained because in the light of more recent developments in *cognitive neuroscience* and *Cognitive Systemscience*, the entire project is dwarfed by these scenarios: This is what is being attempted in this section. This is what is called the commingling of these three paradigms in Eckardt's book which is reviewed below:

What we call as the *interpenetration* thesis of the *three* grand paradigms, in Eckardt's view, depicts the way in which the '*symbolist*' and '*imagist/pictorial*' (i.e., connectionist) models provide certain *equivalent* ways of organizing the world. Here cognitive science assumes that the mind is a presentational device, that is, a device that has states or that contains entities that are captured by symbolicist representation and symbolicist computation, and the imagist represented by vector-representation and vector-computation. Both of the paradigms use representation and computation as the key idea. Therefore, the symbolicist cannot be ignored according to Eckardt. But the major point of symbolicist mental content i.e., semantics is given by conceptual semantics. Fodor is, quite content (most of the time, at lest) to use the term mental representation in its more narrow, information-processing sense.

In the previous section, we have explained the imaging method. That is, what it says about Kosslyn in particular, is that he has developed theories finding room for a variety of *sentential* codes together with a *pictorial* mode of representation. Eckardt's view is that there is an *interpenetration* of imaging and symbolicist ideas. The intermediate representations are representations of intermediate positions in the sense; that is, Kosslyn's principle must be interpreted *semantically*. In Eckardt's point of view, the most preferred semantics is *teleosemantics* with all this together with what he says about Lauden. In this context, Eckardt supports his view about the scientific credentials of cognitive science.

In Kosslyn's model of mental imagery, the ordinary human capacity to image in *reconceived* as a narrow information-processing capacity to generate a *quasi-pictorial* matrix representation in a surface buffer on the basis of *two* sorts of representations in long-term memory: *literal encoding* consisting of lists specifying which cells should be filled in the surface matrix and *propositional representations* encoding facts about to be imaged.

This looks like the way we come up with hybrid models (myth in the face of above interpenetration?) as explained in Fodor, Smolensky, Eliasmith, and Tienson, etc. In recent years, however, a much more radical view has gained ground. This view calls into question the commitment to internal representation itself and the suitability of computational theories of cognition as explanations of the behaviour of cognitive agents. Eckardt suggests that teleosemantics is the best solution because this is one of the valuable candidate for a viable semantic theory.

The past-tense formation to illustrate the apparent conflict between the symbolic and connectionist architectural frameworks, works for mechanistic explanation in cognitive science. More importantly, we then make the case that these architectures are *not* polar opposites for which one winner must emerge. After conceptually reframing the symbolic- connectionist debate in this way, we furnish by pointing to *two* research programs that achieve a more integrative approach: *optimality* theory in *linguistics* and statistical learning of rules in *psycholinguistics*.

There are *two* different mechanistic approaches that are vogue in the last twenty years.

1. According to the *first* approach, the mechanistic explanation is kept close to the characterization of the phenomenon by posting two different mechanisms. This is the symbol processing approach. According to this, the language production system performs *two* different operations depending upon the *regular* and *irregular* verbs.

    a) for *regular* verbs – apply V → V + ed (e.g: need → needed)

    b) for *irregular* verbs – get the appropriate past-tense form from the mental lexicon: i.e., we get the lexical entry for the stem which specifies the past-tense form (give→gave).

In the above (a) represents a rule application and (b) represents a lexical look up.

2. The *second* approach is to explain past-tense formation by means of a *single mechanism* suited at a finer-grained level that is sometimes called sub-symbolic in the way Smolensky has distinguished. The blended account is given, as given in network or architectural model provides an alternative explanation. As noted below, firstly (a) it uses human symbolic capabilities for past-tense formation (b) it also explains additional phenomena like graceful degradation, constraint satisfaction and learning procedures. Such connectionist networks do not follow any rules. Since these representations are subsymbolic, they obviously make use of the symbolic representation.

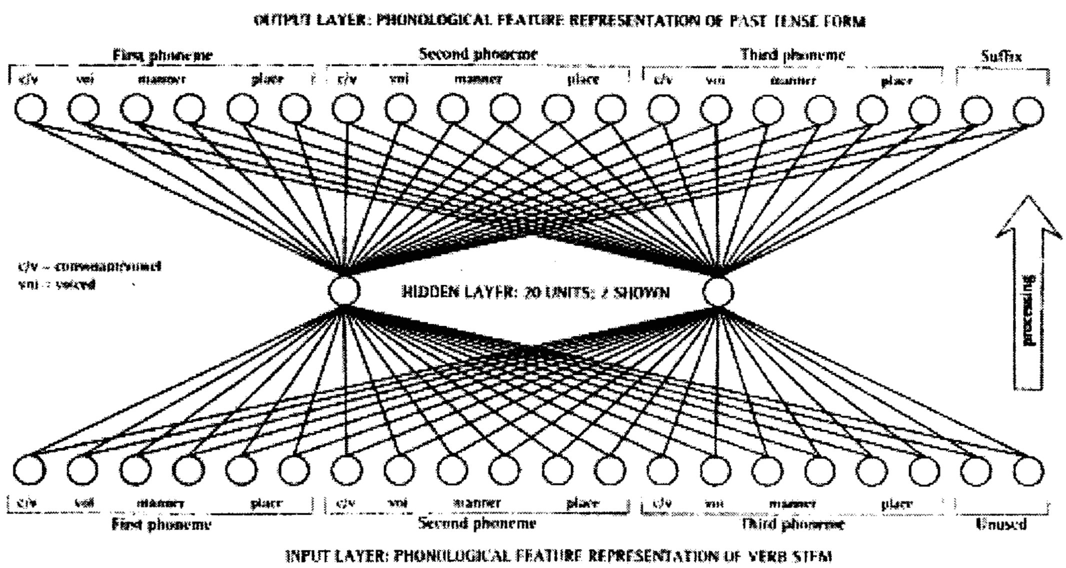


Figure 3.3: Plunkett and Marchman's feedforward network for past-tense formation. Each artificial verb stem gets a subsymbolic encoding on the input units, based on the phonological features of each of its phonemes[39]. Propagation of activation across weighted connections (Shown for two of the 20 hidden layer units) transforms the input pattern into a past-tense form on the out put units.

The *first* connectionist model of past-tense formation as given by (Rumelhart and McClelland, 1986a) performed impressively, but it has certain limitations. It explored some intriguing ideas about representation such as course-coding on context-dependent units[40]. This is superseded by a 'sleeker model' which uses a familiar network design.

As illustrated in figure 3.3, Plankett and Marchman's feedforward network represents verb stems sub-symbolically as activation patterns across the binary units of its input layer[41]. It propagates activation across weighted connections first from the input to hidden layer and then from the hidden to output layer. Each unit in one layer is connected to each unit in the next layer, as illustrated for two of the hidden units, and every such connection has its own weight as a result of repeated adaptive adjustments during learning (via back-propagation). This network contain the following key definitions:

(a) An *activation function*, typically is nonlinear, determines how the various weighted activations coming into a unit will be combined to determine its own activation. In this way, the network transforms the input representations twice as noted below: once for each pair of layers- to arrive at a sub-symbolic representation of the past-tense form on the output layer.

(b) Although all three layers offer sub-symbolic representations, it is the *encoding* scheme on the input layer that most readily illustrates this concept. The verb stems, which would be treated as *morphemes* by a rule appending 'ed' in a symbolic account, are replaced here with the lower-level encoding in terms of the distinctive features of each constituent phoneme in 'three-phoneme stems'.

(c) Moreover, as the pattern gets transformed on the hidden and output layers, it is *no longer binary* but rather a vector of 20 real numbers, making the mapping of stem to past tense a statistical tendency.

What follows from the above is that connectionist networks are mechanisms- they have organized *parts* and *operations*-but the homogeneity, fine grain, and statistical functioning of their components make them quite distinct from traditional symbolic mechanisms[42].

Now, Bechtel attempt to reframe the above debate by calling attention to the fact that symbolic and connectionist approaches are treated in exchange like this as *competitors*, but there are at least two ways of reframing the discussion that make it less contentious and perhaps more satisfactory.

One way is to consider that connectionist networks behaves in way that can be closely approximated by symbolic models. Thus the connectionist has to come to turns with the symbolic model. Identifying this forming a new relationship as the ultimate new alliance, Bechtel offers *two* comments.

(1) Symbolic Mechanistic View: One way of construing this is to appreciate *linguistic rules* as well suited to characterizing the phenomenon of past-tense formation, but to prefer '*feed forward networks*' as a plausible mechanism for producing the phenomenon

(2) Both Mechanistic: Alternatively, both architectures might be viewed as suitable for mechanistic accounts, but at different levels–one, *coarse–grained* and *symbolic*, the other *fine-grained* and *statistical.*

Looking beyond the Chomskian–connectionist axis of the past-tense debate, an alternative linguistic theory exists that has been very amenable to-even inspired by the idea that symbolic and sub-symbolic approaches, each has a role to play in an '*integrated* account'.

A team of cognitive scientists whose integrative inclinations has operated on different commitments. They have offered provocative evidence that the language acquisition mechanism is highly sensitive to distributional statistics in the available language input, but seek to reconcile this with their view that the product of learning is akin to the roles and representations of linguistic theory[43]. That is, a statistical learning mechanism is credited with somehow producing a non-statistical mental grammar. This brings them into disagreement with symbolic theorists on one side, who deny that the learning mechanism operates statistically and with connectionists on the other side, who deny that the product of learning is non-statistical[44].

Attempts like these to *integrate* connectionist or other statistical approaches with symbolic ones offer promising alternatives to polarization. Looking at the rise of connectionism in the early 1980s, it is seen to involve the confluence of a number of research streams. Among those are mathematical models, information processing models, artificial neural networks, and symbolic approaches to the representation of knowledge-especially semantic networks but extending even to the presumed foe, generative grammar.

Most important here is that Dynamical Systems Theory (DST) took shape in a quirky corner of mathematical modelling focused on non-linear physical state changes. It found a place in cognitive science when combined with other influences, such as an emphasis on embodiment, and some of the bends in DST's path even intersected with connectionism when it was realized that such concepts as attractor states shed light on interactive networks. Another example is that information processing models, *neuroimaging* and other research streams in the cognitive and neural sciences came together in the 1990s, making cognitive neuroscience a fast moving field both on its own and within cognitive science, as well. The idea that cognition is distributed not only within a single mind, but also on a social scale, gave rise to socially distributed cognition as a distinct approach in cognitive science[45] . Thus an exclusive focus on polar points of contention would give a very distorted picture of cognitive science.

The above points are captured by the following three steps.

1. Master the past-tense from a list of a few *irregular* verbs eg: ran-ran;
2. Over generalize the regular past-tense to some irregular verbs, which yields over regularized account (eg: run-runned);
3. Eventually re-exhibit the correct form.

The above steps are exactly symbiotic to the back propagation of error in PDP.

Finally, Eckardt's view of cognitive science does currently impose certain constraints on that theorizing. Eckardt suggests that the tradition i.e, the scientific credentials of the tradition is used so as to avoid interpenetration. For this purpose, she develops a particular species of semantics (teleosemantics). But Eckardt does not discuss the scientific tradition within *teleosemantics*, so as to give an answer to the question to what extent we can suppose the scientific credentials of cognitive science. She explains only as to how far our scientific tradition includes *teleosemantics*. So according to Eckardt, the most valuable and preferred theory is *semantic theory*. In a way the thesis about the commingling proves that ANTCOG can after all be defended but this as much as what is evidenced in recent developments of cognitive science.

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Chapter 4

BECHTEL'S MECHANISTIC EXPLANATION AS A FORM OF REDUCTIONISM: FIRST MODEL FROM COGNITIVE NEUROSCIENCE

'There might be mechanism that operate only sporadically (not regularly), or even just once'

(JIM BOGEN)

BECHTEL'S MECHANISTIC EXPLANATION AS A FORM OF REDUCTIONISM: FIRST MODEL FROM COGNITIVE NEUROSCIENCE

4.1 MECHANISTIC EXPLANATION: From Strong Reduction to Weak Reduction:

Squire and Kandel's signpost for memory consolidation research reads: "memory promises to be the first mental faculty to be understandable in a language that makes a *bridge* from *molecules to mind*, that is, from molecules to cells, to brain systems, and to behavior"[1]. At least *three* paradigms center around this exemplar. In this chapter, as part of the last phase of understanding the scientific credentials of cognitive science, we shall review the *two* major paradigms of Memory Consolidation Research which provides the gist for *indirect* method (Churchland). We shall criticize and review the *two* key paradigms suggested by the Memory Consolidation Research: a model from Cognitive Neuroscience (P_1) and System Science (P_2). P_1 is a paradigm in Cognitive Neuroscience as given by Bechtel and the New Mechanistic Group, and P_2 is identifiable with Bickle in the Ruthless Reductionist model supported by experimental work. We will be able to demonstrate Bechtel's ambivalence towards 'reductionism' finally accepting reductionism in a *weak* raise in this chapter, and counterpose the anti-reductionist from an Interventionalist - Manupulationist view of Causation of Craver (P_3) in this chapter. Similarly, in the subsequent Chapter, we will review the Ruthless New Wave Reductionism and counterpose this with Bechtel's own *counter-example* as seen in his passage towards research in Circadian Rhythm. We start with unfolding the story of new mechanical philosophy of science.

Earlier, (scientific revolution of the 17th and 18th centuries), *mechanical* philosophies were first advanced by Aristotle (distinguishes between theory, practice, production), Galileo, Descartes, Boyle, and Newton among others. Descartes, (one of the foremost advocates of the new mechanical science of the seventeenth century) sought to replace the ossified Aristotelian framework by explaining all phenomena of the natural world in terms of mechanical processes and even extended, mechanistic explanation far into what is now the domain of psychology, explaining mechanically all animal behavior, and all human behavior that was comparable to that of animals. Descartes' *general* proposal is that natural systems including bodies and nervous system are mechanical systems. His *specific* proposal is, following Harvey's account of the circulation of blood, to reduce blood to 'corpuscles of the blood' (Mechanistic Components).

Within the past decade, a number of philosophers (Bechtel and Richardson, 1993, Glennan, 1996; Mechamer, Darden, and Craver, 2000) extended Descartes' idea of mechanism this into a new mechanistic philosophy of science even while rejecting his dualism. We review the definitions and set the 'semantic task' it is supposed to perform.

Definition (1A: decomposition into parts): Bechtel's 'working characterization of a mechanism': Taking mechanism as an enduring system that regularly performs some activity, Bechtel defines: "A mechanism is made up of component parts, each of which performs its own operation which are then coordinated so as to accomplish the activity of the overall organism". Bechtel sites the following as examples: Synthesizing proteins, circulating blood, visually identifying objects and encoding episodic memories. Bechtel adds a corollary: if the mechanism breaks and is not able to perform the activity, one may still identify it as a mechanism in terms of activity it was designed or evolved to perform.

Definition (1B: parts and interactions): Bechtel and Richardson characterize mechanistic explanation as accounting "for the behaviour of a system in terms of the functions performed by the *parts* and *interactions* of these parts....[2].A mechanistic explanation identifies these parts and their organization showing how the behaviour of the machine (system) is a consequence of the parts of their organization".

Definition (2 entities and activities) is proposed by Peter Mechamer, Lindley Darden, and Carl F Craver-namely, that mechanisms are "*entities* and *activities* organized such that they are productive of regular changes from start or set-up conditions to finish or termination conditions". They quip: "There are no activities without entities and entities do not do anything without activities"[3]. A mechanism's 'spatiotemporal' organization is also, in part, what makes a composite system '*hierarchical*'. It has sometimes proven fruitful to conceive of organization in terms of levels, such that investigation and explanation of a mechanisms activity is understood as taking place at a higher level than an investigation or explanation of the *constituency* that composes it. Craver is a reluctant to adopt the above characterization, because it puts a premium on *set up* and *finish* conditions and moved on to a different strategy.

A *third* definition (which are constitutive of parts) is still available: complex systems composed of interacting parts that produce the behavior of the *whole* according to direct laws.

While reviewing the features of Bechtel, we shall locate the semantic task:

It accepts mechanism as well as the semantic, logical, grammatical and inferential concerns as thoroughly *reductionistic*: it's appeal to increasingly finer-grain component operations and parts in explaining the activity of a mechanism. But in another sense, a mechanistic explanation is *non-reductionistic*. A mechanistic explanation is both *reductionism* as well as *non-reductionism*. It performs a semantic task. Explanation at a lower level do not replace, sequester, or exclusively preside over the refinement of higher-level explanations, because mechanisms are hierarchical, multi-level structures that involve real and different functions being performed by the whole composite system and by its component parts[4], rather than serving to reduce one level to another mechanism through bridge levels.

(a) When mechanistic explanations appeal to the components of mechanisms to explain their behavior, they are *clearly reductionistic* (at decomposition level). Moreover, the process of decomposition is *iterative*; the operation of a component part can itself be explained by another round of decomposition (local).

decomposition	→ 1 level :	Working parts of the mechanism	Level of explanation (1)
decomposition	→ 2 level :	Working parts will be mechanism having their own parts	Level of explanation (2)
↓		↓	
So, the process is recursive		So, the process is *not* recursive	

(So, intervention at level is not the some as intervention at level 2 and this works against Bickle's model as it will be shown later on)

(b) The working parts within these working parts are *not* themselves working parts of the *first* mechanism, as they do not *directly* contribute to the phenomenon for which the *first* mechanism is responsible.

(c) As an explanation, it does not fit into the standard deductive nomological account of explanation, (IC+BL → *Explanandum*).

Bechtel might agree to reformulate his model along the following lines.

1. Decomposition clause: Initial micro-level conditions.
2. Integration Clause : Bridge laws are non-linear (heuristic?).
3. Carnapian Clause : Limiting Assumptions and Boundary Conditions.
4. Reifying Clause : Alternative tasks in modal space.
5. Therefore, explanation at the macro-level.

The idea of *Boundary Conditions* is unpacked in a much more interesting way as *maintain-break-bridge* (i.e., reify alternatives given as 4 above) in the context of linguistics and/psychology. So also, it is between neurophysiology and molecular biology.

