Chapter 10

An Attempted Integration of Theories of Creativity and Innovation

The present theory of innovation is intimately connected with theories that are tentatively accepted as explaining certain types of creative activity. The comparative study in this chapter is limited to a handful of possibilities and restricted cases in which a process or mechanism of innovation is postulated. Further, the cases examined are supported by empirical evidence from field studies, historical observation, or (occasionally) laboratory data.

It will be argued that the present theory bears up quite well and does a useful job of work in unifying the theories scrutinised. Insofar as this and other theories are not at odds, even though most other theories taken alone have significant points of difference, it is reasonable to claim that our theory is a generalisation of the others and is also in some respects more detailed. This pretentious-sounding claim is duly qualified; the fact is, the present theory, though it has predictive power, is also tailored to fit limited experimental situations. The others, in contrast, have a far richer field of interpretation. Let us stress at the outset that the present theory is no "better" than the others. It is systemic and the others have a systemic core; the "generalising capabilities" of the theory are limited to the systemic core. But, seen in this light, the unification achieved is extremely useful.

Section 1 contains a brief review of the literature, as a result of which certain comparable theories are winkled out for attention. Next (Section 2), the present theory is expressed in a form applicable to unfettered creativity (yielding an approximation to the statement in Chapter 6 and Chapter 7). Section 3 is devoted to comparing the selected themes with the paradigm of Section 2,

and the results are summarised in Section 4. Methods of fostering creativity (most of them already discussed in a different guise) are noted in Section 5, and Section 6 briefly explores the educational implications.

1. EXISTING THEORIES AND THEIR COMMON FEATURES

The literature on innovation and creativity is widespread and oddly mixed. One aspect of it is concerned with the psychometrics of innovation; ever since Galton's (1883) studies, attempts have been made to demonstrate traits, usually inherited, that are conducive to innovation. For example, Guildford's (1956) divergent-production factors (analysed into several components in his "Structure of Intellect" model) go along with a tendency to innovate, or at least to eschew convergent thinking. Several important facts are generally acknowledged; for instance, given a careful study (such as Taylor and Ellison, 1964, using the biographical-inventory multiple-factor test batteries), it turns out that a propensity to innovate is *not* in register with academic performance and is not differentially predicted by academic success. But, unless the psychometric devices are used in sequential investigations of developmental psychology (Piaget 1968, Baldwin 1966), no specific mechanism of innovation is directly involved.

It is clear that the present (mechanism oriented) theory cannot be compared with theories which involve no serious postulated mechanism; this in no way derates the value of studies aimed at describing or predicting the distribution of creative mental traits in a population or their development as a function of age. However, it seems imprudent to identify reliably testable traits *with* creativity, as some researchers are prone to do. The easily made confusion between a testable feature and a process or mechanism is a category error; committing this error (often in a very sophisticated form) leads to the well-known hazards of (unwittingly) equating "intelligence" with "performance in an intelligence test". The perils are especially great within education, where individual value judgements, "he is intelligent" or "he is creative," are apt to hang upon the results. If only for this reason, we insist that creativity/innovation, whatever else it may be, *is* a process or a mechanism, rather than a cognitive manifestation/behaviour pattern. Hence-

forward, the discussion is confined to theories which postulate a process or mechanism and which may, as an incidental result, be compared with the present theory.

Proposed mechanisms of creativity may very roughly be classified as linguistic or cultural (on the one hand), and individual (on the other). The demarcation is not at all clearcut; individual innovation takes place in a cultural context and is often mediated by linguistic tools such as metaphors designating analogies and parables. For example, the theories of Upton and Sampson (1963), of Cassirer (1946), and Fromm (1951) posit general classes of mechanism that are evidenced by the history of societal transformation or the structure inherent in a corpus of knowledge convention or tradition, for instance, the structure of myths or a style of expression. In contrast, individualistic theories — due to Schon (1963), Koestler (1964), Barnett (1953), Gordon (1961), Elshout and Elshout (1960), Fischer (1969, 1974), and Maslow (1954) — propose more or less specific mechanisms for innovation, and find support either from detailed protocols, laboratory experiments, or the observations made at the level of interviews by designers anthropologists and social or educational psychologists. It is still true from a systemic point of view that the form of innovation in the large (social, cultural or linguistic) is identical with the form of personalised and miniscule innovation.