(d) Mechanistic explanation is *reductionistic* insofar as it emphasizes the decomposition of system into parts and operations. But it equally emphasizes that the parts and operations must be appropriately organized and the mechanism as a whole situated in an appropriate environment. It therefore rejects the claim, often associated with reductionists working in the D-N Model, that resources at the lower level are adequate to achieve a complete account of the phenomenon of interest (Bechtel tries to use this as a leverage against Bickle).

(e) At a more fundamental level, Bechtel's merit consists in his attempt to reconcile the following trends (especially in his Cardinal Merciar Lectures):

[A] Naturalism and Mechanism (adopts *a posteriori* method)

[B] Naturalism and Reductionism (*weakens* reductionism)

[C] Naturalism and Epiphenomenalism (takes mind as emergent)

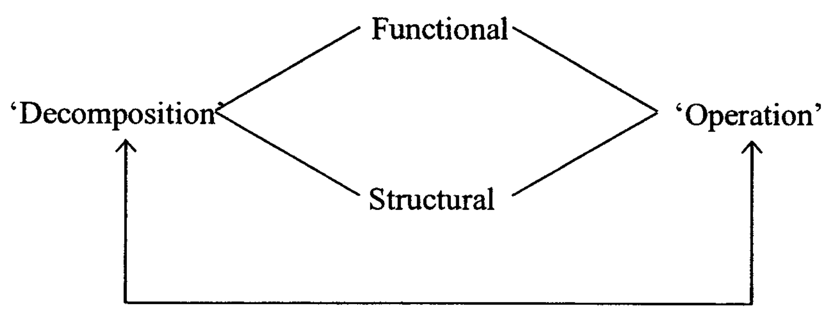
[D] Naturalism and Phenomenalism (grants autonomy to psychology)

[A] + [B] + [C] + [D] = yield some form of <u>constructivism</u>

(f) In general the two-way investigation can identify the component of a mechanism: they can specify their structures and they can specify what they do. For a given mechanism at a given time, these modes of decomposition may be easier to accomplish than the other. At times, researchers may have various ways of differentiating the components of a system structurally without yet knowing what they do.

(a)-(f) yields the Bechtel's Model of Mechanistic reduction as schematized below:

MR (weak) = *df.* {Parts: [Decomposition (*structural* –componential and *functional* – computational → Localization)] → wholes: integration }



The 'Link' is called 'localization'

Operation of the component parts of the mechanism are determined *not* just by their internal constitution (their sub-parts, the operation of these sub-parts and the way they are organized) *but also* by *both* the condition arising within the mechanism as a result of the operation of their components and external factors impinging on the mechanisms.

The *boundaries* of the parts *partially isolate* it from other parts, but do not completely encapsulate it in Fodor's sense. Insofar as it focuses exclusively on a sub-component (or a sub-sub-component) and relates it *directly* to behaviour, it *risks* ignoring the other components of the mechanism and the organization which enables the components to work together to produce the phenomenon of interest.

So long as he uses *three* concepts namely decomposition, localization and integration that are used as heuristics (means: to guide to further enquiry). In explaining any mechanistically produced phenomenon, it adopts the *fallible*, *explanatory heuristics* (as opposed to algorithms) of localization and decomposition. *Localization* refers to mapping the component operation's onto components parts. *Decomposition* refers to taking apart or disintegrating the mechanism into either component parts (*structural* decomposition) or component operations (*functional* decomposition). These two forms of decomposition typically require different experimental tools and techniques, and successes in decompositions component parts and operations often occur on different timescales in different sciences.

Within Bechtel, we come across the following phases:

[A] Mechanism as Reductionist phase:

a) A mechanism is a structure performing function in virtue of its component parts and component operation and their organization[5].

b) The orchestrated functioning of the mechanism is responsible for one or more phenomena.

[B] Mechanism as Interactionist-Constructivist phase:

A mechanism involves decomposition and recomposition (conceptually reassembling the parts *in lieu of, the earlier* unit *a la*

Carnap) and operations into organized arrangement with a subtask that includes determining how the mechanism interacts with environment in which it is situated.

[C] A Dynamic Mechanistic Explanatory Phase:

Modified: b) the orchestrated function of mechanism, manifested in patterns of *change over time* in properties of its parts and operation, is responsible for one or more phenomena[6].

Besides the Synergic Clause attempts to split the differences between the Linguistic/Imagistic models; propositions and figures are considered as equivalent; by advancing a response to all the three models.

Lastly, HIT, which is basically advanced as explanation of identity, uses the 'Heuristic' Identity Theory. One peculiar trait is that it admits of rival or alternative systems within a broad range of theories.

Like Craver, the term 'model' is introduced to capture mechanism as proving one model among others.

It is also proposed to extend to *ethics* (question of Freewill); some of the above features are not readily reconcilable with each other, unless we bring into the view an interface of cognitive and social science.

Mechanism is characterized as a putative D-N model. But Bechtel wants it to be characterized as *reduction* + *interactionist* + *constructionist.*

Bechtel's model is *interactionist* in a specific sense in which it takes into consideration the way on *organism interacts with the environment.* In doing so, he does not fully subscribe to the '*exogeneous*' (externally produced) factor that influences the organism. On the other hand, Bechtel never abandons the '*endogeneous*' (internally produced) factor which are responses to the variety of external influences. This is the way he arrives at point where he can reconcile his mechanistic account with phenomenalism. This involves preservation of the 'autonomy' of the individual.

Again, Bechtel's model is *constructionist* in the specific sense in which it 'recomposes' what it 'decomposes'[7]. Together with other features it is perfectly in tune with a dynamic model which needs the key idea of 'representation' and 'computation'. Bechtel refuses to subscribe to the general dynamicist plea for *rejecting* representation (Van Gelder), or favouring a *quasi-representation* in the way Andy Clark recommends.

Thus Bechtel's dynamic mechanistic explanation is well poised to all the *three* fundamental models of cognitive science. For Bechtel, mechanical model is the *implicans* of all the *three* models, *plus* the self-organization as envisaged by Grush (emulator models). Thus in a sense, constructivism *saves* the other model from falling prey to controversies.

While Bickle is intervening at the molecular level, for Bechtel it is to intervene into parts and parts of *parts. As Carver admits that the notion of level is a vexed one* (Craver). The working parts within these working parts are *not* themselves working parts of the *first* mechanism as they do not *directly* constitute to the phenomenon for which the first mechanism is responsible.

We insist that the mechanistic explanation is 'half-heartedly reductionistic', that is up to a point, and hence formal (a sort of statement view) and the mosaic is to be counter- posed to the case for the side of non-formal (non-statement explanation). A weakening of the orthodox view, according to Craver, leads to the 'semantic' or 'interpretative' systems. For Craver, mechanism is a form of non-formal or 'mosaic' explanation involving 'levels'. The *mosaic* explanation is *modally mosaic* in that it includes the notion of many possible worlds. We shall see that the notion of levels is also a 'vexed one' according to critics.

4.2 FROM MECHANISM AS REDUCTIONISM TOWARDS MECHANISM AS CONSTRUCTIVISM

We have seen that mechanism is a structure performing a function in virtue of its component parts, component operations, and their organization. The orchestrated functioning of the mechanism is responsible for one or more phenomena[8]. With the advent of cognitive neuroscience, mechanistic explanations of mental phenomena have increasingly included identification of the brain parts responsible for the component operations. Mechanistic explanation requires researchers to determine how the various component parts are organized such that the operations are coordinated appropriately to realize the overall phenomenon. When mechanistic explanations appeal to the components of mechanism to explain their behaviour, they are clearly *reductionistic*. Moreover, when the process of decomposition is iterative, the operation of a component part can itself be explained by another round of decomposition and localization. The conception of mechanism has its roots in the machines the humans build.

Although mechanistic explanation is *reductive* insofar as it appeals to the component parts and operations within a mechanism to explain the behavior of the mechanism, the *reductive aspect alone* is insufficient to explain the behavior of the mechanism. The parts of a mechanism behave in a particular way because of how they are organized in the mechanism. Finally, mechanistic explanation is *reductionistic* insofar as it appeals to the components of a mechanism to explain its activity.

But insofar as the phenomenon generated by a medium depends upon the organization of the parts and the conditions impinging upon the mechanistic form without, mechanistic explanation also recognizes the *autonomy* of higher-level investigations. The contribution of organization in creating mechanisms that do things their parts cannot do undergirds the need for scientist to discover the particular forms of organization realized in a mechanism. At the same time, mechanistic explanation also recognizes the value of reductionistic investigations into how the components perform their operations. Higher-level inquiries complement each other, and often provide *heuristic* guidance to each other.

[1] Mechanistic explanation is incomplete (as originally it was conceived as mechanical philosophy);

[2] As Mechanistic explanation, it has the *four* following features: *First*, mechanisms are characterized in terms of the activities they perform. *Second*, explaining an activity performed in a given context requires decomposing that activity into component operations and localizing them- that is, linking them to component parts of the system. *Third*, critical to the explanation is determining the organization within the system that allows the component operations to be coordinated appropriately to produce the overall activity. *Fourth*, the operation of a component can itself be treated as an activity to be explained by another round of decomposition and localization at a lower level; repeatedly carrying out this process generates a cascade of finer and finer-grained mechanistic accounts. The inadequacy is seen in the dynamic interaction with the environment;

[3] Central to the operation of the mechanism is the organization; the difficulties pertain to the non-linear organization;

[4] Such difficulties are also similar to the way certain polarizing positions work. (i) Nature vs Nurture (ii) Rationalism vs Empiricism

(a) Bechtel has already connected linguistic/imagistic (e.g., past tense model)

(b) He is ready to agree to connect connectionism with innatism.

[5] So the solution requires a *third contender* (e.g., Elman's Network) → Bechtel raises a question, and answers it by saying that they can

be *reconciled* with 'third contender' called *interactionism* and *constructivism*;

[6] All the three constraints can now be met. The *first* constraint is that connectionist models are instruments of empiricism that cannot represent innate knowledge, *second* constraint is that it involves the timing the developmental events (Elman et al.)[9] and the *third* class of constraints is the one most relevant to classic, polar nativism and least explored in connectionist modelling: innate representations (i.e., innate knowledge or content);

[7] How to make it work keeping this end in view is not very clear except by making an assumption that *constructivism* is an *overarching* hypothesis.

The strategy of explaining phenomena by subsuming them under laws as formalized in the deductive-nomological model of explanation. The framework renders explanation a linguistic activity- one explains a phenomenon by deriving a statement describing that phenomenon from a statement of one or more laws and statements identifying initial conditions. In this construal, it is commonly referred to as the deductive-nomological (D-N) model, (1) logic becomes the glue or cement (or gum) of explanation and (2) laws become the primary *explanans*.

In Covering Law Model: there are bridge-laws (connecting two predicates from two disciplines). In ME, there are no bridge laws. In the

Covering Law framework, explanation is understood as a linguistic activity involving the derivation of a sentence describing the phenomenon from a statement of laws. The mechanistic framework does not require this linguistic turn (no bridge laws). And Diagrams (Churchland's *standard* picture that gives the neurobiological basis) becomes parts of the explanation.

Another feature of mechanistic explanation is that, insofar as it emphasizes the important contributions parts of a mechanism make to the operation of a mechanism, a mechanistic analysis inherently looks to lower levels of organization. The account of the mechanism straddles the two levels of organization, showing how the mechanism performs its activity as a result of the process performed in the organized context by the components. And the mechanism carries out this activity as a result of being itself situated in a particular context, perhaps as a component of a yet higher-level mechanism.

It is necessary to juxtapose the view of philosophy of *mechanistic science*, as it is understood in contemporary neuroscience, especially with the view advanced by *others*. On Craver's view, mechanistic explanation is to be understood as having 'formal' and 'informal' (semantics in a sense) equivalents as schematized below:

$M = [(\text{Entities} + \text{Activities}) \rightarrow \text{Behaviour}]$

which has a linguistic (non-formal or semantic) equivalent such as

(Names + Verbs)

↓

actually (excitatory/inhibitory)

specially (relative location, sizes, shapes)

temporally (order, rates, duration and frequencies)

hierarchically.

And then, the schemata: (S) x + ϕ-ing (lower level)

(action potential)

ψs + s (higher level)

(actually)

σ of (voltage gated Na^+)

They are collections of entities and activities organized in the production of regular changes from '*start*' or *set-up* conditions to '*finish*' or 'termination conditions'[10]. The entities in neuroscience include things like neurons, neurotransmitters, brain regions of mice. The activities are, the various doing in which these entities engage: neurons fire, neurotransmitters bind to receptors, brain regions process, and mice navigate mazes. Activities are the things that entities do; they are productive components of a mechanism, and they constitute the stages of mechanisms.

Mechanisms are characterized by both temporal and spatial organization. With respect to temporal organization, a mechanism, typically, has stages, that are ordered and that have characteristic roles and durations. Our primary aim is to examine the usefulness of the mechanism approach to gain an understanding of explanation in cognitive neuroscience.

Mechanistic descriptions vary not only with respect to degree of completeness or specificity; they can also vary with respect to their "vertical" scope. To capture the idea that a mechanism can consist of other mechanisms, Craver has developed the notion of a mechanism *hierarchy*. He will refer to this activity or behavior of the mechanism as a whole as the role to be explained by the description of the mechanism. The role is the activity at the phenomenon (top) and its mechanism (bottom) of Figure 4.1, below it are the entities and activities composing the mechanism for that role.

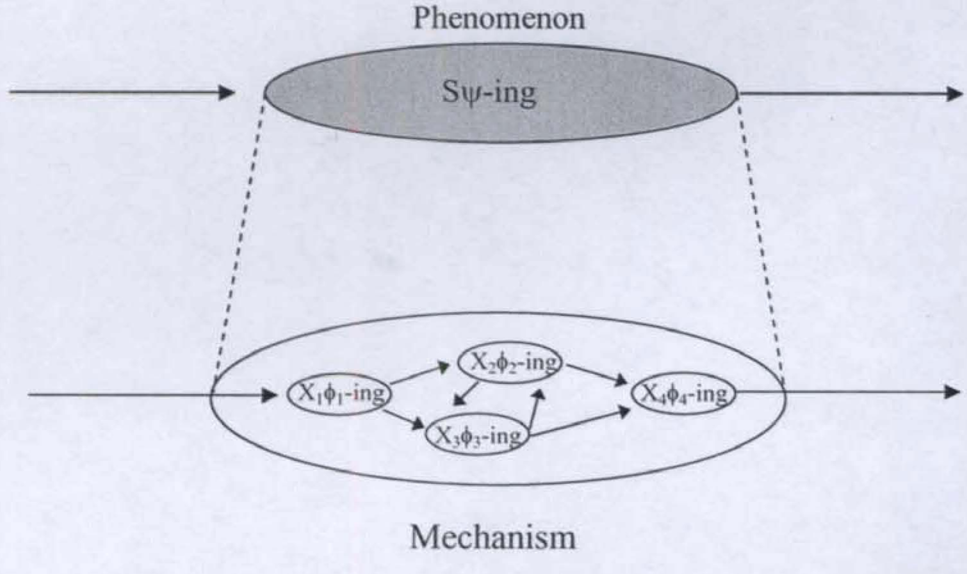


Figure 4.1: ***A Phenomenon (Explanandum) and its Mechanism (Explanans)***

Mechanistic descriptions can be used for various explanatory purposes. Craver distinguishes *three* kinds of mechanistic explanations: etiological, constitutive, and contextual. Only the second-constitutive is relevant for our purposes. The *explanandum* in a constitutive explanation is the activity (or "phenomenon") exhibited by a mechanism. A *constitutive mechanistic explanation* of how Sϕs makes reference to the mechanism that constitutes S and its ϕ-ing[11]. It (S) exhibits an activity of ϕ-ing *Explanandum* (constitutive explanation): activity taken by a *whole*.

Explanans: activity in a lower-level activity and their interrelation (parts).

So integration is to be alone for completing the process of explanation. Mechanisms are entities and activities organized such that they exhibit the *explanandum* phenomenon. The components of this most abstract sketch of a mechanism are illustrated in Figure *4.1.* At the top is the phenomenon to be explained. For economy, Craver often refers to the phenomenon, the property or behavior explained by the mechanism, as ψ (pronounced 'psi', as in psychological), and to use S (English pronunciation) to refer to the mechanism as a whole. Beneath S's ψ-ing are represented the entities (circles) and activities (arrows) that are organized together in the mechanism. For economy, he uses X (English pronunciation) to describe the component entities in the mechanism and ϕ (pronounced 'phi', as in physiological) to refer to the component activities in the mechanism. S's ψ-ing is explained by the organization of entities $\{X_1, X_2 \ldots.., X_m\}$ and activities $\{\phi_1, \phi_2, \ldots., \phi_n\}$.

The causal explanation is characterized as: the *interventionist-manipulationist-contrastive-counterfactualist-invariance account of causation* irrespective of its application to memory consolidation or Circadian Rhythms[12].

For Bechtel, on the contrary, mechanistic approaches also reconfigure a number of issues in the philosophy of psychology beyond that of explanation. Cory Wright and Bechtel have considered *two* questions: the question of reductionism, and the question of scientific discoveries[13]. Mechanistic explanation is *partially* reductionistic, in the sense that it appeals to lower-level parts and their operations in explaining why a mechanism behaves as it does; but mechanistic explanation is *not reductionistic* in the sense of deriving higher-level theories from lower-level ones, nor in the sense of supplanting explanations of causal processes at higher-levels, where the mechanism as a whole engages other entities in its environment. Causal processes at each level are different, and the ultimate result of a mechanistic account is an interfield theory that bridge levels. As to the question of scientific discoveries, mechanistic approaches are particularly apt for analyzing them, despite a tradition in philosophy of science that limits philosophy to characterizing justification of already discovered laws and disallows any prospect of contributing to the understanding of discovery. In particular, philosophers are engaged in articulating *heuristics* such as decomposition and localization, identifying what different investigatory techniques contribute to discovering components and operations, and understanding how scientists have discovered different modes of organization found in mechanisms, characterized their significance, and articulated relations between phenomena at different levels of organization.

In psychology and the cognitive sciences, as in biology, numerous investigators have sought a middle ground between the polarized positions of *nativism* and *empiricism.* Almost invariably, such positions are rejected by advocates of nativism as essentially empiricist, but distinctive and powerful ideas have emerged from such efforts. A prime example is Piaget's account of development. His position is sometimes called '*interactionism*' because he emphasized the interaction of '*nature*' and '*nurture*' during development called *interactionism* because he emphasized the interaction of *nature* and *nurture* during development, and is also known as 'constructivism' because he viewed mental structures as being constructed and becoming more complex in the course of children's active engagement with their world. It is Piaget's *constructivism* that is the key idea here, because without a way to build more complex structures from simpler structures, the interaction between nature and nurture will not yield interesting outcomes.

The metaphor of *constructivism* points to an important element in the challenge of establishing a *third* option. It emphasizes putting together components to build something that the components alone cannot do. It is worth nothing that this is a general features of mechanisms-mechanisms perform their tasks as a result of the coordinated operation of their components and a whole mechanism does something that the components individually cannot do. In mechanisms built by engineers, what a given engineer contributes is a new means of organizing components so as to accomplish a task that previous mechanisms could not perform. For constructivism to meet the challenge set by nativism and constitute a viable third way that isn't simply a version of empiricism, a procedure must be identified for constructing something that is more powerful than the components out of which it was constructed. Recent work in chemistry and biology moves in the direction of taking systems as having the property of self-organization (otherwise called auto-catalytic and auto-poietic - e.g., Kreb Cycle). Let us carry the semantic task further.

4.3 CARDINAL FEATURES: Decomposition + Localization + Integration (Recomposition) ⇒ Unity of Science

This section aims to unfold the underlying nuances of the *three* major concepts that constitute the dynamic mechanical explanation. We will discuss how.

The mechanistic explanation consists of three key ideas i.e., (1) Decomposition, (2) Localization and (3) Integration.

Decomposition into entities and activities organized in the performance of a higher-level role. The activities and properties of the entities in the lower-level mechanism may themselves be subject to mechanistic decomposition. In such cases, each working part of the mechanistic decomposition adds another level to what may become a multilevel mechanism. It is typically possible to distinguish levels by the different entities and activities that populate them and, as we will see, by the different techniques that are used to investigate those entities and activities.

Consider a sketch of the mechanisms of *spatial* memory. This sketch has roughly for distinct mechanistic levels.

At the *top* is a *behavioral-organic* level, having to do with, for example, the various types of learning and memory, conditions under which different memories may be stored or retrieved, and the conditions under which storage or retrieval are likely to improve or fail.

The *second* level is a *computational-hippocampal* level, having to do roughly with the role of the hippocampus in the mechanisms of memory, its cytological, and structural features, its pathology, it's connectively with other brain regions, and the computational or processing stages it is thought to perform. Techniques for investigating phenomena at this level include ablation, pathological anatomy, multicellular recording, EEG, PET, MRI, as well as various computational approaches.

The *third* level is the *electrical-synaptic* level, this level includes such entities as neurons, synapses, and dendritic spines and such activities as vesicular release and the generation and propagation of action potential. Phenomena at this level are typically investigated with pharmacological and electrophysiological techniques. Bottoming out this hierarchy are entities and activities at a molecular-kinetic level. At this level, entities like a NMDA and AMPA receptors, glutamate, Ca^{2+} ions, and Mg^{2+} ions engage in activities like attracting and repelling, binding and breaking, phosphorylating, and hydrolyzing. These components are investigated with a host of biochemical, and increasingly, molecular biological techniques.

Localization: As controversial as it often is to establish, a proposal or locus of control for a function is generally only a preliminary step forward in explaining it. A simple identification of a function with a structure does not really explain the function since it provides no account how the function is accomplished and how they change at the electrical impulses in the membrane of the cell. Localization is understood in two specific ways one is *simple* and other is *complex*.

Simple or *direct* localization is by itself no solution, though it can serve as a preliminary stage bridging toward a more adequate account. When additional constraints are imposed, whether empirical or theoretical, they can serve simultaneously to vindicate the initial localization and to develop it into a full-blooded mechanistic explanation.

What we call *complex localization* is localization multiply *constrained*, that is, it proposes a set of components that contribute differentially to system function, and it incorporates independent constraints on allowable mechanisms from lower levels.

Simple localization differentiate task performed by a system, localizing each in a structural or functional component. Complex localization requires a decomposition of systematic tasks into *subtasks*, localizing each of these in a distinct component. Showing how systematic functions are, or at least could be, a consequence of those subtasks, is an important element in a fully mechanistic explanation. As we shall see, the routes to complex localization are varied. Frequently, a program of research begins with direct localization, which then develops into a more complex localization in which functional decomposition of tasks assumes a more control role[14].

According to Bechtel, philosophy of neuroscience opens up the following *four* facts[15]. The *first* is the methodological *bind.* The methodological bind is concerned with the way neurological explanation can take the form of the celebrated D-N model of explanation if only to explain the neurological basis of what is called 'subjectivity'. The *second* is the way it casts fresh light on reduction, not the *ersatz* reduction but the reduction that takes us in the direction of integrated explanation. The *third* is the integrated explanation of hitherto unexplainable phenomena including subjectivity. And the *fourth* is the new way of understanding modularity in terms of *revisionary* notions of representations and computations (Pete Mandik).

A rough sketch of Bechtel's modification of the early (A, B, C) formula is necessary to understand the *constructivistic* turn (D (Circadian Mechanism));

[D]M = *df.* Decomposition + Recomposition + Situating Mechanism (Bechtel)

[E]M = *df.* Decomposition+Recomposition+ Feedback Mechanism

Those amendments are proposed in the context of his 'turn' to Circadian Rhythms:-

[F] M = *df.* Circadian Rhythms + Systems (Positive + Negative Feedback)

which is supposed to combine machanism with dynamic modelling so as to yield a *new* type of Reduction.

i.e., (1) Reduction + (2) System Approach, where (1) and (2) are considered as *complementary*. The major advantage of including 'feedback loops' is to *contextualise* the working components in the context of the whole organism.

It transpires therefore,

CR = Cells in the *Central* Oscillator → Integrate→ Entrainment systems (called *Zeitgebers*: environmental cues like light, exercise, food etc) → *Peripheral* Oscillators.

No doubt, the above sketch takes us beyond the memory consolidation paradigm towards a 'new exemplar' of Circadian Rhythm which will be seen in the counterexample proposed to Bickle's model of New Wave Reductionism. So it will get its feet later on. But for the present, let us note that the *three* fundamental models receive equal attention from Bechtel:

a) Symbolic Representation + Symbolic Computation
   (vehicle) + (content)
   ↓ ↓
   syntax + semantics
b) Vector Representation + Vector Computation

c) Dynamic Representation + Dynamic Computation

Controller + Plant (as in Watt Governor)

Controls

as in Neural Engineering Format of Eliasmith and Anderson

Thus what is called the 'dynamic mechanical explanation' is poised to counterpose Craver's own reading of *Circadian Rhythm* that is based on his 'interventionist-manipulationist account of causal invariance'. As expected Craver's critique is pointing its finger at the way temporal sequence of light and CR is brought into relation with causal sequence. Since this is not plausible, Bechtel is unlikely to succeed to reach a full-blooded philosophy of mechanical science. The contention stands as a challenge but not to the scientific leanings of cognitive neuroscience. It invites a more interesting dimension of understanding temporal sequence and causal sequence (we shall review the broad features of Craver in Section *1.5* below.)

An important consequence is that the D-N model has been suitably extended. It need not be homogeneous type but a heterogeneous type which explores the 'broader conditions' of one discipline with another (neurobiology with psychology). The 'another' here means 'higher-level theory' which should explain the 'lower-level theory'.

Decomposition and localization inherently involve fractionating a system into components. In cognitive and neuroscience inquires, these components are often referred to as *modules*, the most prominent examples of a proposed module in the cognitive domain is that of a module for language. The essential questions are about the nature and static of modules. Fodorian modules have the following traits: (1) domain specificity, (2) mandatory operation, (3) limited output to central processing, (4) rapidity, (5) information encapsulation (6) shallow outputs, (7) fixed neural architecture, (8) characteristics and specific breakdown patterns, and (9) characteristic pace and sequencing of development. For Fodor, it is the fact that modules rely only on *encapsulated* information that allows them to be extremely fast in their processing, but limits them to specific domains of information, reduces their flexibility, and results in their outputs being shallow.

But for Bechtel, the modules divide a given cognitive task into its many subtasks and the computational tasks become accordingly difficult and non-linear. Let us close this discussion with a quote from Bechtel[16]:

'One of the most promising roles for connectionist modelling is to serve as an explicit medium for pursuing an interactionist/ constructivist perspective'.

So the interactionist/constructivist perspective requires yet another dimension of evidence and that is what is provided by the complementarity thesis (see Section *4.4* below).

In Cognitive Neurosicience, where a major goal is to relate neural structures to cognitive operations, no one technique can reveal what cognitive operation is performed by a given brain area, but integrating the results from multiple techniques can provide a much better understanding. To illustrate this, Bechtel focus on *three* techniques commonly invoked in cognitive *neuroscience-lesion, cell recording,* and *neuro- imaging.*

The *First* challenge, the exemplar of the use of lesion studies to assign a cognitive function to a brain area was Broca's assignment of the deficit in articulate speech in his patient. Leborgne (Tan) to damage in the third frontal lobe in the left hemisphere. Subsequently lesions, either naturally occurring or due to surgery to relieve symptoms of illness in humans or ones experimentally produced in other animals, and examinations of the resulting deficits, have been one of the most widely used tools for relating structures and function. A lesioned brain is not just a whole brain *minus* the lesioned site, but a brain in which processes performed in other areas may be altered. From the lesion studies, you cannot make a strict bridge-law.

The mechanistic explanation is preferable, because, the inter-theoretic reduction doesn't work and it takes explanation as integration so as to find out that hypothetico-deductive method did not work in mechanistic explanation; so all hypothetic-deductive method is altered. Now, at present, neither logic nor Bridge-laws, therefore the alternative knowledge will not be explained. It leads to the consequences that there is no inter-theoretic reduction, bridge laws, logic and deductive nomological laws are explained in mechanistic explanation in cognitive science.

Finally, the mechanistic explanation in cognitive science finds out how to intervene into the cellular and molecular basis of mind. We can intervene into the neuronal changes (cellular level) and deficiency of brain. These cells are producing electrical impulses, known as action potentials, which propagate along their surface membrane. The mechanistic explanation initiates cellular processes such as the release of neurotransmitters molecules or the contraction of muscles. These electrical impulses are the means by which living cells transfer information over large distance in short time intervals, allowing information processing in the nervous system, movement and many other processes. The semantic side of reduction must be allowed to support constructivism which could possibly reify alternatives. So in a sense constructivism can stand in support of reductions for sustaining the scientific credentials of cognitive science. The semantic task is not complete without the addition of a new epistemology of evidence to refute the possible skepticism which is developed as a 'complementarity thesis'. This has to be separately placed below.

4.4 BECHTEL'S NEW EPISTEMOLOGY OF EVIDENCE (counterposed to skepticism about imaging)

Epistemology is a project where skeptics are refuted. How far Bechtel can go to us this sense in developing his new epistemology will be the focus in this section. The *three* sources of evidence, Bechtel considers, are namely, *Lesion study, Single cell recording*, and *Neuroimaging*. The challenge for the epistemology of evidence is to understand how the instruments and techniques for producing new evidence are themselves evaluated. If researchers had independent evidence about how the techniques worked, then we would have a regress, but the procedure of epistemically evaluating theories. Bechtel develops this analysis of the '*new epistemology of evidence*' by focusing on *three* of the most important sources of evidence employed in cognitive neuroscience-lesion, single-cell recording, and neuroimaging studies. The techniques and instruments discussed here are all designed to reveal the operation of mechanisms. Bechtel develops a *complementary* view of all the three in developing them into a new epistemology.

A mechanism, as Bechtel used the term, is a system whose behaviour produces a phenomenon in virtue of organized component parts performing coordinated component operations. A brain mechanism, for example, might be involved in analyzing what object or event is seen or in encoding information into long-term memory. The component parts will be different brain regions (systems of neurons) which carry out specific information processing operations (e.g., analyzing an object's shape). These components are typically spatially and temporally organized so as to coordinate the operation of the parts to produce the cognitive phenomenon in question.

Bechtel is offering a mechanistic explanation in cognitive neuroscience at the cellular and the molecular level. This has become a frontier research area in cognitive science. If so, Bechtel disputes the *received view on the evidence* which is supposed provide an objective link to reality.

As opposed to the *received* view, Hanson and others argued that observation are theory-laden[17]. Bechtel's derives a lesson from the above. When observations are mediated by complex instruments (fMRI), they run parallel to the way the object seen by the *naked eye*. At that point of time, our observations are conformed because there are many processing steps between the registration of the objects or events seen. What is not understood from an epistemic point of view that this techniques often radically alter the phenomena (Golgi staining of neurons). This raises the question *how evidence is to be understood at the molecular level.*

Bechtel is focusing on *three* questions (1) whether the instrument or technique is producing repeatable and well-defined results that exhibit a definite pattern, (2) the degree to which the results from one instrument or technique agree with results generated with other techniques or instruments, and (3) the degree to which the purported evidence coheres with theories that are taken to be plausible[18].

Bechtel states the consequent definition of mechanism as follows: A mechanism, as he used the term, is a system whose behaviour produces a phenomenon in virtue of organized component parts performing coordinated component operations. It is applied to the study of brain mechanism and the cellular level. At the core of understanding how the mechanism produces a given behaviour is a decomposition of the mechanism. There are *two* different ways of decomposing mechanism. They are decomposed *functionally* into component operations and *structurally* into component parts. The link between this *two* is called *localization*. How they play a role in the activity of the mechanism is determined by a heuristic role[19].

Whereas in *lesion studies*, we intervene within the system, disabling a component of the system, and typically detect the effects in terms of changes in the overall activity of the system (Figure *4.2*), both single-cell recording and neuroimaging, on the other hand, intervene on the stimulus presented to the system and detect the effect on components within the system. In addition to these above we have need to determine how the components are integrated or organized.

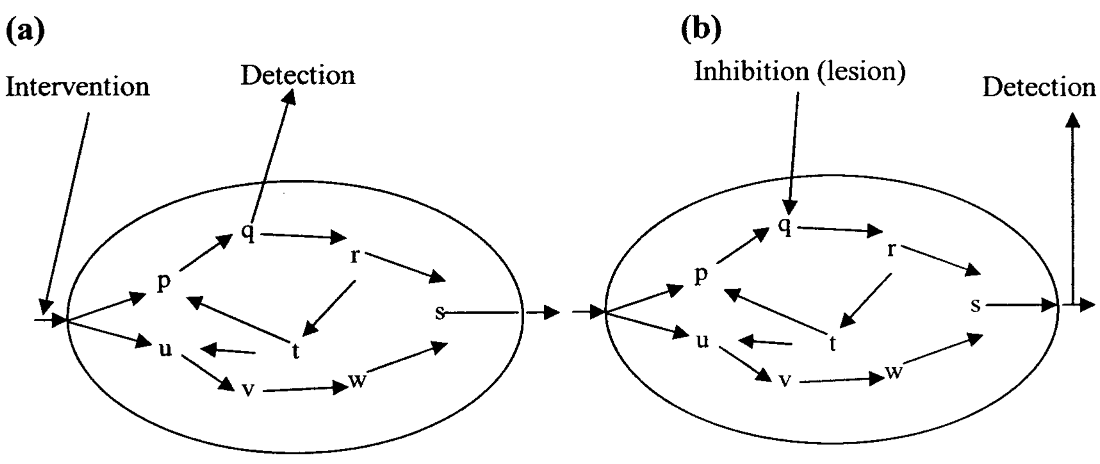


Figure 4.2: The locus of intervention and detection in (a) single-cell recording and neuroimaging studies and (b) lesion studies

One of the oldest approaches to identifying the function of brain regions is analysis of the deficits resulting from lesions (localized damage) to those regions. Lesions can originate either from illness or injury or from intervention by neuroscientists that actually destroy neural tissue[20]. By the time, Broca encountered LeBorgne, a number of researchers had proposed that areas in the frontal lobe of the brain were involved in speech and language. Broca maintained that LeBorgne's deficits were limited to this central area. Broca went on to contend that this region was the locus of articulate speech. A decade after Broca's work, Carl Wernicke (1874) described a different pattern of language deficit, one apparently affecting comprehension of language following lesions in a part of the temporal cortex known as Wernicke's area[21].

Lesion studies have provided a principal avenue for understanding brain operations in both neuro-psychology and behavioral neuroscience. The approach extended for beyond deficits of language (aphasias, apraxias), providing important clues to other cognitive phenomena such as perception and memory. Lesion research raises a number of epistemic challenges. One is determining precisely what areas of the brain are injured. Until the recent introduction of imaging technology, researchers could only determine what areas in the human brain were damaged after the person died and an autopsy was performed. The variety of memory deficits found in amnesic patients led to the differentiation of different types of memory processing[22]. These investigations of deficits in human patients were often coupled with lesion studies in other species, where the lesions can be experimentally induced.

Perhaps the greatest epistemic challenge in using lesions and deficits to understand brain operation is to infer precisely *what the damaged* *component had contributed to normal function.* In lesion research, the attempt to dissociate *two* mental activities by showing that damage to a given brain part may interfere with one but not another. The *first* one is called *Single Dissociation*, however, do not show that the damaged brain part is only involved .The *second* is called the *Double Dissociation* which are often taken as compelling evidence that the two activities are performed separately in the brain[23]. The discovery of a double dissociation encourages researchers to think comparatively about the two activities, asking what operations they might utilize in common and what different operations each requires. Such a strategy is a productive way to generate a decomposition of a task into more basic operations.

A *lesion* may interrupt an operation by removing the part that performed it, but it may also interrupt more indirectly by removing inputs to the responsible region or critical modularity feedback to the responsible region. It may also create a deficit in an even more indirect manner such as by occluding blood flow to other regions or creating swelling that affects operations performed in other regions. Lesion studies themselves provide no way to resolve these worries and determine what operation the lesioned component performed in the normal organism. One way to address these worries is to try to correlate activity in a region in a normal system with the tasks being performed.