1.1. Common Features

The theories of Schon, Barnett, Koestler, Fischer, Gordon, Maslow and Elshout have (or may be interpreted as having) certain important features in common. These are:

(1) All of them are concerned with *relations*, either abstract or holding, between tangible objects. For example, innovations in scientific theory deal with relations involving coherent sets of propositions called *theories* (but henceforward, and in line with the terminology of the book, called *theses* to avoid confusing "theories that are innovated" and "theories of innovation"). In contrast, a technical invention, even if backed up by a thesis, results in a relation instanced by a tangible object.

(2) There is a phase of schism or disunity of attention whereby amorphous knowledge is divided into isolated units. The units may

either be problems, specified by adjoining a context to the original relations, or distinct perspectives.

(3) The isolated units are juxtaposed (as a rule, in a larger context or by union in a contrived or accidental event).

(4) The result of this juxtaposition may be abortive; it may be productive.

(5) If productive, the result is an analogy between the original units (relations).

(6) Suppose coalescence does take place and yields an innovation. A "large" innovation corresponds to a *generalised analogy* (our nomenclature), rather than an *isomorphism;* however, isomorphic analogies are usually countenanced as limiting cases of innovation.

(7) The result of coalescence, if it takes place, is accredited as an innovation (rather than an insight or a bright idea) insofar as the general concept, often interpreted in its own universe, can also be represented in one or both of the universes proper to the units generated by a schism.

(8) Very definite subjective events are correlated with the phases (1) to (7); these may be given neurophysiological interpretations.

1.2. Qualifications and Disclaimers

The kind of mental activity countenanced as innovative, either by theories of the type outlined in the previous subsection or by our own theory, is quite narrowly bounded. The definitions involved are technical, and their value rests upon a possibly blinkered specificity.

For example, suppose some children are playing with Papert's (1970) LOGO. A child discovers a principle (for instance, "subroutine" or "partitioning") applicable to existing programs, and the novel program is unequivocably an extrapolation on this basis from the old programs. According to the hypothesis under discussion, this extrapolation is not *in itself* an innovation. But Papert (1970), Bruner (1966), and others sometimes maintain that it is.

There is no fundamental disagreement. On the one hand, it is stupid to argue over teminology (we have already hinted that our technical definition might be unfair and concede that the other usage may be more equitable). But, nomenclature apart, we only

noted that extrapolation is not *in itself* an innovation. Let us agree that extrapolation is necessary (in LOGO, it *is*), and comment that so far as our technical usage is concerned, the child's inventiveness depends upon what is done with the extrapolation, i.e., the new program and its productions (geometrical patterns or whatever), henceforward just "P".

In particular, the child will be innovative if P is used to *suggest* a new idea; that is, if P is juxtraposed with some P* (in the LOGO universe or not) and is found to be analogous, so that P solves a problem suggested by this means. If so, P is used as an *Eolith*: the word is culled from the early work of Storm (1922), resuscitated and developed by Hawkins (1969). In the original context, an Eolith is an object, conventionally a slab of stone or wood, which an innovator stumbles across by accident. It differs from other objects in suggesting a novel use; for example, its shape fits it for use as a plough. The innovator did not have a plough in mind, but he did (say) have in mind the notion of breaking up the ground. He innovates (and his innovation *is* a plough) insofar as the Eolith (P), in juxtaposition with the *class* of earth cutting instruments (P*), forms a functional analogy that is resolved as an invention (the plough). Here, we submit that potential Eoliths are generated by extrapolation, to form P; rather than cropping up by accident. In this respect, the child's extrapolation is like the act of walking over the earth. The result of extrapolation is innovative if P is assimilated in the context of P*, and yields a program that has a radically different function. Probably everyone would agree that *this* is "more innovative" than the extrapolation itself and they might agree (depending upon the detailed conditions) that *only* such *uses* of extrapolation count as "innovative".

It is also worth pointing out that under everyday circumstances an apparent extrapolation can be due to a (technical) innovation, and it is only in an operating system like THOUGHTSTICKER (or a "paired experiment" or a "depth interview" perhaps) that the original assertion, "the program is unequivocally an extrapolation," is justified at all.