Single-Cell Recording has been used most effectively in decomposing the information processing tasks performed by the visual system. Single-cell recording, however, enabled researchers to do something that was not possible with lesion studies-determine the expanse of the visual field of which a single-cell would respond[24]. *Single-cell* recording has provided a great deal of information about the response properties of individual cells and supported inferences as to how cells in a pathway process information from earlier cells.

The Single-Cell Recording is the discovery of the nature of electricity and the brain in port operates on electrical principle enabled neuroscientists to study the brain in the same way investigators study other electrical systems. These include applying electrical stimuli to intervene in its operation or recording its electrical activity. Two ways of recording electrical activity have played major roles in cognitive neuroscience. *One* involves recording from electrodes placed on the scalp that pick up aggregate electrical currents. These currents originate primarily from pyramidal cells that are aligned in columns in the cortex, stimulation of these cells produces ion flows into and out of the cell. When the cells are aligned spatially and activated synchronously, these ion flows create an electric field strong enough to be recorded at the scalp[25]. Recordings of these fields constitute an electroencephalogram (EEG). Another is to sum the response over numerous trials to average out background information. This generates another measure (the Evoked Response Potential or ERP), which has been very useful in fixing the temporal pattern of neural processing.

The *alternative* approach to recording electrical activity in the brain is to record from individual neurons, either by inserting an electrode into the neuron or by placing it next to the neuron. Although the procedures for doing this are now routine, they were challenging to work out. One problem stemmed from the weakness of the electrical signal. The combined effort of numerous investigators was required to develop instruments capable of amplifying the signal sufficiently to detect it. Finally, and from a cognitive perspective, a very serious worry is that ethical considerations only permit single-cell recording in non-human species. This poses challenges for employing this technique to study higher cognitive functions exhibited primarily in humans.

Neuro imagers have returned to the original simple 'substraction approach' of Donders although neuroimaging would seem to confront the same problem of assuming a pure insertion of the additional operation (e.g., generating a verb)[26]. So as to better appreciate the epistemic issues arising in neuroimaging research, Bechtel turns to a specific case in which new localizationist claims were advanced on the basis of neuroimaging.

The type of evidence neuroimaging provides is of the same form as that generated by single-cell recording activity in the brain. That is correlated with cognitive operations a person is performing. A major reason for this is that neuroimaging is non-invasive and imaging can be done on normal humans while they are engaging in cognitive tasks that are thought to be most distinctively human, including abstract reasoning tasks or making ethical judgments. Imaging operation (function) as opposed to parts (structure) requires recording a signal that is related to the operations being performed in a given brain area.

The two techniques that have been most successful and have attracted the most attention-positron emission tomography (PET) and Functional Magnetic Resonance Imaging (fMRI)- both measure blood flow. These basic processes are reasonably well understood and are not the focus of concern in the application of PET and fMRI to measuring neural activity.

Most of the epistemic issues concerning PET and fMRI turn on the connection to cognitive operations. The *second* challenge stems from the fact that during the performance of cognitive tasks, there is blood flow throughout the brain[27]. Accordingly, shortly after the introduction of PET to study cognitive activity, Endel Tulving and a number of his associates initiated a study of encoding and retrieval processes associated with episodic memory- the memory a person *has of being* directly involved in an event in the past. The main finding of these studies was that encoding of episodic memory resulted in increased blood flow in the *left* prefrontal cortex, whereas retrieval produced increased blood flow in the *right* prefrontal cortex.

This led Tulving and his collaborates to propose the Hemispheric Encoding/Retrieval Asymmetry (HERA) model[28]. Recent neuroimaging studies have identified yet more brain locations that show increased activation in encoding and retrieval studies in addition to those first targeted by Tulving. The final measure is that results fit into coherent theoretical perspectives, especially accounts of how neuro- cognitive mechanisms work. In addition to linking brain regions with component operations of cognitive processing, this requires accounts that agree with the known neuroarchitecture of the brain and show how the component operations figure in performing a variety of cognitive tasks. This is an ongoing effort in cognitive neuroscience that appears to be making rapid progress, which in turn supports the credibility of the empirical evidence imaging produces.

The epistemic issues raised by PET and fMRI are of critical importance since these techniques, together with ERP and lesion studies, are the primary tools for studying the neural formulations of cognitive processing in humans[29]. Their strength is that, unlike lesion studies, they can *correlate* activity in the brain with cognitive operations a person is performing. Although concerns remain about the origins of the signal measured, PET and fMRI are generally regarded as *providing highly credible information* about neural activity. The main epistemic issues concern the procedures for relating this information to cognitive operations. A primary procedure for doing this is the *substractive method* and Bechtel have focused on some of the epistemic issues it raises.

Evidence in science is frequently the focus of contest. This is true in cognitive neuroscience as in other sciences. Bechtel examined the development of *three* of the principal sources of evidences linking cognitive processes to the brain-*lesion studies*, *single-cell recording,* and *neuroimaging*. In each case, the results advanced involve manipulation of the phenomena under study and researchers must evaluate the results as to whether they reflect in the appropriate manner the component operations in cognitive mechanism. Bechtel tried to show how researchers commonly appeal to *three* different features of the evidence itself to determine whether results from these techniques of cognitive neuroscience are artifacts. *First* is whether there is a definite pattern in the results that can be procured reliably. *Second* is whether the results are consistent with results produced by other techniques. *Third* is whether the results fit into a coherent theoretical account.

The final measure is that results fit into coherent theoretical perspectives, especially accounts of how neurocognitive mechanisms work. In addition to linking brain regions with component operations of cognitive processing, this requires accounts that agree with the known neuroarchitecture of the brain and show how the component operations figures in performing a variety of cognitive tasks. This is an ongoing effort in cognitive neuroscience that appears to be making rapid progress, which in turn supports the credibility of the evidence imaging produces.

4.5 CRAVER'S NON-FUNDAMENTAL MOSAIC THEORY OF SCIENTIFIC EXPLANATION

Craver gives the following two definitions of interventionist strategy. *Definition (1)*: semantics of intervention involves semantics of counterfactuals: How it would be true under counterfactual circumstances (called *W*-question or What-if things change?), leading to an introduction of 'modality' into scientific explanation. This lends credence to the sense of alterity. *Definition (2)*: Idea of Intervention: how changes in the *explanandum* are systematically connected to changes in the *explanans* which gives a non-canonical method of explanation. This supports a case against normativity.

Craver is opposed to the logical model (DN model) and he favours an interventionist – manipulationist account of causal explanation.

(1) Craver is a *Non-foundationalist*: Craver is equally opposed to any canonical model of scientific explanation which is foundationalist in character. Churchland is *foundationalist* and treats the canonical model in two steps calling it as explanatory understanding in 2 steps.

Normative Step 1: Construct a neural theory of *understanding*;

Explanatory Step 2: Apply it to a model of scientific *explanation*.

(1) + (2) yields:

Scientific Explanation: *df.* Applied canonical understanding; what follows from this is that cognitive science is not a science (like any other science, say, physics) unless it has an interface with social/behavioural science.

(2) He is as much a constructivist as Bechtel. Craver's opposition to Bechtel is at a *deeper* level (he opposes the memory consideration project to which he has made a worthy contribution so also, he opposes Circadian Rhythm as an exemplar in cognitive science). Craver does not wear his reductionist credentials on his sleeve. Both Craver and Bechtel belong to a family of constructivists among others.

(3) Craver is a Unity Theorist (like Kitcher or Wimsatt): Following Friedman, DN (deductive nomological model) is to be thrown away, but unity alone matters[30]. Now we shall see *how* this is transformed into a sort of *irreduction* → mosaic *via* unity.

So the different ways in which reductionism i.e., (1) reductionism is logical, (ii) reductionism is empirical (causal) → causal at mechanical level (Salmon), (iii) reductionism is intertheoretic reduction (Churchland)-fundamentalism, (iv) reductionism is not reductionism but unity of all sciences, (v) and reductionism is integration (Craver extends Wimsatt who gives a more accurate view of Kitcher's 'modesty' unity (modest) (elementary particles, atoms, molecules, cells, organisms, societies). Following Wimsatt, Craver stretches it further Bechtel is opposed to this type of Unity.

(4) Synaptic Plasticity is the main issue: Reductionism is mechanism: Memory consolidation is a paradigm (it assumes that LTP is a case of synaptic plasticity which is not true)[31].

(5) Memory has a *separate* conceptual achievement: Craver opposes the above saying that LTP cannot explain plasticity of learning[32]. So they are not to be connected without experimental warrant.

Explanation: The most studied form of synaptic plasticity is known as Long-Term Potentiation (LTP). Many believe that LTP, a laboratory phenomenon in which a synapse is strengthened through exposure to a high-frequency pulse, reflects the existence in the synapse of a mechanism for encoding and storing memories. Here Craver focusses on a type of LTP mediated by a subtype of glutomate receptors that is highly responsive to the pharmacological agonist, N-methyl-D-asparate (NMDA). These receptors are called NMDA receptors, and this variety of LTP is commonly called NMDA-receptor dependent LTP. The defining mark of LTP is explained by a coincidence detector mechanism involving the NMDA receptor (See Figure *4.3*). The NMDA receptor gate the diffusion of Ca^{+} into the post-synaptic cell. When the pre-synaptic neuron is active, it releases the neurotransmitters, glutamate and glycine, which travers the synapse and bind to receptors on the post-synaptic cell, including NMDA receptors.

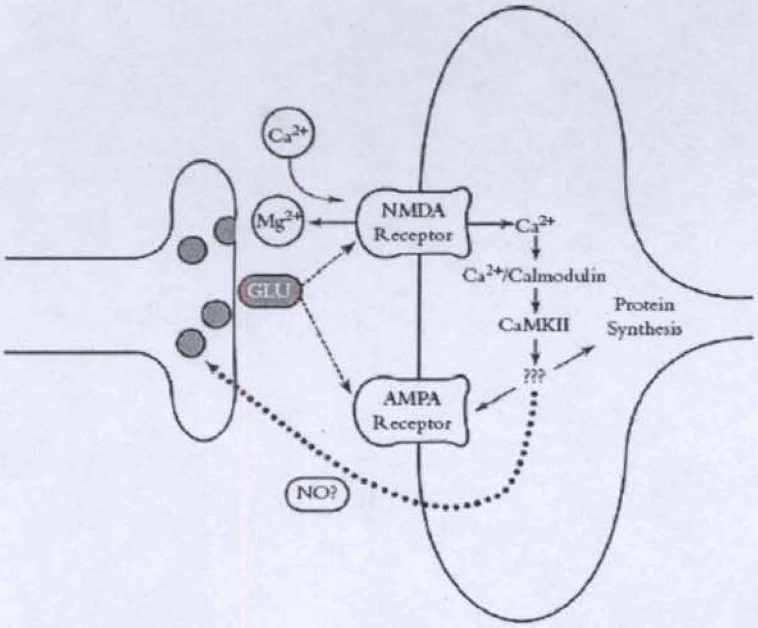


Figure 4.3: A sketch of the synaptic mechanism of LTP*

*Beginning with the release of glutamate (GLU) from the pre-synaptic neuron (left) and terminating with changes tot he post-synaptic neuron (right) and/or the pre-synaptic neuron (via nitric oxide, NO)

(6) Memory needs multi-level explanation: Finally, mechanisms can be individuated by their (1) *active*, (2)*spatial*, and(3)*temporal* organization. A mechanism's active organization includes activities and interactions (excitatory and inhibitory) of the mechanism's component entities[33]. Spatial organization includes the relative locations, shapes, sizes, orientations, connections, and boundaries of the mechanism's entities. Finally, a mechanism's temporal organization includes the orders, rates, durations and frequencies of its activities[34].

(7) Memory is Seen in *three* different ways:

(i) Memory is a reduction: Reduced to learning (plasticity is an example or model of learning).

(ii) Memory is Analogical: Link between hippocampal synaptic plasticity and learning for memory was a separable conceptual achievement.

(iii) Memory in mechanism: Plasticity is a component in learning or a memory mechanism (but not learning).

So memory consolidation is cast in a bad light. Cautions approach is needed to ground it to a model of scientific explanation. Thus Craver strikes a sceptical note: Therefore, memory consolidation is a historical *counterexample*. Craver concludes that LTP research program is clear *historical counterexample* to those that who present reduction as a general empirical hypothesis about trends in science[35].

(8) Craver is an anti-theorist: Once D-N (Deductive Nomological) model is thrown away, the orthodox understanding of science becomes questionable. Craver's way of stating this involves two observations (a) They are 'theories in the wild', (b) so also, 'theory dynamics' (successional account of theory change) is also in the wild. This opens the space for non-formal (non-statement) considerations in which non-statement views are readily accepted. A mechanic theory of explanation is a therefore a *part* of the non-statement view, which Craver identifies with what you call a model *model*. This is how the structure of the scientific theory is to be understood according to Craver.

(9) Evading the classical philosophy of science: Neither ORV (Old Received View) nor the *Globalists* views (Kuhn's 'paradigm' philosophy of science, research programme theorist like Lakatos, interfield theorist like Darden and Maull, modest unity account of Kitcher) are acceptable[36]. Similarly, the alternatives in the New Experimentalists category (theorist like Lauden's- who decenter theory- research tradition) are to be equally evaded.

(10) Moving onto complete the '*semantic*' task: No doubt they invariably provide a *semantic* dimension of the theory (Suppe's : the state-space approach given as set-theoretic formulation; Sneed, Stegmuller,and Van Frassen take it in this direction)[37]. According to this, theories are constructed on multidimensional state-spaces or configurations of sets of such spaces which define a class of models.

(11) Craver's *Decentering* Theory: Model model is identified as opposed to Globalists. It is not monolithic, but it generates stratigraphic levels of enquiry[38].

No correspondence rules in theory-observation relation, therefore tenability of realism is questionable; some how we have to *decenter* theory (non-formal). Besides, this *does* not warrant any correspondence rules; following this, there is no theory-observation relation.

(12) The *Explanans-Eplanandum Bind* needs/a novel multi-level/casual relation: Its core account of mechanistic explanation and relevance is causal- manipulationist in spirit, and offers substantial insight into causal explanation in brain science and the associated notion of levels of explanation. Craver's causal-mechanical account of *constituitive* explanation is restricted and elaborated variant of accounts developed within the systems tradition (especially these found in the work of Bechtel, Cummins, Hugeland, Simon and Wimsatt).

(13) Intervention at Multi-levels: Mechanisms, in contrast, are not mere static or spatial patterns of relations, but rather patterns of allowance, generation, prevention, production, and stimulation. There are no mechanisms without active organization and no mechanistic explanation is complete or correct if it does not capture correctly the mechanism's active organization. Active organization in mechanisms is sustained by the spatial and temporal organization often yield activities joined in

different spatial and temporal organization often yield different mechanisms. The spatial organization of a mechanism includes, for example, the sizes, shapes, structures, locations, orientations, directions, connections, and compartments of its components. Several kinds of spatial organization are crucial for understanding the mechanism of the action potential. Mechanistic explanations, however, are embodied. They are anchored in components and those components occupy space and take time to act. A description of a mechanism is not merely a summation of parts or capacities, it is a description of how they work together. The description involves- in addition to a list of component entities $\{X_1, X_2……., Xm\}$ and activities $\{\phi_1, \phi_2, ……\phi_n\}$ – an account of how they are organized together actively, spatially, and temporally in S's ψ-ing.

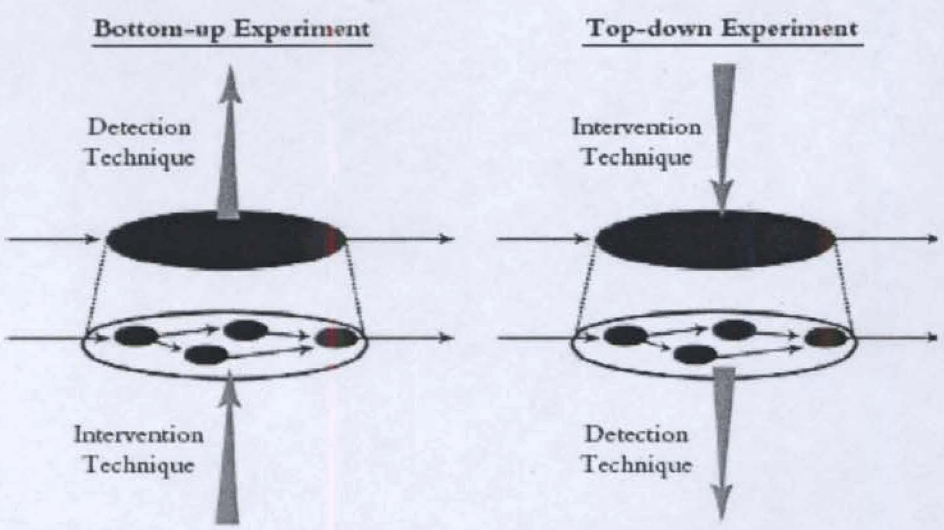


Figure 4.4: Abstract representation of experiments for testing constitutive (or componential) relevance

(14) Stratigraphic Level Theory: The Figure (4.4) shows a bottom-up experiment, in which one intervenes to change a component in a

mechanism (X's ϕ-ing) and detects changes in the behavior of the mechanism as a whole (S's ψ-ing). He top-down experiment, in which one intervenes to manipulate the phenomenon (S's ψ-ing) and detects changes in the activities or properties of the components in the mechanism (X's ϕ-ing).