2. A GENERAL REPRESENTATION

In order to obtain a clear set of comparisons between specific examples of the creative mechanisms discussed in outline in Sec-

tion 1.1. and the theory under consideration, the present theory will be represented as a scheme. Nothing new is added, and the scheme is merely a collection and crystallisation of points which have already been made.

One prefatory note is in order. All studies of creativity make use of the notion "context". As remarked in Chapter 8, Section 4, a context is needed if any problem or question is to be posed; a relational structure does not, in itself, specify a *problem*, though it may determine an indefinite number of possible problems (Von Foerster and Weston, 1974).

The word "context" is also double edged. The act of attending to a particular universe of compilation and interpretation with a topic in mind furnishes one kind of context insofar as the constraints of this universe impose boundary conditions and dictate that only certain topic relations can be realised. A far richer notion of context (closely related to the meaning imputed in Chapter 8) appears as soon as there are two or more P-Individuals (or, in the original discussion, one P-Individual and an interrogating heuristic). If so, one P-Individual can question the other from his perspective (with queries apposite to his universe) and, of course, vice versa. Insofar as the forthcoming scheme posits the co-existence of two P-Individuals having distinct universes of compilation and interpretation, the idea of a context, in both senses, is firmly embedded in the creative process.

SCHEME 1

Main Postulates	Commentary and Identification
(1) Two or more P-Individuals exist. Two or more contexts are thereby determined.	Two or more people with one focus of attention; each, or one person, having two roles or perspectives, posing two or more problem classes.
(2) These P-Individuals have distinct universes of compilation and interpretation, but their languages have a modicum of syntactic communality.	The universes of compilation and interpretation may be distinct brains or distinct areas in the same brain. Universes of interpretation may be conventionally and metrically distinct (magnetic as against gravitational phenomena; Peru as against Brazil), or they may be different state descriptions of the same object (a classical and a quantum mechanical view of a molecule).

SCHEME 1 (continued)

Main Postulates	Commentary and Identification
(3) One, and only one, focus of attention (P-Individual or aim) is a seat of awareness; though this awareness may be (and if externally observable *is*) the origin of consciousness on the part of one P-Individual *with* another *of* something. Expressed in terms of the macrostate (subjective probability) variables, d_0 (doubt about focus of attention) is high because there is more than one aim so that d_1 (doubt about method) and d_2 (doubt about outcome) are undefined.	Two people may be jointly aware of one topic or two. One person may only say he is aware of one topic at once, though he may say that he is conscious *with* some other person of a topic, or that he is conscious *of* entertaining some other perspective *about* this topic. Whatever else, neither you nor I can say we are aware of two foci of attention (two aims) though our attention may oscillate between two foci of attention (alternative theses or ambiguous figures), and we may be aware of the oscillation.
(4) From (2) the languages of the P-Individuals in question have certain commonly formed expressions. Hence, common meaning agreement is possible in certain universes. Moreover, as a weak postulate, common meaning agreement is *likely*. We shall later argue that it is a *necessary* occurrence.	Common meaning agreement may be deemed likely because of geographical proximity or cultural similarity between people. By the same token, if several P-Individuals are compiled and undergo execution in the same brain the likelihood of overlap may be due to physical limitations. The argument of necessity does not deny the various phenomena responsible. But they are regarded as secondary consequences (secondary, that is, to common meaning). In other words, we maintain that people *must* come into geographical proximity, belong to specific cultural groups, and that brains (or other L-processors) *must* have structures guaranteeing overlap of P-Individuals *because* of the primary requirement, occurrence of common meaning.
(5) If (or, given the necessity of common meaning, whenever) common meaning is resolved, the result is either an isomorphic analogy relation or a generalised analogy relation; these cases, hitherto discussed at some length, are summarised in	Several comments are in order (a) The other than analogical topics in Fig. 10. 1 and 2 may, at one extreme, be simple relations or, at the other, coherent sets of propositions which constitute theses or (apart from the reserved notation) theories.

SCHEME 1 (continued)

Main Postulates	Commentary and Identification
Fig. 10.1 and in Fig. 10.2. The productions of Fig. 10.1 may be counted as innovations and the productions of Fig. 10.2 are invariably counted as innovations. Any of these productions is (formally) a *topic* and is associated with one aim, or attentional focus. Since coalescence of P-Individuals is believed (Chapter 5, Section 11) to involve concurrent operation d_2 will be high (doubt about the stages in computation) whenever d_0 is low enough for the definition of d_1, d_2. There are many processes acting in parallel until a common meaning is reached; as a result, we predict little or no awareness of "an outcome"; at most, there is a Fuzzy "set of outcomes". In contrast d_1 (doubt about method), may be low; and is predictably lower than d_2. That is, the innovator may (d_1 low) or may not (d_1 high) be able to specify a Fuzzy Method for innovation.	(b) An example of Fig. 10.1 is the *discovery* of the isomorphism between mechanical and electrical oscillators; or the invention of an electrical oscillator given a mechanical oscillator. An example of Fig. 10.2 is the *discovery* of the information theoretic interpretation of thermodynamics, or the construction of topics given a realisation of this generalised analogy relation. (c) The productions are taken to include covert and overt exaplanations, as well as the construction of models. The latter productions, being tangible artifacts, are usually tagged as *inventions*. (d) To apprehend the scope of these examples it is important to realise that information theory *could* have been devised as a generalisation of thermodynamics, or vice versa, and someone may, in fact, have discovered information theory by following that route. (e) Since common meaning gives rise to a fresh (single) aim the innovator (whether encompassed by one brain or residing in several) *becomes* aware of the innovation as a novelty produced at the moment when the common meaning agreement is reached.
(6) Resolution of a common meaning may (Chapter 6) and usually does give rise to a richer structure (a generalisation) and it *does* entail mutual interpersonal hypotheses (in the sense of Chapter 6). Moreover, if the conditions of Chapter 6, Section 7 and 8 are satisfied, fresh P-Individuals are created by the resolution through "Conversation Breeding". These conditions sometimes *are* satisfied and "Conversation Breeding" sometimes takes place.	Resolution may either involve an "internal" or an "external" productive interpersonal conversation. The latter case is widely discussed by social psychologists and social anthropologists; notably by Bateson (1972, the Double bind effect, and Higher than Deutero Learning); Bateson (1958, the Naven Ceremonies); Mead (1957); and Shwartz (1962, especially in connection with the "Cargo Cultures" and other Messianic movements).

The postulate (clause 4) that common meaning agreement is necessary is supported on the following grounds, though it could certainly be justified, more satisfactorily perhaps, by means of a formal argument.

The conversation breeding process (clause 6), or some essentially similar variant, is the only mechanism able to produce two or more P-Individuals de novo from one P-Individual, apart from a random process. Notice, that any random process which might be invoked is of a peculiarly fundamental kind; for example, "Noise Sources" and "Background Noise" will not suffice to explain the random element, though appropriate sorts of random generating processes might be employed to describe it. The existence of two or more P-Individuals is required as a base (clause 1) to render this series of definitions recursive, rather than vacuous or terminating. As a matter of empirical fact, the process adumbrated by these definitions does take place.