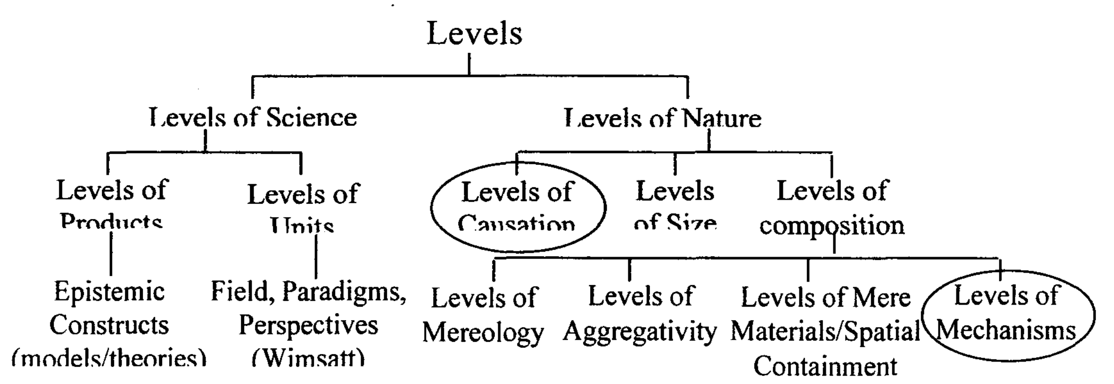


Figure 4.5: A *Taxonomy of levels*

Craver's view is that the levels in this multilevel explanation are best understood as levels of mechanisms[39]. Lower levels in this hierarchy are the components in mechanisms for the phenomena at higher levels. Components at lower levels are organized to make up the behaviors at higher levels, lower and higher-level items stand in relationships of mutual manipulability. The top node of Figure *(4.5),* for example, marks a distinction between levels of *science* and levels of *nature*. The *relata* in levels of science might be other *products* of science or *units* of science. Products of science are epistemic constructs, such as analyses, descriptions, explanatory models, and theories. When one says that theories about molecules are at a lower level than theories about cells, or that brain regions and cells occupy different level of description, one is talking about levels of products of science. Units of science include such groups as *fields* (Darden), paradigms (Kuhn), *perspectives* (Wimsatt) and *research* programmes (Lakatos)[40]. The levels of *nature* relate items in this world, such as activities, entities, properties, and states.

In the case of the explanation of spatial memory (henceforth LM) levels and other hierarchically organized explanations, theories, fields, and levels of nature (in Oppenheim and Putnam's sense) dissociate from one another. Researchers in single fields do research at multiple distinct levels of nature, and sometimes multiple fields bring their resources to bear on a single level. For these reasons, Craver confines his attention from this point on to multiple levels of nature rather than to multiple levels of science.

Craver proposes then that we start by thinking of levels as primarily features of the world rather than as features of the unit or products of science. As possible *relata* in levels of nature, Craver includes entities, activities, properties, and mechanisms[41]. He also distinguishes among *three* inter-level relations: *causation*, *size*, and *composition*. LM levels exhibit a special kind of *composition* relation. Craver distinguishes *four* kinds of composition: *mereological, aggregative, spatial/material*, and *mechanistic* composition. Mechanistic composition, he claim, is the crucial feature of LM levels.

Craver admits that talk of *levels*, however, is 'multiply ambiguous'. The '*levels metaphor*' is very flexible, and it is often used without specifying the sense of level under discussion. To prevent equivocation, Craver has developed a set of taxonomic principles for distinguishing different reading of the levels metaphor. This taxonomy also helps clarify a central interpretation of the levels metaphor: levels of mechanisms. The mechanistic interpretation is central because it fits core cases of neuroscientific explanation, such as LM levels. It also extends the view of mechanistic explanation and also show that realized phenomena (that is, phenomena at higher levels of realization) are often causally, and so explanatorily relevant for many of the explanation of interest to neuroscientists.

(15) The Mosaic Unit of Explanation: Craver shows that how multilevel mechanistic explanations scaffold the unity of neuroscience. Philosophers of neuroscience traditionally envision the unity of neuroscience as being achieved through the stepwise reduction of higher-level theories to successively lower level, and ultimately fundamental, theories[42]. He argues, in contrast, that the unity of neuroscience is achieved as different fields integrate their research by adding constraints on multilevel mechanistic explanations. The goal of finding multilevel explanations provides an abstract sketch or scaffold for integrating fields. The findings in different fields of neuroscience are used, like the files of a mosaic, to elaborate this abstract mechanism and to shape the space of possible mechanisms. The mosaic unity of neuroscience is achieved both through interfield integration at a given level and through integration across levels

in a hierarchy of mechanisms. Craver develops this model using a putative exemplar of reduction in contemporary neuroscience: the relationship between the psychological phenomena of learning and memory and the electrophysiological phenomenon, long-term potentiation (LTP). Craver thereby demonstrates that the mosaic view is superior to reduction as a model of the unity of neuroscience.

To conclude, that we have seen Bechtel places his account of *alterity* in an open-ended constructivist account of explanation which complements his *weak* reduction with system account (in his work on Circadian Rhythms which will be reviewed next).

But, so long as Craver embeds his account of causal invariance within a counterfacutal artefact of '*how-actively, how possibily, how-plausibily*' *alterity* within the ambit of *explanandum-explanans* relation, leaving the critics to wonder the computational significance of his theory, he fails to give the final word on the scientific credentials of philosophy of mechanical science (in his constitutive sense). Placing the entire burden of causation thus invites a counter which calls for a position with the slogan: 'the devil is in the details' (microlevel cellular-molecular voltage gated ion channels and proteins). This serves the ammunition for the second paradigm which is to be discussed in the *final* chapter.

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Chapter 5

NEW-WAVE REDUCTIONISM AS A MODEL FROM SYSTEM NEUROSCIENCE

'The Superchiasmatic Nucleus Circadian Clock is more than just the sum of its cells'

(LIN *et al.*, 2007: 612)

'Churchland provides a plan for applying neuroscientific evidence to philosophical problems. Bickle applies it with a vengence'

(CHEMERO:2005)

NEW WAVE REDUCTIONISM AS A MODEL OF SYSTEM NEUROSCIENCE

5.1 PHILOSOPHY OF SCIENCE (NEUROPHILOSOPHY) AND PHILOSOPHY AND NEUROSCIENCE

In the previous chapter, we were collating Bechtel's philosophy of mechanic science and Craver's variant of constitutive explanation with the deliberate purpose of anticipating some sort of opposition between them. While this is being so, Bechtel spells out of his opposition by constructing an *Alternative Model of Memory Consolidation* before moving on towards a safer haven of Circadian Rhythm Exemplar for Cognitive Neuroscience. Thus his opposition to Bickle's philosophy of *Ruthless Reductionism* (New Wave Reduction) is concrete because it sponsors *not only* a '*revisionary*' exemplar but also moves on to an entirely *new* paradigm of Circadian Rhythm to which Craver is somewhat opposed if only for the same reason he has made clear in his adherence to a theory of causation which he builds up from Woodward's account which is primarily aims targeting experimental economics[1]. But in 2010, we find that the question of its applicability to causal relations in Neural Mechanism is finally resolved. We will spell out the nuances of the opposition towards the end of the chapter.

So altogether there are *two* reigning paradigms, *one* sanctioned by Memory Consolidation Research (which divides itself into two opposing models) and simultaneously *two* opposing Circadian Rhythm exemplars, which need to be carefully evaluated further for the purpose of demonstrating the scientific credentials of cognitive science. The former requires the CREB Molecular Biology for Memory Consolidation (Long-Term Potentiation) and the latter requires the Molecular Level Understanding of how Superchiasmatic Nucleus interacts with time.

Before outlining the exact opposition, we shall delve into the question of how philosophy *meets* neuroscience, which far surpasses philosophy of cognitive science or whatever.

For 'Wide-Eyed Quineans' (we identify this with Cognitive Neuroscience) *philosophy of neuroscience* still tends to pose traditional questions from philosophy of science specifically to neuroscience. Such questions now include: what is a neuroscientific explanation? What are the *explananda* of neuroscience? How is it that the instruments used by neuroscientists (e.g. Neuroimaging, Cell recording, Genetic Manipulations, Simulations) yield knowledge? Answers to these questions can be pursued either descriptively (how does neuroscience proceed?) or normatively (how should neuroscience proceed?). Normative projects in philosophy of neuroscience can be deconstructive, or constructive, by proposing theories of neuronal phenomena or methods for interpreting neuroscientific data.

Often a combination of neuroscience *and* philosophy may raise the eyebrows of more than a few neuroscientists and philosophers. Not so for the 'Narrow-Eyed Churchlandians' (let us identify this with Philosophy and neuroscience) like John Bickle, for whom, the working concept of reduction in the neurosciences consists of the discovery of systematic (single-bound causal?) relationships between interventions at lower-levels of organization (as they are recognized in Cellular and Molecular Neuroscience) and higher level behavioural effects (as they are described in psychology). Bickle calls this perspective 'reductionism-in-*practice*' for what he calls 'meta-level' reductionism, as opposed to 'reductionism-in-*theory*'. The adjective 'Ruthless' here means that 'this is in actual practice'[2].

Philosophers of science have recognized the primary of mechanism in neuroscientific explanations. Applied explicitly to neuroscience, Carl Craver (forthcoming) contends that mechanistic explanations are causal and typically multi-level[3]. For example, the explanation of the neuronal action potential involves the action potential itself, the cell in which it occurs, electrochemical gradients, and the proteins through which ions flow. Here we have a composite entity (a cell) causally interacting with neurotransmitters and its receptors. Parts of the cell engage in various activities (the ligand and voltage-gated opening and closing of ion channels) to produce a pattern of change (the depolarizing current constituting the action potential). The mechanistic explanation of the action potential countenances entities at the cellular, molecular and atomic levels, each of which are causally relevant to producing the action potential. This causal relevance can be confirmed by altering any one of these variables (e.g., the density of ion channels in the cell membrane) to generate alteration in the action potential, and by verifying the consistency of the purported invariance between the variables. Craver's point is both that explanations in neuroscience are mechanistic, inherently multi-level ones as well as causal, invariant explanation in neuroscience, as opposed to merely etiological (Salmon)[4]. The issue here is about the way we should combine mechanism with causal explanation.

According to epistemic norms shared by neuroscientists, good explanations in neuroscience are good mechanistic explanations, and good mechanistic explanations are those that pick out invariant relationships between mechanisms and phenomena. Supposing mechanism, as a position on neuroscientific explanation, assumes some type of autonomy for psychology, then, ruthless reductionists can come up with a challenge to mechanists on this assumption. On the other hand, Bickle's reductionism-in-practice clearly departs from inter-theoretic reduction, as the latter is understood in philosophy of science and, as Bickle himself acknowledges, his latest reductionism was inspired heavily by mechanists' criticisms of his earlier "new wave" account. Mechanists can challenge Bickle that his departure from the traditional accounts has also led to departure from the interests that motivated those accounts. We identify this with Cognitive Systemscience as standardized by Bechtel.

So, we differentiate between Cognitive Neuroscience and Cognitive Systemscience with a certain emphasis on phenomenal cognition (endogeneous entity) in the former and molecular-linked cognition in the latter CREB-

Molecular Biology in the latter. Pictorially represented, the whole controversy boils down to the schema like the following:

M= { C: Multilevel where wholes are part of greater wholes (herme- (unity).
BI: Single level: but, four distinct (Convergence Four) lines of SR.
BE: Inter-and intra-level that does not favour the recursivity of parts.

In other words, Craver subscribes to multiple inter-level causation for sustaining unity hypothesis questioning at the same time the correlation between 'temporal relationships' and causal relations. Light may temporally precede, but may not cause oscillations in the SCN. Bickle sustains the temporal dimension of two phenomena at the microlevel to prove CREB→ Memory Consolidation and thereby smoothens out plasticity. It is questionable whether his idea of intervention overlays plasticity (Kanthamani)[5]. Bechtel thinks that time's sensitivity of the Suprachiasmatic Nucleus, together with feedback mechanism, go a long way towards an understanding of mental causation, and probably refuse a recursive strategy to mechanistic components and allows 'flexibility' Andy Clark characterizes causation as Continuous Reciprocal Relation and acknowledges that it is a complex loop. Both Clark and Bechtel agree that 'System S is both continuously affecting and simultaneously being affected by, actively in some other System O'[6]. Churchland is normative whereas Craver is non-normative.

Knowing which brain areas are activated when a subject performs a given task helps us to better understand the mental processes involved in performing task. In addition, scalp recordings of electrical or magnetic activity (through the Electroencephalography or EEG machine, or the *Magneticencephalograph* or MEG machine) evoked by particular stimulus events have provided detailed information about the time course of brain processing.

The second half of the twentieth century has witnessed not just an explosion of research at the behavioral end of neuroscience, but also extraordinary advances in understanding the basic cellular, synaptic and molecular processes in the brain. The idea that neurons constitute the basic functional, cellular units of the brain was not widely accepted until the beginning of the twentieth century, but this provided the formulation for subsequent micro-level research. This research, in turn, has increasingly been integrated with research into higher brain functions. For example, the introduction of electrodes that allow recording from awake, behaving primates has provided a means for linking local neural behavior to particular cognitive tasks. More recently, new tools in Simulation-Based Science for *manipulating genetic material* have extended the inquiry even further. These advances have required the collaboration of scientists trained in a number of specialties, including neuroanatomy, neurochemistry and neurophysiology.

Thus while *philosophy of neuroscience*, like philosophy of psychology and philosophy of cognitive science, however, represents more than an attempt to address foundational issues in neuroscience, *philosophy and neuroscience* represents a *metalevel* philosophy of science (called the Science of Research which is purported to explain how scientists go about their given task). It is called the '*Science of Science*' and not referring to any sociology of science.

While the approach to philosophy of neuroscience represented is *naturalistic, philosophy and science is chary of any brand of naturalism*. The focus of the former is on neural systems and their relation to cognitive processes, while the latter focus on more basic cellular and molecular processes such as the chemical events involved in neural transmission[7]. The philosophical issues concerning neuroscience have been addressed in Bechtel's view on cognitive neuroscience.

The interplay between philosophical and neuroscientific ideas has been present from the earliest inception of the discipline comprising the neurosciences (neuroanatomy, neurophysiology, parts of molecular biology, biophysics, pharmacology, genetics, etc.). Indeed, the roots of their conceptual entanglement can be found in the *a priori* engagement of philosophy with the medical, biological, and psychological sciences (wide-eyed Quineans). From a more contemporary point a view, today's research at the intersection of philosophy and neurosciences was catalysed in the 1950s with the articulation of the mind-brain identity theory by Place, Smart, and Armstrong. In the tradition of those philosophers who have looked at the neurosciences with a focus on how the brain supports mental or cognitive capacities, we have focused primarily on those parts of neuroscience that constitute cognitive neuroscience.

On the other hand, Bechtel has argued for the importance of dynamic mechanical explanations in biology. Mechanists see their work as 'explaining types of phenomena by discovering mechanism.....[8]'. Stuart Glannan provided a characterization of mechanism in terms of decomposition into parts and their interactions: "A mechanism for a behavior is a complex system that produces that behavior by the interaction of a number of parts, where the interactions between parts can be characterized by direct invariant change-relating generalizations"[9].

In molecular biological mechanism, types of entities include macromolecules (such as proteins and the nucleic acids, DNA and RNA), and sub-cellular structures, such as ribosomal particles (composed of RNA and Proteins). In→Nuclues (per)→mRNA→Cytoplasm (Molecules of corresponding Protein) →PER

Returns to Nucleus→ release/suppress→New Cycle

In terms of Bechtel's schema for dynamic mechanistic explanation, the above process can be explained as follows:

Decomposition: per, per mRNA, PER

Operations: transcription, transportation, translation, inhibition

Recomposition: Rebuild

The entities and activities are organized in productive continuity from beginning to end; that is, each stage gives rise to the next. Entities having certain kinds of activity enabling properties allow the possibility of acting in certain ways, and certain kinds of activities are only possible when there are entities having certain activity enabling properties[10].

Thus cases from molecular biology have been used to analyze the issues of laws, theory structure, explanation, and experimentation. For each of these philosophical issues, it will be argued, evidence from molecular biology directs philosophical attention toward understanding the concept of a mechanism for addressing the topic. Rejecting on the historical origins of molecular biology discussed above, it should come as no surprise that the field appeared to many philosophers of science to offer an ideal case of reduction. This is a pointer to cognitive system science, as we call it.

Kenneth Schaffner used and developed Ernest Nagel's analysis of derivational theory reduction to argue for the reduction of classical Mendelian Genetics (T_2) to Molecular Biology (T_1) and refined it over many years[11].

Kitcher argued that the relation between Mendelian and Molecular genetics was "explanatory extension"[12]. The theory of Molecular Genetics provided a refined and expanded set of promises when compared to the argument schemata of a classical genetics.

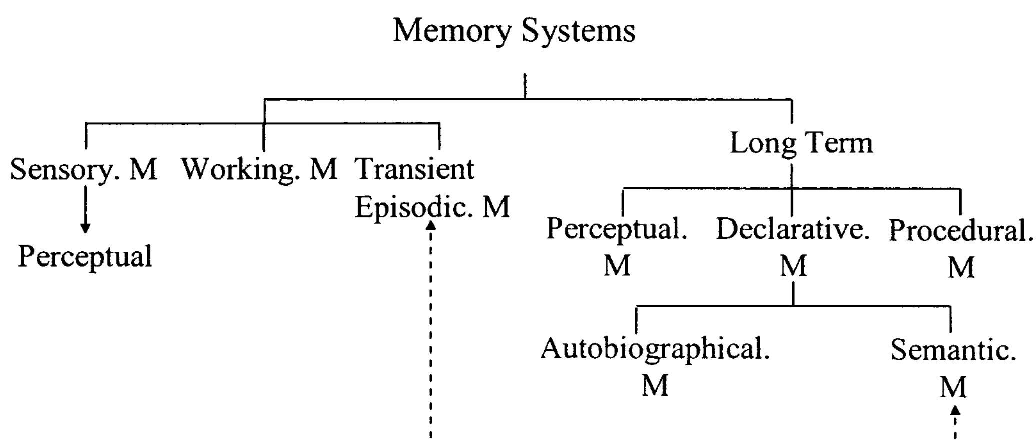
Molecular biologists, who have discovered different mechanisms that operate before and after chromosomal pairing and separation, were found to have different working entities of different sizes, and required molecular techniques rather than Mendelian/ cytological ones to find them. The working entities differed in the hereditary mechanisms discovered by classical genetics and molecular biology.

Bechtel and Richardson elaborated the strategies of decomposing a system and localizing subcomponents to find the mechanism that produced the behavior of the system. They discussed experiments on connecting the genetics of eye pigment inheritance in fruit flies with its decomposition to find the biochemical mechanisms of eye pigment production. These experiments, they claimed, forced a reconceptualization of "Mendelisms one gene-one trait" to a lower level of analysis of "one gene-one enzyme"[13]. What they meant was that they are equivalent but rival systems; they are statement forms of two rival descriptions that cannot be identical without being revised.