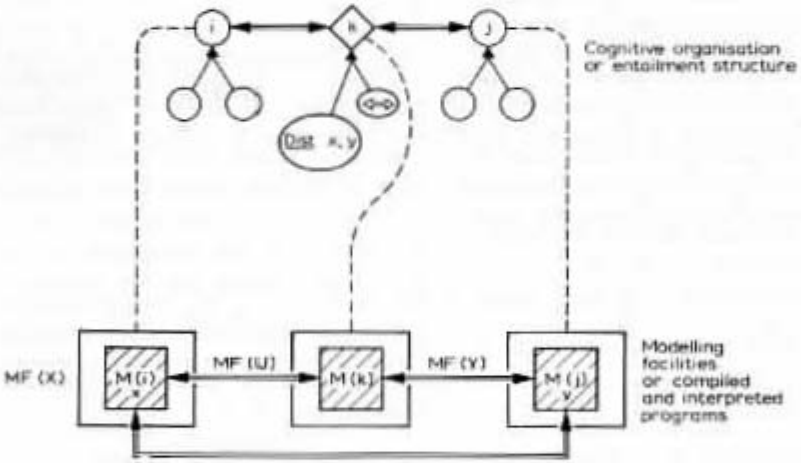

Fig. 10.1. Simple analogy configuration. The isomorphism may be replaced by a *topic* k which expresses the syntactic or formal similarity common to a model (Mi) of *topic* i (in X) and a model M(j) of *topic* j (in Y) which is represented as Model M(k) in any distinct (abstract) universe of interpretation. The universes of interpretation are shown as modelling facilities *MF*(x), *MF*(y), *MF*(u) for simplicity. In general, the interpretations and compilations are in the L-processor of a brain when the Proc i, Proc j notation replaces the representative models M. However, the crux of the construction is captured by noting that the entailment structure induces an isomorphism between models.

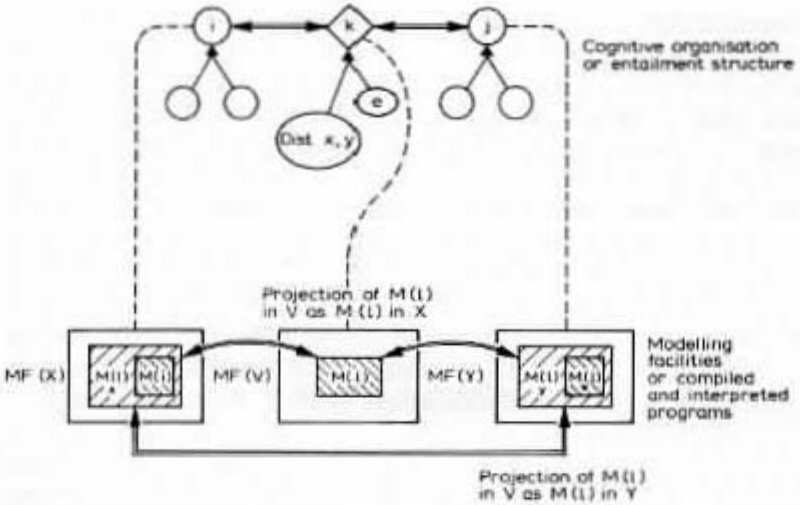

Fig. 10.2. A generalised analogy relation supported by generalised topic ℓ, with a model M(ℓ) in a distinct universe of compilation and interpretation *MF*(V). Projection of M(ℓ) to *MF*(X) yields $M_X(\ell)$ and of M(ℓ) to *MF*(Y) yields $M_Y(\ell)$. Notation is same as Fig. 10.1. M(ℓ) in *MF*(X) is isomorphic with M(ℓ) in *MF*(Y) and M(i) in X is a subsystem of $M_X(\ell)$ and M(j) in Y is a subsystem of $M_Y(\ell)$. At least *one* of these projections *must* exist for a useful material analogy. But models (M_x(i) and M_x(j) are not ismorphic. If modelling facilities *MF* (shown for clarity of expression) are replaced by L processor of brain, and compilation and interpretation of procedures as Procs, then generalised analogy is concurrent execution of Proc i and Proc j. Similar comments are applicable if *MF* is replaced by the fuzzy interpretation set (chapter 4) of a natural language.

We are unwilling to countenance as part of our theory the peculiarly fundamental and subtle type of random event which might, as an alternative to conversation breeding, give rise to the required supply of P-Individuals, because no clear meaning can be given to random events of this calibre. Instead, we invoke the already stated principle, "The least unit is a conversation," and augment it by the further postulate, "In any conversation accommodating more than one possible aim (consequently *not* in general a strict conversation), at least one common meaning agreement is reached after a finite number of occasions (n) and is resolved as a generalised analogy relation".

3. COMPARISON OF THEORIES

In the following section several theories are compared with the present theory in an attempt to achieve non trivial unification. Something is gained by all the theories (our own included).

3.1. Schon's Displacement of Concepts and Innovation

Schon (1963) is primarily concerned with technical innovation, invention on the part of people or teams, and the kind of creativity manifest in understanding (rather than proving) a mathematical proposition. His theory is fruitfully exemplified by mulling through records of industrial invention such as Rossman's (1964) classic and compendious work.

The bare bones of his argument are as follows: the unitary entities in the theory are *concepts* designated "Schon Concepts" *SC*, *contexts*, *metaphors* designated "Schon Metaphors" *SM*, and "displaced concepts" *SD*. A concept may be a proposition, an analogy, or a thesis (alias, a theory). Any concept brings about a relation (R), and it is "structured" by the context in which it appears. All concepts occur in some context. The context is a set of facts, other concepts, and propositions; typically, a thesis, together with an interpretation and an intention (for example, to solve a class of problems).

To show that Schon's theory and our own hypothesis are isomorphic, it will be sufficient to consider the most general case examined by Schon, and to point out that he permits all diminutive or constrained formulations as special cases. Any composite of the general case or a special case is also permissible.

The theory is outlined as follows. Certain concepts are entertained by one person or several, but are distinguished with respect to their universes of interpretation, as for example:

SC_i realises R_i in X
SC_j realises R_j in Y

where X and Y, at least, characterise contexts and problems.

At some point SC_i and SC_j are juxtaposed and related by a Schon Metaphor *SM* which designates a putative or actual analogy relation. In general, the analogy relation

SC_i (*SM*) SC_j

cannot be realised unless steps are taken to modify (displace) SC_i or SC_j or both; for instance, it is not generally possible to realise SC_i in Y or SC_j in X.

Suppose SC_j is transformed, in this conceptual system, to yield *SD* and that *SD*, if realised in Y, yields R_j^* (vice versa, displace SC_i). The displacement is useful if *SD* can be realised in X (though SC_j cannot be) and if it realises R_i^* in X; where R_i^* encompasses R_i. If so, *SD* is *created*, and the model constructed under *SD* in X (which brings about R_i^*) is an invention.

To give a concrete example of the process, one of Schon's colleagues was familiar with the context, X, of recycling and refreshing the constitutents of a closed environment in contact with a polluting entity or further environments. One system, characterised by SC_i, filters and recycles air in a living space after carbon dioxide and other waste products accumulated during habitation are removed. The relation thus preserved is R_i. At the outset, when the requirement for a cleaning device was mooted, Schon's colleague did not immediately muster these ideas, but learned about relations and processes in a further context, Y, of cleaning machines (for example, vacuum cleaners, brooms for brushing sawdust) by a systematic investigation. One machine characterised by SC_j uses a buffer material that is in equilibrial contact with a dirty surface and is readily removable (for instance, dirty sawdust that is thrown away) and preserves a relation R_j in Y. The buffer material must be discarded as soon as the concentration of dirt in *it* is equal to or greater than the concentration of dirt on the *surface* to be cleansed; otherwise, "cleaning" ceases and dirt is transferred back to the surface.

At this stage, it was recognised (*SM*) that the buffer material *is* an *environment* in contact with the larger "open" environment of the surface (a notion from context X). But, if the buffer material (alias, the buffer environment) can be recycled and renewed, the act of cleaning can continue without limit. Various mechanisms are able to secure these requirements, but none of them is identical with the system under SC_i (for recycling and filtering air). One such mechanism, characterised as a *displacement* (*SD*) of SC_i, consists in a buffer environment of fabric in contact with the surface to be cleaned and permeated by a continually flowing liquid dirt solvent. The liquid solvent is recycled so that the dirt it carries can be removed, either by differential absorption, or else along a con-

centration gradient, and the purified liquid used again and again as the primary solvent.

Suppose that *SD*, the displaced concept under examination, really *works*, in the sense that a system or program representing *SD* can be modelled and realised in some concrete or intellectual universe distinct from X or Y (say, in U). If so, *SD* may be, but need not be, realisable in X and/or in Y. At this stage in the proceedings, *SD* is a workable idea and a candidate for realisation in X.