An overview of the history of molecular biology revealed the original convergence of geneticists, physicists, and structural chemists on a common problem: the structure and function of the gene. Conceptual and methodological frameworks from each of these disciplinary strands united in the ultimate determination of the Double Helical Structure of DNA (conceived of as an informational molecule) along with the mechanism of gene replication, mutation, and expression. With this recent history in mind, philosophers of molecular biology have examined the key concepts of the field: mechanism, information and gene. Moreover, molecular biology has provided cases for addressing more general issues in the philosophy of science, such as reduction and the integration of fields, explanation without laws of nature, the structure of biological theories, and strategies for experimentation. It has been argued that, given the importance of the discovery of macromolecular mechanisms throughout the history of molecular biology, a philosophical focus on mechanisms generates the clearest pictures of its history, of its concepts, and of the cases from its past utilized by philosophers of science.

5.2 THE 'INTERVENING CELLULARLY/MOLECULARLY AND TRACK BEHAVIORALLY' MODEL

Earlier, we have distinguished between *direct* and *indirect* approaches made by Churchland. The *direct* approach sets the tone for the 'phenomenal' understanding of Qualia ('What-it-is-to-be-something') and to Neurophenomenology (*via* neural correlates of consciousness), the *indirect* approach needs system approaches to memory, attention and other cognitive tasks. The indirect approach gives a fillip to memory consolidation research. A standard classification due to Franklin *et al.*, (2003) is given below[14] (the dotted lines show a sort of link which we do not know at present):



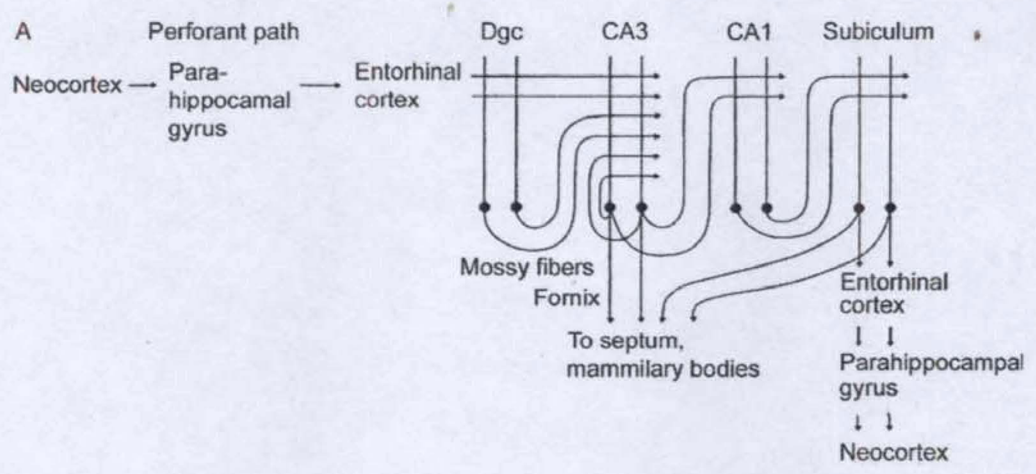


Figure.5.1 (A): The Computational Matrix of Hippocampus

A schematic representation of hippocampal circuitry. Note that input from the neocortex reaches the hippocampus via the parahippocampal gyrus and the entorhinal cortex, and output from the hippocampus reaches the neocortex via the entorhinal and the parahippocampal gyrus. Note also a second input path that projects from the dentate gyrus (perforant path). Its axons make synaptic contact with the CA3 neurons below the level at which the entorhinal axons make contact. This arrangement suggests a computational matrix (From Rolls 1989.)

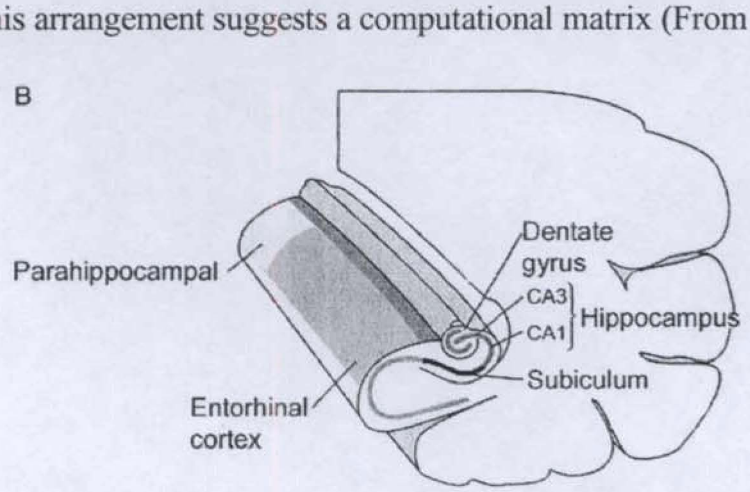


Figure. 5.1 (B): The Neuro-Anatomical Picture of Hippocampus

An anatomical diagram showing the location of the hippocampus in the temporal lobe of the brain, as viewed from a coronal section (top is rostral, bottom is caudal), where the hippocampal structures are pulled out from the other tissue to be viewed in depth (facing sections interior) [15].

For Patricia Churchland, the reduction of neurophysiology to molecular biology and bio-chemistry was not in serious doubt: "Researchers have begun to reduce electro-physiologically defined properties, such as spiking and synaptic potentials to the basic molecular biochemistry of cell membranes"[16]. But one can still doubt whether Churchland undertook to provide the necessary "*link*" that bridged neurophysiology and functional neuroanatomy with "higher functions". Philosophers of neuroscience who have followed Churchland's lead virtually ignored developments in cellular and molecular neuroscience over the past two decades and have instead sought "psychoneural links" at the levels of neuronal regions, ensembles, their connectivities, and their "systems" properties and dynamics[17].

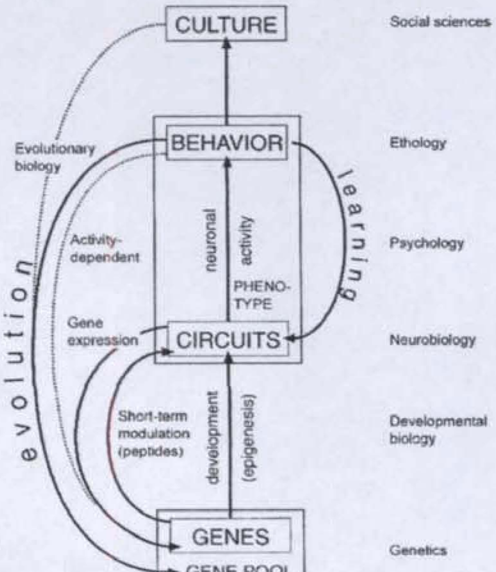


Figure 5.2: Levels of structural organization involved in cognition

The above Figure explains how causal interactions between many levels of structural organization involved in cognition, and the particular sciences that address the levels and the connections between them[18].

Following Kim who remarked that a reductionist is a bit like being a logical positivist or a member of the old left-an aura of doctrinaire naiveté hangs over him[19,] Bickle thinks that this attitude is completely at odds with that among neuroscientists, especially among the cellular and molecular neuroscientists who now constitute the disciplines' mainstream. So Bickle describes how neural science is attempting to *link molecules to mind-how* proteins responsible for the activities of individual nerve cells are related to the complexities of neural processes[20]. Bickle thinks that today it is possible to link the molecular dynamics of individual nerve cells to representations of perceptual and motor acts in the brain and to relate these internal mechanisms to observable behavior. He believes that current neuroscience can step across so many "levels" in a single bound. Between the behavioral, and the molecular-biological levels lie (at least) the cellular, the neuroanatomical, the circuit (neuron networks) the regional, the system (including the motor system, to generate measurable behavior), and perhaps even the information-bearing and processing.

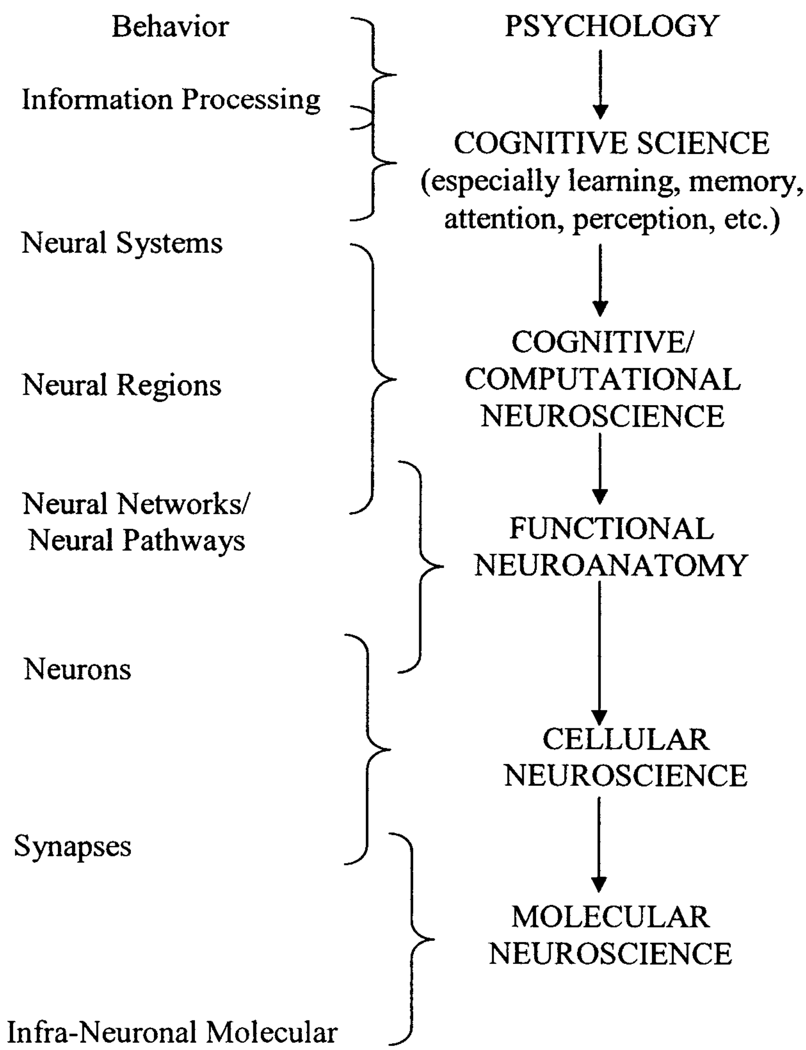


Figure 5.3: Schematic illustration of the currently standard view of levels of organization within the nervous system, relationships to higher levels of organization (behavior, information processing), and the scopes of the mind-brain sciences addressing these levels. Allied with this standard view is a "step-by-step view of psychoneural reduction (downward arrows), in which reduction succeeds only when features of a higher level of organization (via their affiliated scientific theories) are linked to features at the next level down.

Figure 5.3 illustrates this "multitude of levels" picture of the mind-brain scientific endeavor and the step-by-step task thought to confront reductionists. This figure should be crashingly familiar since it is now part of the accepted background in current philosophy of mind (at least in the "analytic") traditional and cognitive science.

Bickle has become a sort of the Devils-in-the-Details Enthusiast. Bickle begins with the refutation of *two* popular claims about neuroscience and its explanatory potential:

- "We don't know much about how the brain works".
- "Lower level neuroscience can't explain cognition and behavior directly. For that, we need higher-level theorizing-we need cognitive neuroscience".

The *second* claim is so enshrined in cellular and molecular cognition, which claims to "intervene cellularly/molecularly and track behaviorally", i.e.,

- Intervene causally at the level of cellular activity or molecular pathways within specific neurons.
- Then track the effects of these interventions under controlled experimental conditions using behavioral protocols well accepted within experimental psychology.

The cellular or molecular events in specific neurons into which experimenters have intervened, in conjunction with the neuronal circuits in which the affected neurons are embedded, leading ultimately to the neuromuscular junctions bridging nervous and muscle tissue, directly explain the behavioral data. These explanations set aside intervening explanatory levels, including the psychological, the cognitive/information processing, even the cognitive-neuroscientific[21]. The level relations illustrated in Figure 5.3 above are replaced in the explanatory practices of cellular and molecular cognition by the picture in Figure 5.4.

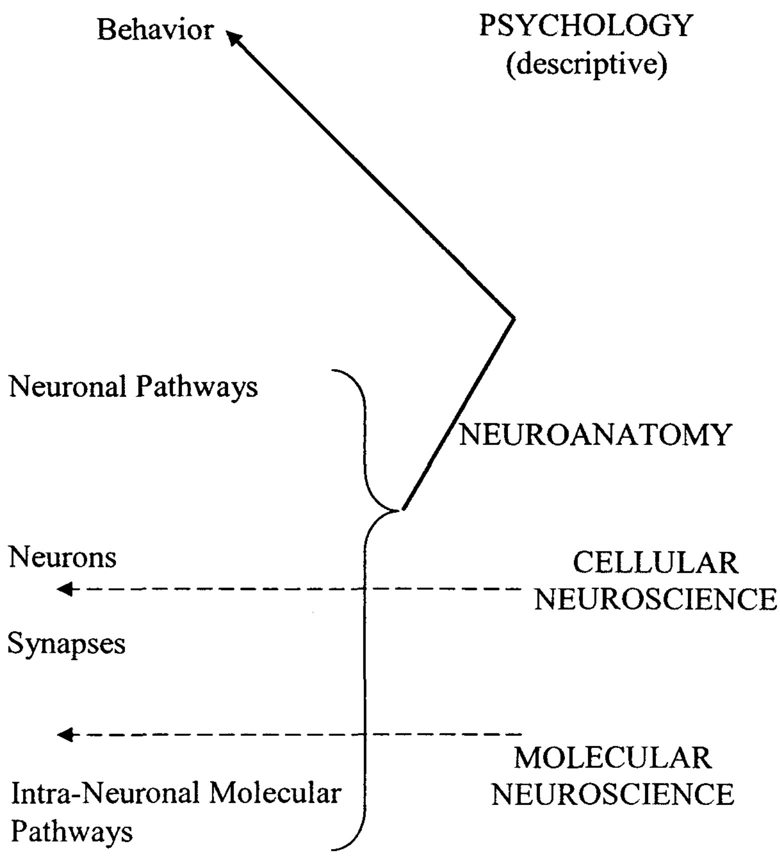


Figure 5.4: Schematic illustration of the "**intervene cellularly/ molecularly and track behaviorally**" account of reduction from cellular and molecular cognition and scopes of the mind-brain sciences addressing these levels. Dashed arrows represent levels of experimental intervention; solid arrow represents the level at which these interventions are measured. Psychology is a descriptive endeavor generating behavioural data, rather than explanatory, contrast with *Fig. 5.3.*

The "intervene cellularly-molecularly and track behaviourally" approach succeeds to reductions of mind to molecular pathways in neurons and their embedding anatomical circuits. This is what reduction is in "ruthlessly reductionistic" current neuroscience. Philosophers (and cognitive scientists) who ignore developments in cellular and molecular neuroscience, will continue to either voice anti-reductionist worries or look for mind-to-brain linkages in the higher-level reaches of cognitive neuroscience. But molecular neuroscientists have developed experimental practices that bridge the behavioral to the molecular pathway levels directly, and these practices are common to all recent empirical successes. These case studies at least bring light the way neuroscience is currently done "on the bench"[22].

Since its explicit discovery in 1973, *Long-Term Potentiation* (LTP) has held promise as one neurobiological mechanism for memory consolidation. LTP is easy to induce and measure physiologically. With the development of improved electrodes and electrophysiological techniques over the past three decades, a popular neural site for studying LTP is the Schaffner Collateral Pathway, a bundle of axons internal to the mammalian hippocampus. The hippocampus itself is a bilateral structure in the medial temporal lobe whose implication in memory consolidation has been known for nearly a half century[23].

Long-Term Potentiation quickly became a popular experimental target. The early experiments on late-phase (L^{-}) LTP were done using hippocampal slices[24]. These experiments confirmed that E–LTP→ L–LTP requires multiple-spaced pulse trains through the stimulating electrode for induction, begins only after the first 1-3h following stimulation, lasts for at least 10h, and requires new protein synthesis.

The search for molecular mechanisms of human memory consolidation: "Finally, social memory requires the hippocampus in both mice and humans, which suggests that social recognition studies in mice may be relevant to the study of human memory mechanisms"[25]. "Molecular and Cellular cognition", as Silva and his colleagues call their field, is alive and thriving in "ruthlessly reductive" cellular and molecular neuroscience[26].

Bickle is right to note that many researchers use techniques from molecular biology and electrophysiology to understand the molecular and synaptic mechanisms implicated in the phenomenon of learning and memory[27]. Some focus on the molecular mechanisms involved in the induction and maintenance of LTP, some on the anatomy of changes in dendritic spines, and some on the structural basis for conformation changes in the NMDA receptor. Others evaluate the relevance of LTP to higher-level phenomena. Different aspects of learning, and memory are found to be localized in different areas of the brain.

LTP was no longer proposed as identical to or as an example of memory, but rather as a component in a multi-level memory mechanism. This shift in explanatory perspective closely defined the goals of the LTP research program and, at the same time, situated the LTP phenomenon in the theoretical framework for integrating fields in the young neurosciences of memory. The kinds of neuronal activities seem to be explained here may be Synaptic plasticity which involves molecular mechanisms.

This fact explains why these two disciplines recognize the levels of organization and methodology pictured in *Fig.* 5.3. but as familiarity with the scope of scientific results already gathered in cellular and molecular cognition reveals, a more "ruthlessly reductive" approach is thriving in cellular and molecular neuroscience, namely the one pictured in *Fig. 5.4.* And neuroscience has already progressed to that stage for more cognitive phenomena than philosophers and cognitive scientists are aware.