Let *SD*, in fact, be a successful candidate, insofar as a system or program representative of *SD* can be modelled (compiled and executed) in X to bring about a relation R_v of which R_i is a subrelation, so that R_i is satisfied if R_v is satisfied. Alternatively, if M_X as before stands for "model in X of," let both M_X (representative *SC*i) and M_X (representative *SD*) bring about the same relation (R_i), but let M_X (representative *SC*i) be a subsystem of M_X (representative *SD*), so that *SD* furnishes a more general set of cleaning methods than *SC*i. If one or both conditions are satisfied, then any M_X (representative *SD*) is an *invention* (in the concrete sense of an artifact); M_U (representative *SD*) is also an innovation (often, though not necessarily, an abstraction of the invention); and *SM* is the analogy relation, or a metaphor designating it, which Schon regards as closely akin to Cassirer's "Radical Metaphor". Schon also notes that a successful displacement (*SD*) is irreversible. Once that *SD* is established, *SC*i even if evocable is seen in the context of *SD*, since *SC*i is a subsystem of *SD*.

Some of the special cases to which we alluded earlier can be obtained by permuting the origin of the displacement and the universe in which the invention is constructed as a model. For example, *SC*j may be displaced rather than *SC*i or both of them may be displaced. All of the models M_X (representative *SD*), M_Y (representative *SD*), and M_U (representative *SD*) may be constructed as stable entities or only one of them. Further, it is quite possible for Y to play the pivotal role of U (and if U = Y, then U need not be made explicit in the formulation).

Two classes of innovation are distinguished by Schon, and these also are special cases of innovation in general. The two classes differ in the polarity of mental operations.

For *Problematic Enquiry* (stressed so far), there is a problem obtained by juxtaposing X with some *intention* to generate a con-

text and noting that the currently existing repertoire of X interpreted concepts do not solve this problem: here, the problem of making effective cleaning equipment. The inventor casts around another universe, such as Y, in an endeavour to find *SM*, such that *SC*i (*SM*) *SC*j, after which the other operations are applied, either successfully or not.

Speculative Enquiry reverses this order of events. Some *SM* exists (in the inventor's mental repertoire) and *SC*i, *SC*j, or both are built up as hypotheses to satisfy *SC*i (*SM*) *SC*j.

All this is in accord with the present theory, given the following series of identifications (under which the special cases of displacement are given by substitution in Fig. 10.2.). Notations are culled freely from previous chapters, notably 4 and 6.

(a) A Schon concept *SC*i is a concept in the present sense of a compiled procedure. Thus, some typical *SC*s are

*SC*i ⇔ Proc^{0}i; *SC*j ⇔ Proc^{0}j; *SD* ⇔ Proc^{0}k.

The crucial feature is that any *SC*, like any Proc, can be expressed in terms of a syntactic or programmatic part, together with a compilation and interpretation part. So, as before

*SC*i ≙ ⟨Prog a, Inter x⟩, *SC*j ≙ ⟨Prog b, Inter y⟩

where a = b only in the relatively uninteresting case where the displacement is trivial (an isomorphic analogy; the same program is compiled and interpreted in a different universe).

Further, *SD* ≙ ⟨Prog c, Inter u⟩ = Proc^{0}k

where U is generally an abstract universe (concrete if viewed as a brain or L-Processor, but having no direct correspondence with other than mathematical realities).

(b) R_i is computed by *SC*i (alias Proc^{0}i) in a universe X; R_j is computed by SC_j (alias Proc^{0}j) in a universe Y.

(c) The usual situation is that Prog b in *SC*j (alias ⟨Prog b, Inter y⟩) cannot be compiled and executed as it stands in universe X (that is, ⟨Prog b, Inter x⟩ is either impossible or impossible in the context of other concepts in the innovator's repertoire. From Chapter 5, Section 11, recall the expedient of writing *DB** to represent an actually more subtle act involving the synchronisation of a priori asynchronous procedures.

(d) There is a transformation $DB^*(R_j, R_m) \Rightarrow R_k$ and a transformation $PB^*(\underline{Proc}^0 j, \underline{Proc}^0 m, R_k) \Rightarrow \underline{Proc}^0 k$ (the notation of Chapter 5 with m, ℓ and n free indices) that yields the displaced concept *SD* (alias $\underline{Proc}^0 k = \langle \underline{Prog}\ c, \underline{Inter}\ u \rangle$) compiled and executed in a universe U. From the preceding description, *SD* is useful if, and only if, Prog c can be compiled and interpreted in universe X also; that is, as a further concept written $\underline{Proc}^0 \ell$. With *DB* an isomorphism, the transformation is the generalised analogy operation of Chapter 5, Section 11, namely, $DB^*(R_k, R_l) \Rightarrow R_\ell$; $PB(\underline{Proc}^0 k, R_\ell) \Rightarrow \underline{Proc}^0 \ell$. We stress the important caveat of Chapter 4 that this expression only simulates an actuality or furnishes a convenient shorthand. Strictly and practically, we have no right to talk of *DB* or *PB* acting between P-Individuals, and it is maintained (clause j below) that $\underline{Proc}^0 i$ and $\underline{Proc}^0 j$ belong to distinct P-Individuals.