5.3 NEW-WAVE 'MOLECULAR-LINK' REDUCTIONISM (RUTHLESS) MODEL OF MEMORY CONSOLIDATION

How to intervene directly with those intercellular molecular pathways in controlled experiments? By manipulating gene expression (knock of specific genes) and insert 'trangene' to overexpress the protein components. Thus we create a mutant mice working with CREB α δ- Knockouts-mice. They are specially bred so that the activator α and δ *isoforms* of the *CREB molecule are not expressed* in cells throughout the body. Further, the scientists have demonstrated that this *Intervention* induces long-term *amnesia* for social recognition memory while leaving intact learning and short-term social recognition memory. That is, this intervention induces a *specific disruption* in the 'consolidation switch' for social recognition memory. Let us try to recollect the hippocampal structures that are involved here with the help of the following figure:

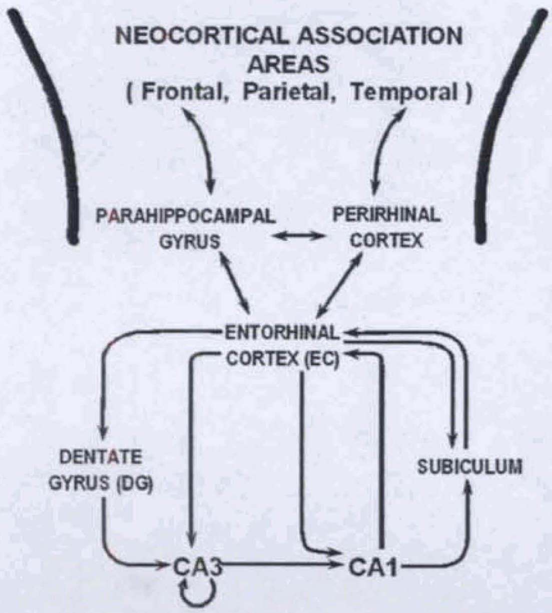


Figure 5.5: Schematic diagram of the hippocampal system

Information from widespread areas of neocortex converge on the parahippocampal region (parahippocampal gyrus,perirhinal cortex, and entorhinal cortex, EC) to be funneled into the processing loops of the hippocampal formation. The tightest loop runs from EC into the core areas of the hippocampus (CA1 and CA3) and back; the loop through the dentate gyrus and there current connections in CA3 are also important; and the subiculum, which is not part of the hippocampus proper, provides an alternative return to EC. Not shown are a number of subcortical inputs and details of pathways and their synapses.

The cellular and molecular processes targeted by the ruthless reductionist are typically not operating parts of these mechanisms but are parts of their operating parts. Whereas on the ruthless reductionist account, their role is primarily heuristic and preparatory of the ultimate account in terms of cellular and molecular processes, the mechanistic reductionist holds that are real causal processes at different levels of organization, and that appropriate research techniques are required to identify these causal processes and relate them in a mechanistic account.

For Bickle, naturalism and reductionism are two competing attitudes (for Bechtel naturalism and reductionism are to be reconciled to each other). Ruthless reductionists try to accomplish mind to molecules "linkages". That is they try to link molecules to mind. In other words, they describe how proteins responsible for the activities of individual nerve cells are related to the complexities of neural processes. Today, it is possible to link the molecular dynamic of individual nerve cells to representation of perceptual and motor acts in brain to relate these internal mechanisms to observable behaviour[28] . Mechanists also cannot easily take refuge in the claim that the types of cognition they are interested in are still at earlier stages of development, warranting the multi-level explanatory approach heuristically. Their favorite neuroscience examples-spatial learning and memory, visual perception-are exactly the cases where "ruthlessly reductionistic" cellular and molecular cognition has enjoyed it greatest successes to date. There is still lots more ink to spill on this issue, but Bickle contends that "intervene cellularly/ molecularly and track behaviourally" account of reduction better captures the practices of cellular and molecular neuroscience than does the analysis of the "new mechanists".

Thus Bickle's formula has as many empirical ways as follows.

Pre-synaptic level → gene expression →
{ [Protein synthesis (DNA →m RNA)] → post –
synaptic level } → motor behavior

We present a mechanism of intervention in three steps.

Step 1: Identify the underlying cell and molecular mechanisms (detection).

Step 2: The technique of intervening (causally via genetically engineered mutant animals).

Step 3: Tracking behaviorally (under controlled conditions with behavioral protocols).

For the ruthless reductionist, this represents the form of explanatory advance that marks important progress in science. Bickle characterizes the project of the ruthless reductionist with the aphorism "intervene cellularly/ molecularly and track behaviorally"[29] which he then explicates:

- Intervene causally at the level of cellular activity or molecular pathways within specific neurons (e.g., via genetically engineered mutant animals).

- Then track the effects of these interventions under controlled experimental conditions using behavioral protocols well accepted within experimental psychology.

The strong claim in Bickle's account of reduction is the appeal to intervening molecularly. He articulates the standard for success in terms of finding cellular or molecular components on which intervention affects the phenomenon of interest: "one claims a successful explanation, a successful search for a cellular or molecular mechanism, or a successful reduction, of a psychological kind when on successfully intervenes at the lower level and then measures a statistically significant behavioural difference"[30].

Bickle contrasts his ruthless reduction approach to that of philosophers who have appealed to cognitive neuroscience as the appropriate locus in neuroscience for explaining cognitive functions. He focuses the difference on the question of whether one can drop multiple levels down in explaining cognitive function.

Many philosophers will still wonder how current neuroscience proposes to step across so many "levels" in a single bound. Between the behavioral and the molecular-biological levels lie (sic) (at least) the cellular, the neuroanatomical, the circuit (neuron networks), the regional, the systems (including the motor system, to generate measurable behavior), and perhaps even the information –bearing and-processing. Must not reductive "bridges" be laid between all these inter-mediaries before we can claim "mind-to-molecular pathway reductions"? And is not cognitive neuroscience-the branch of the discipline that at least some philosophers can claim familiarity with – having enough trouble "bridging" the higher levels to warrant reasonable worries about whether neuroscience will ever pull off the entire reduction?[31].

However, this attitude is completely at odds with that among neuroscientists, especially among the cellular and molecular neuroscientists who now constitute the discipline's mainstream.

Recently, in the introduction to the 4th Edition of their monumentally influential textbook, *Principles of Neural Science*, Eric Kandel, James Schwartz, and Thomas Jessell announce accomplished mind-to-molecules "linkages":

'This book...describes how neural science is attempting to *link molecules to mind* – how proteins responsible for the activities of individual nerve cells are related to the complexities of neural processes. Today it is possible to *link the molecular dynamics of individual nerve cells to representations of perceptual and motor acts in the brain* and to *relate these internal mechanisms to observable behavior*'[32].

Now, Bickle's *first claim* is that these "links" are nothing less than *reductions* of psychological concepts and kinds to molecular-biological mechanisms and pathways.

Bickle's *second claim* is that 'LTP is easy to induce and measure physiologically'.

With the development of improved electrodes and electrophysiological techniques over the past three decades, a popular neural site for studying LTP is the Schaffer collateral pathway, a bundle of axons internal to the mammalian hippocampus.

The hippocampus itself is a bilateral structure in the medial temporal lobe whose implication in memory consolidation has been known for nearly a half-century[33].

What is meant by 'Consolidation" here?

Consolidation is a term that is used to refer to the conversion of labile, easily disrupted short-term memories into their stable long-term form.

The Schaffer collateral pathway projects from neurons in the CA3 region onto neurons in the CA1 region (see pictures). The experimental work revealing the cellular and molecular mechanisms of LTP was done primarily using viable tissue slices, 300–400 microns thick, cut from the hippocampi of young laboratory rats and maintained on slides in a nutrient bath.

Now a stimulating electrode is inserted into the Schaffer collateral bundle projecting from CA3 neurons of the slice and a recording electrode is inserted into the CA1 region. Baseline responses of CA1 neurons are first recorded, either as amplitude of membrane voltage depolarization or time to maximum amplitude of *excitatory post-synaptic potentials* (EPSPs), or as frequency or time to maximum frequency of action potentials, in neurons nearby the recording electrode.

Then either a single burst of electric pulse or a chain of pulses is delivered through the stimulating electrode, inducing strong activity (i.e., a high frequency of action potentials) in Schaffer collateral axons near the stimulating electrode.

The result of this strong afferent (incoming) stimulation "potentiates" specific synapses between affected axons and their CA1 neuron targets.

In other words, in CA1 neurons with potentiated synapses, subsequent pre-synaptic activity produces EPSPs with greater amplitudes and shorter onset times to maximum amplitude, and action potentials at a higher frequency and with shorter times to maximum frequency, compared to (pre-potentiation) baseline values. This effect maintains for durations depending on the potentiating current.

Single bursts through the stimulating electrode potentiate affected Schaffer collateral-CA1 synapses for up to 2 or 3 h. Multiple bursts have potentiated synapses for days, even weeks, and in vivo (in the living animal, a variety of chronic physiological recording techniques).

The whole process is called as: the CAMP-PKA-CREB molecular pathways that uniquely realize memory consolidation across biological classes.

PKA – Protein Kinase (Protein)

CAMP – Cyclic Adenosine Monophosphate (Molecule)

CREB – CAMP-Response Binding Protein

Long-term potentiation quickly became a popular experimental target when the "molecular wave" began washing over neuroscience two decades ago. An influential account of its molecular mechanisms is now in place. Their initial elucidations are from work on invertebrates, and early experiments on late-phase (L-) LTP were done using hippocampal slices[34].

These experiments confirmed that L-LTP requires multiple-spaced pulse trains through the stimulating electrode for induction, begins only after the first 1-3 h following stimulation, lasts for at least 10 h, and requires new protein synthesis[35].

Multiple pulse stimuli through the stimulating electrode in the Schaffer collateral pathway activate interneurons that synapse on the same neurons that receive excitatory projections from the Schaffer collateral axons. The Schaffer collateral axons release glutamate, an amino acid, as their neurotransmitter. Fibers from the *mesolimbic dopaminergic* pathway innervate the hippocampus and release dopamine, a catecholamine, onto the same CA1 pyramidal cells that receive glutamatergic inputs from the Schaffer collateral axons (Fig. 2). Dopamine binding activates a G-protein complex that primes adenylyl cyclase molecules in the post-synaptic dendritic spine to increase the conversion of *adenosine triphospate* (ATP, a principal energy-carrying molecule in cells) into *cyclic adenosine monophospate* (cAMP). This quickly raises the number of cAMP molecules present in the spine. cAMP is the classic "second messenger" substance in molecular biology, which induces activity throughout the cell.

In the case of LTP, cAMP molecules quickly bind to sites on the regulatory subunits of cAMP-dependent *protein kinase A molecules* (PKA), freeing the PKA catalytic subunits.

Adenosine Triphospate (ATP, a principal energy-carrying molecule in cells) cAMP is the classic 'second messenger' substance in molecular biology, which induces activity throughout the cell.

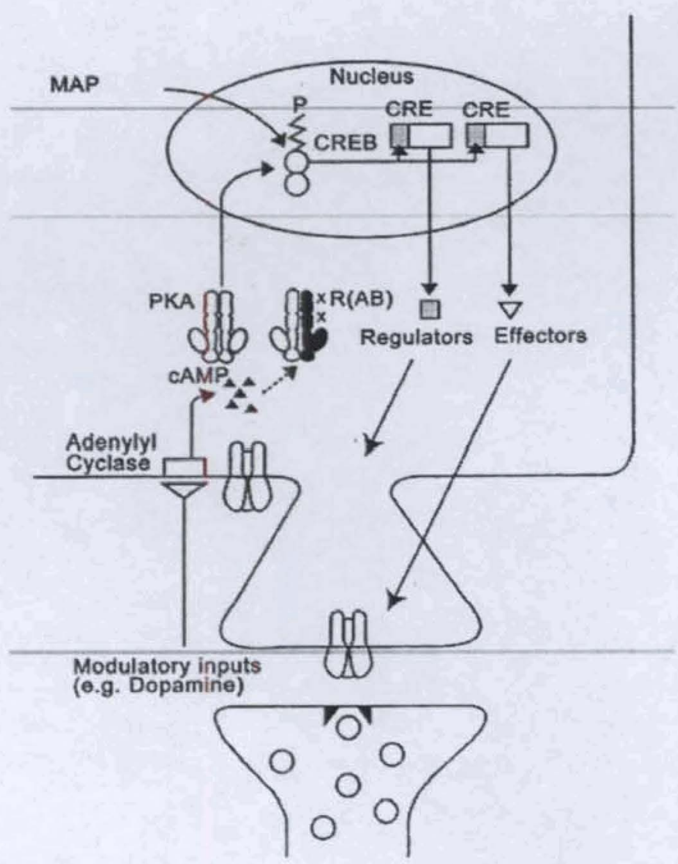


Figure 5.6: Steps in the molecular mechanisms inducing L-LTP at an individual synapse. See text for discussion. Reprinted from Abel et al., (1997), with permission from Elsevier Science[36]

It is extremely hard for a student of philosophy to read the above picture of CREB Molecular Biology. Roughly the steps after omitting the details are as follows:

- The Stem Cell Bio Technological Method (successful in Aplysia: Sea Slug; and Drosophila: Fruit Fly) takes the (ES) Embryonic Stem Cell and injects (Neo) Neomycin-Resistant Gene into it;
- Culture in the lab (on a mitomycin (anti-biotic) solution;
- Then, successful ES Cell are injected into mice to disrupt some of its isoforms (CREB alpha Delta);
- The Consolidation Switch' is turned on;
- That is, knock out specific genes (CREB alpha delta);
- Insert specific transgene (and protein generating → Muting: alpha delta not expressed. When turned on/off;
- CREB alpha Delta loses the long term amnesia for social recognition memory. Thus we intervene at the cellular and track the behavior.

Step 1: CREB is a response element binding Protein. It can activate transcription factors.

DNA → mRNA

Step 2: Some isoforms act as transcription factors.

Step 3: CREB Activity: They turn on/off.

Step 4: One mechanism binds the neurotransmitter dopamine to Post-synaptic receptor.

Step 5: This binding results in conversion of ATP into Camp.

Step 6: This binds on the subunits of PKA molecules.

Step 7: This frees PKA and translocates to the nucleus.

Step 8: The configuration of DNA is changed.

Step 9: This turns on RNA transcription.

The upshot is to show that the interneuron passage includes a new configuration of genetic material as depicted in the above.

5.4 BECHTEL'S ALTERNATIVE MODEL OF MEMORY CONSOLIDATION AND THE LEAD TO CIRCADIAN RHYTHMS

1. The metascientific reductionism carries conviction because it uses the latest simulationist method to produce '*mutant*' mice. A genetically modified mice is shown to His method takes us afar in the field. Bechtel's vision of memory consolidation uses no such method but describes the mechanism in terms of genes (proteins) as well as neurons, even while combines the computationalist as well as 'system' outlook. This becomes very much apparent in what he calls the dynamic mechanistic explanation.

2. Bechtel suggests a shift in focus to Circadian Rhythm for the convenience of experimental accuracy. The molecule is located in midbrain structure of apparently 10000 neurons in each hemisphere located above the optic

chiasm in the anterior hypothalamus. It is the brain's 'Central Clock' which receives appropriate projection from the eyes for the entrainment of light. Craver subjects this to a further critique and counter this by saying that underlying account of causation is not yet made clear from experimental studies.

3. Churchland mentions that LTP and LTD as warranting an untoward consequence. Probably the impending shock can be absorbed in the simulationist account of science. Craver's use of the simulationist account is rather minimal since his central focus lies in adopting a 'transtheoretic' stance which seeks to decentre theory and searches for a normative science which has a nonfoundationalist character.

4. While Bechtel continues to talk about the decompositional structure of mechanic science and takes us to parts and parts of parts without rejecting the dictum the whole is greater than the parts, Craver takes the inversion saying that the greater is part of the greater whole and that is still a part of a greater whole. The underlying hermeneutic point is difficult to fathom.

The upshot is just to point out that the methodological nuances are enough to impinge on the correct picture of explanatory method in biological sciences.

While this is being so, Bechtel's description of NMDA receptor molecule, an idea of plasticity is subtly different from that of others. (1)The major operations in a mechanism were discovered over the ensuing years and involve a number of molecules. In brief, when glutamate, the neurotransmitter that activates neurons exhibiting LTP, binds to *N-methyl-D-aspartate* (NMDA) receptors, they undergo a shape change that exposes pores in the membrane. These pores remain blocked unless the post-synaptic cell generates an action potential, in which case Ca^{++} ions flow into the cell and initiate a chemical cascade the alters the response properties of *α-amino-3-hydroxy-5-methyl-4-isoxazole proprionic acid*(AMPA) receptors,which also binds glutamate but in addition regulate the flow of Na^{+} and K^{+} ions that determine the voltage across the membrane of the post-synaptic cell; (2)The processes of protein synthesis requires activation of DNA in the neuron's nucleus and the engagement of the protein synthesis machinery in the cytoplasm; (3)Communication with the nucleus is realized by *protein kinase* A (PKA) that is released by the binding of cyclic adenosine monophosphate (cAMP) with camp – dependent – PKA molecules. In the nucleus PKA serves to phosphorylate cyclic AMP response element binding protein(CREB), which in turn activates genes that then initiate the synthesis of two proteins.

Let us try to capture his own account before seeing the exact opposition to Bickle's paradigm. The most important point here is that while mechanists can go the whole hog with *molecular* level understanding, still they continue to talk about the whole organism. The other objective will be enlisted below:

Bechtel's opposition is briefly described in terms of the following features:

1. The target of memory consolidation research is a typically *not operating parts themselves at a lower level.* So his *exclusivist concern for 'cellularly-molecularly intervening' level* may be wrong. Both Bechtel and Craver are inclusivists. They favour constitutive invariant relations.
2. Bechtel raises a point against Bickle's holding it as *purely* neuroscientific, conveying that it is only neuroscience and not philosophy. Bechtel argues that it has more cognitive orientation because it is the result of many intervening components.
3. The working parts are decomposed into subcomponents and that is again divided into sub-sub component that get manifested in the behaviour. So there is a no start up → finish linearity.
4. Memory consolidation gets modified into reconsolidation.
5. There are competing architectures.
6. CREB is the 'crux point' but it fails to describe the whole process. The contribution of Amygdala which makes memory to go critical; that is Amygdala modulates the memory process.
7. The memory is also equally affected by REM and NREM Sleep.
8. So Bickle's memory consolidation experiment has serious limitations.
9. Again, in the light of disciplinary settings, Bickle's project can be criticized.

What is Circadian Rhythm (CR)? 'CR are periodic fluctuations in behavioural cognitive and physiological processes that are synchronized with the light-dark cycle of the environment. These Rhythms have a period of about one 24 hour day'.

SCN Cells are found just above the optic chiasm containing 8000-10000 neurons located on both sides of the anterior hypothalamus. It is the Central Clock with an oscillation phenomenon in biology. It brings into integration the subjective experience of time with the objective time.

Computational modelling and research on mechanisms both play important roles in the attempts to understand phenomena in the cognitive sciences and in the life sciences generally. Bechtel's focus is on computational modelling of the oscillators responsible for Circadian Rhythms, the approximately 24 rhythms that are exhibited in a wide of physiological functions (e.g., body temperature), behavioral phenomena (e.g., locomotor activity), and then cognitive activities (as exhibited in e.g., reaction times in performing cognitive tasks)[37]. In particular, circadian modelers probe how the mechanism's organized parts and operations are orchestrated in *real time* to produce dynamic phenomena what we have called dynamic mechanistic explanations (Bechtel and Abrahamsen, in press). Research in this period focused on delineating the phenomenon to be explained: detailing features of *Circadian Rhythms* (e.g., how they change with environmental stimuli) and measuring them. Since circadian phenomena are exhibited in all organisms in which measurement has been possible, including single-cell Cyunobacteria, it seemed likely that the critical oscillator was intra-cellular.

A mechanism is a structure performing a function in virtue of its component parts, component operations, and their organization. The orchestrated functioning of the mechanism, manifested in patterns of change over time in properties of its parts and operations, is responsible for one or more phenomena. Moreover, the model itself shows why computational modelling, not just mental simulation, is required for this- there are many values of the parameters under which the phenomenon does not occur. Mental simulation alone cannot reveal these. Goldbetter's model only `generates what Craver calls a "how possibly" explanation, but when the issue is whether a particular organization of components could realize an effect, that itself is an important contribution to understanding the mechanism[38].

The relation between modelling and mechanistic explanation is very different in cognitive science than in *Circadian Rhythm* research and many other areas of biology. This can be seen by considering more specifically the two forms of computational modelling that until recently, have dominated cognitive science- symbolic modelling and neural network modelling. Despite their differences, symbolic and neural network models share certain points of contrast with circadian models. All involve connectionist neural network models, and were discussed at greater length in Bechtel and Abrahamsen[39]. However, the same points could have been made using symbolic models of the 1980s and 1990s as well as most contemporary cognitive science models.

Attempts to develop mathematical models of *Circadian phenomena* developed simultaneous with their systematic delineation. But as components of the mechanisms were identified, modelars began to incorporate them into their models so as to understand whether and how mechanisms with such components could produce rhythms. These models will be the focus of our discussion, although he will also briefly characterize approaches to modelling circadian rhythms that do not focus on the components of the mechanism. Thus, in addition to modelling efforts directed at the intracellular mechanism he will examine models of synchronization of oscillation between cells. In addition, the population of cells in the SCN is not homogeneous and different regions oscillate somewhat out of synchrony with each other. There are also populations of circadian oscillators in other organs of the body whose oscillations are coordinated with those of the SCN (usually lagging considerably behind the oscillation in the SCN).

Although mechanistic explanation depend upon identifying components whose operations do not produce the phenomenon themselves but only in a collaboration with other parts performing different operations (otherwise there no explanatory gain), generally only the simplest way of linking the components are envisaged (e.g., *linear strings* as in assembly lines). But, as biological mechanisms that enable them to exhibit the properties of living organisms. First *negative feedback* and later *positive feedback* and self-organizing cycles have enriched the ability biologists to understand distinctive features of living systems[40].

At this point they could begin to coordinate *decomposition* with *recomposition* (figuring out spatial and temporal organization of the parts and operations). One clue was that peaks and valleys in concentrations of PER lagged behind those of per mRNA by approximately 8 hours. Moreover, since PER was detected not only in *cytoplasm* (where it is synthesized) but also in the *nucleus*, they proposed a mechanism incorporating a negative feedback loop to explain circadian oscillations in *Drosophila*. Its parts, operations, and organization are illustrated in Figure 5.7. On this account, synthesis of the protein PER is initiated by the transcription of *per* into *per* mRNA, which must be transported to the cytoplasm to be translated into PER. Several hours thereafter PER is transported back into the nucleus, where it slows synthesis of additional PER by somehow inhibiting *per* transcription. (Though not shown, *per* eventually is released from inhibition by the breakdown of nuclear PER, allowing a new turn of the 24-hour cycle to begin).

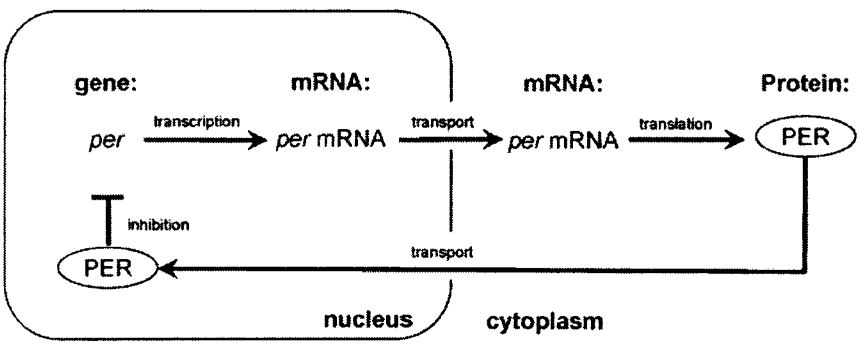


Figure 5.7: Proposed mechanism for generating circadian rhythms in *Drosophila*[41]

While the awareness that organizes coordinate various of their activities with the time of day has been recognized since ancient times, and investigators often suspected that the organisms themselves kept time, the demonstration that this was the case required developing experimental procedures for keeping organisms in constant stimulus conditions and monitoring their activities. The fact that organisms still maintained regular rhythms that were about, but not exactly, 24 hours lead to them being characterized as Circadian (*Circa-about + diem-day*). Two other features of this rhythmic behavior came to be identified as constituting the phenomenon of interest-the ability of the rhythms to be entrained to external cues (Zeitgebers), which is crucial for responding to different day lengths during different seasons (or for those of us who travel across time zones), and the ability to maintain time in different temperature conditions (which usually cause chemical reactions to proceed at different speeds). There is a long legacy of circadian research devoted to providing detailed quantified accounts of circadian phenomena.

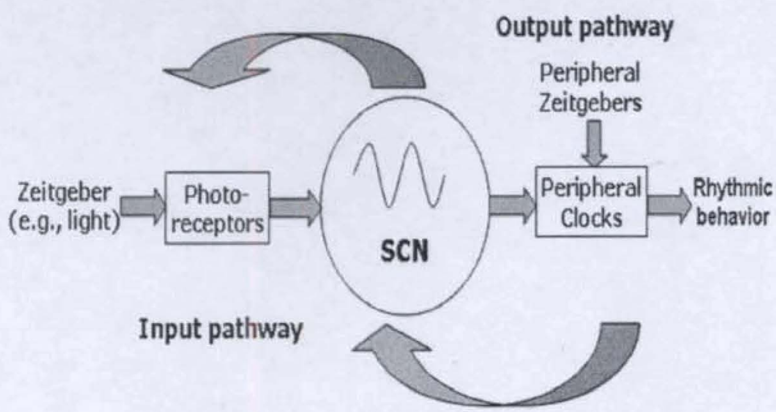


Figure 5.8: Feedback (curved arrows) help integrate components of the overall system responsible for circadian rhythms. Previously these components were construed as forming a linear system (straight arrows)

Moore also demonstrated, using radioactive traces, a pathway from the eyes to the SCN through which a signal about the presence of light could serve to entrain the clock[42]. Further evidence that the SCN was the clock in mammals was provided by finding rhythms in electrical activity even whom the SCN was isolated from the organism and that shortened rhythms could be generated in golden hamsters by transplanting the SCN from a mutant with shorter than usual rhythms into a host whose SCN had been removed, by extracting SCN tissue on to multielectrode arrays, determined that individual neurons in the SCN maintained rhythms, albeit the periods different considerably between individual neurons. The fact that the oscillator within SCN cells can be entrained by light and other *Zeitgebers* and that the SCN can effect behavior generated elsewhere in the organism require linkages between the SCN and other parts of the organism.

After reviewing the research and modelling of intracellular oscillators, Bechtel will more briefly examine modelling of intracellular synchronization and entrainment of the SCN by signals from the retina.

In modelling *Circadian phenomena*, α is set to π/n to make the period of oscillation close to 24 hours. β is commonly set to 4/3 and the parameter ε, referred to as the stiffness since it determines how quickly solutions coverage to a steady state, is set to a low value between 0.1 and 0.25. These models do not make any effort to describe the components of the oscillator but to describe its overall behavior. They continue to be used for a variety of purposes where detail concerning internal operations is not needed. Jewett, Forger and D. Kronauer (1999) for example, used it in their study of entertainment of Circadian Rhythms by light-dark cycle and phase shifts after light pulses[43]. The Goodwin Oscillator has directly or indirectly inspired many efforts to model circadian rhythms once a feedback process like that Goodwin envisaged was identified as central to the Circadian Oscillator. The challenge posed by the unrealistically high hill coefficient has been dealt with in several ways. One strategy is to introduce non-linearity into the degradation terms.

(a)

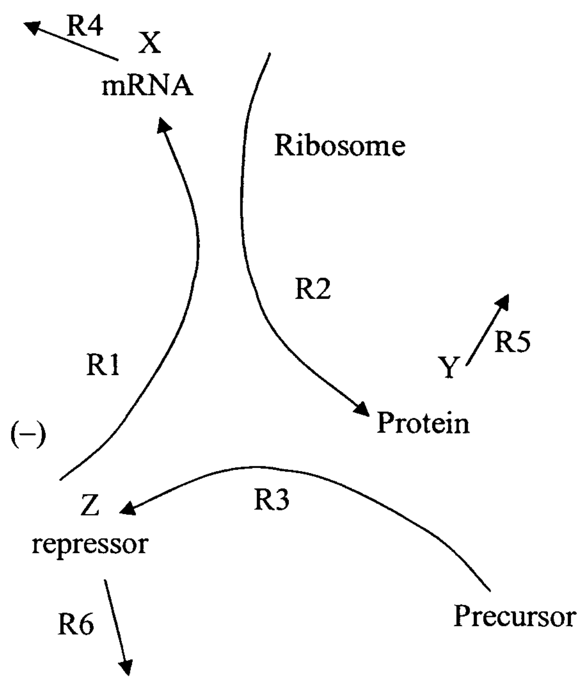


Figure 5.9: The Goodwin Oscillator as developed as a model of circadian rhythms by Gonze *et al*[44].

The first key component of the circadian clock in vertebrates was discovered in *Drosophila* (Fruitfly) in research that involved inducing mutations chemically and screening for mutants which showed aberrant circadian rhythms. Konopka and Benzer found a locus where mutations resulted in rhythms with shortened or lengthened periods or in loss of rhythms altogether, and they designated the responsible gene period (*per*)[45]. Once per had been sequenced in the 1980s researchers discovered that its mRNA and it protein, PER, both cycled in neurons that seemed to be the pacemakers for circadian rhythms in flies with PER lagging about six hours behind the loop. First per was transcribed into an mRNA that was transported to the cytoplasm and translated into a protein, PER. Subsequently, PER was transported back into the nuclear where it ended up suppressing per transcription and translation.

While mechanistic research has developed a powerful array of tools for studying the behavior of mechanisms and for decomposing them into their parts and operations, it does not have as highly developed resources for studying the organization of mechanisms and for understanding how the operations of the parts are organized are orchestrated to produce the phenomena of interest. Accordingly one of the major contributions of computational modelling has been to determine whether the components will interact as anticipated or exhibit phenomena such as instabilities that were not anticipated. The various computational models Bechtel have presented have illustrated this use computational modelling in the study of *circadian rhythms.*

Finally one of the major differences between the various models Bechtel has discussed in the detail at which they represent the mechanism. Both highly abstract modells using the Van der pol oscillator and highly detailed models incorporating roles are to play. Given the different aspects of mechanisms that need to be understood there are needs for different styles of models.

5.5 THE MARCH FORWARD

We are for a final evaluation of the *scientific credentials of cognitive science* in the light of what we have seen in the slightly adjusted format of cognitive neuroscience and cognitive system science. For us, the qualificative term 'cognitive' matter: cognitive in neuroscience speaks of *inclusion* of psychology, and, 'cognition' in systemscience refers to the 'linking' reductionism or what is called *metalevel* cognitive science. There are altogether two paradigms in each.

1. Bechtel is alternative to Bickle in the case of *Memory Consolidation* Exemplar.
2. Craver is alternative to Bechtel in the case of *Circadian Rhythm* Exemplar.

The issue before us is how to adjudicate between these *two* alternatives so as to seek a conclusion regarding the scientific credentials of cognitive science. It matters least whether mere opposition between them impugn the credentials. One may choose to argue that one seeks to do cognitive science in a better way than the other, so much so that no adjudication is called for. Nevertheless we are obliged to show that the issues they raise are acutely scientific that no one writer has been able to unloosen the knots in the above controversy. No Indian writing has gone before to serve as a model (not ever science). This is the first time that these paradigms are imported into India, that too in philosophy department on the West Coast. This is enough to underscore the originality of the thesis which is executed in a set of challenging circumstances.

Thanks to the Cognitive Science Group which facilitated the unlimited access to internet sources which brought the names of the statements who are associated with internationally acclaimed centres of cognitive science. We must note the singular influence of William Bechtel, Carl F. Craver and John Bickle who have provided valuable sources for the pursuit of this project.

We have not spent time to elaborate the challenges for the extent that this will turn the thesis into text book. The major impetus for the work is to learn through the challenges that are fast becoming 'homily' and to assess how these challenges are adequately met.

It is therefore a great opportunity to dwell briefly what we have achieved at the contributing level.

1. <u>The Continuity Thesis</u>: We started with an account of *Cognitive Neuroscience* and *Cognitive Systemscience* as bequeathing two distinct paradigms of memory consolidation research under indirect approach. We have taken the continuity of the Analytical turn and the Cognitive turn as an initial assumption. Such an assumption is a bolt from the blue that is not generally acceptable to the Anglo-American

understanding of cognitive science. The account given by the French Tradition (Daniel Andler) is an exception to this trend.

2. The Ambitious Work: To some extent, we have portrayed the *two* models of memory consolidation and *two* models of *Circadian Rhythms*. By juxtaposing them with each other, it is hoped, we brought out clearly where exactly the scientific claims lie. This is the first venture to bring them all under one doctoral level work.

3. The Need to model on Philosophy of Science: Chapter 1 is a distillation of many of the major issues of philosophy of science. Written within the small campus, it has become too dense in this respect. This is a very original attempt to present the multiple issues in philosophy of science, philosophy of cognitive science together with philosophy of language and mind and it succeeds without sacrificing the details. It is executed after a great deal of reflection on these issues. The Acute Controversy: In the end, we presented two pair of models one pair of opposition in Memory Consolidation Research and another pair of opposition on Circadian Research by way of helping us to assess the scientific credentials of cognitive science. These researches contain the rudiments of simulation based science. We suggested also that they all under an overarching hypothesis of *constructivism*. The question how much of this can save scientific realism in the senses we have considered is moot. We conclude that

the scientific credentials are not only really saved but takes us further into regions of simulation based science.

4. Evaluating ANTCOG: ANTCOG model has been completely reviewed and found to be inadequate even after foisting the gene-neuronal considerations as suggested by developments in Biosemantics in the light of more recent developments in genomic-connectomics oriented Neuroscience and Systemscience.

5. Figures by Courtesy: The most of the schematic figures were developed in the seminars on cognitive science given to the Cognitive Science Group. The other figures are from courtesy from other writers.

6. The New Schema for Reduction: The figure about reduction is a distillation from nearly half a dozen field guides on reduction given by various philosophers of science. But the arrangement is original and the remarks are to the point. The effect must be instant that there is still a way beyond the pointer is to alterity.

7. The Models Galore: The intermixing of the paradigms (fundamentally 3-4) and others is attempted on a somewhat broad campus than it has hitherto been done by other writers. This gives the facility to advance the overarching hypothesis of *Constructivism*. The Sceptic at the Elbow Room: At the same time Craver's reflections on causal relations has shown to intervene into the main controversy between the above twin programmes (*Memory Consolidation and Circadian*

Rhythm). This represents the state-of-the-art in cognitive science because it has a lesson. The lesson is that the relation of temporal and causal sequences need more understanding.

8. Weakens Reductionism to Save Realism: Weakening of the reduction and seeking to obtain a proxy for D-N model (Bechtel). What serves the backdrop here is a third contender model of constructivism. So constructivism taken has an *overarching hypothesis*. In a sense excluding Bickle, all cognitive scientists (Bechtel, Churchland, Craver, Clark, and Hooker, etc.) are shown to be constructivists in one sense or other. The idea of constructivism is not to give a canonical method of scientific method, but to save the phenomena in Fraassen's well-meant sense.

9. Hard to exempt Bickle: while Bechtel is a constructivist in Piaget's sense of Self-Organization, Bickle is not a constructivist, but his account of memory consolidation at the *cellular/molecular level* lays bare an account of synaptic plasticity, which is essential to potentiate memory. Craver's constructivism is drawn from instrumentalist accounts of theory (e.g H-H equation for synaptic potential) and it searches for an account of anti-normative causal description without conceding much to reductionism. Craver's objection is shown to have a starting point here, by telling us that synaptic plasticity which is part of learning is not to be identified with memory. So there emerges a

very complex picture of cognitive science at this level. No attempt however has been made to study plasticity as such.

10. Centralising Bechtel: Throughout the thesis, we have centralised Bechtel's dynamic mechanistic account of cognitive neuroscience as a serious contender of the scientific temper of the age because it gives a complementary account of reductionism. This is as it should be. Bechtel's multifaceted approach brings to the fore an unusual rallying point even if it enters into minor controversies with others.

11. Future Science: We have shown that the scientific credentials of cognitive science lie in *simulation based science*, which takes us further from these controversies. But still the simulation based science is a very much inherent in the approach to *memory consolidation* and *Circadian Rhythm.* Simulation based science almost coheres with computational neuroscience as well as theoretical neuroscience. In no sense the scientific merit of behavioural science is excluded from the purview.

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