(e) The formalism uncovers an otherwise elusive feature of Schon's theory. *SD* is slightly (and, in the original frame of reference, harmlessly) ambiguous; it stands for both $\underline{Proc}^0 k$ and $\underline{Proc}^0 \ell$, designating uniquely only the syntactic component (Prog c) which these concepts share in common. Schon's argument implicitly calls for an extra-theoretic universe of interpretation; hence, we spoke in our previous discussion of "*SD* interpreted in U" and of "*SD* interpreted in X".

(f) An acceptable displacement usually has the further property that $\underline{Proc}^0 i$ is a subsystem of $\underline{Proc}^0 \ell$, and it is often true that Prog can be compiled and interpreted in Y, as $\underline{Proc}^0 r$, such that $\underline{Proc}^0 j$ is a subsystem of $\underline{Proc}^0 r$. These conditions usually imply that Prog a is a subprogram of Prog c and that Prog b is a subprogram of Prog c. * Hence, the irreversibility of displacement provided that $\underline{Proc}^0 \ell$, $\underline{Proc}^0 r$ are replicated by appropriate memories (as they must be if able to count as concepts in the first place).

(g) The invention, previously glossed as M_X (representative *SD*), is a model realised in universe X. For consistency with the previous discussion, X is characterised as a modelling facility *MF*(X), and the invention becomes simply a model M_ℓ compiled and submitted for execution in *MF*(X). Thus, the invention is M_ℓ and is a more general construction than M_i (which is a subsystem of M_ℓ).

* More complex possibilities can be envisaged but will not be discussed because they do not modify the main contention of irreversibility.

(h) Recalling the earlier chapters, M_i and M_ℓ figure as compilations in X of S Prog i and S Prog ℓ, where S Prog i is a serial representative of Prog a, and S Prog ℓ is a serial representative of Prog c. The execution of M_i in $MF(X)$ brings about R_i; the execution of M_ℓ in $MF(X)$ brings about R_ℓ, and R_i is a part of R_ℓ.

(i) The crucial feature of this line of argument — recall the caveat in clause (d) — is that two (or more P-Individuals exist with distinct foci of attention or (if the whole construction is referred to a conversational domain) two or more aim topics. That is, the node of R_i is in the EntSet of a node I with subordinates (at some depth) circumscribing X, and the node of R_j is in the EntSet of a node J with subordinates (at some depth) circumscribing Y. Equisignificantly, R_i is interpreted in X; R_j in Y; and X, Y are distinct.

(j) Displacement may be initiated by an externally presented problem; for example, that an existing artifact, M_i realising R_i is inadequate for a certain purpose or in a certain situation. Equally well, it may be engendered internally insofar as pairs of concepts (Proc^{0}i, Proc^{0}j) which are capable of displacement to yield Proc^{0}k, Proc^{0}ℓ, and M_ℓ arise in the course of an ongoing conversation between P-Individuals A_1 and A_2 (Proc^{0}i in A_1's focus of attention, or aim; Proc^{0}j in A_2's focus of attention or aim). As a matter of interest, it appears that any displacement which is engendered by external constraints or boundary conditions may be represented with some advantage in a conversational domain (so that "aim of A_1" and "aim of A_2" correspond to markers placed on an entailment structure).

Whether external constraints exist or not, two cases need attention. Either the displacement involves a team of two persons $\langle A_1, \alpha\rangle$, $\langle A_2, \beta\rangle$, or one inventor in the transient condition of maintaining two P-Individuals; namely, $\langle A_1, \alpha\rangle$, $\langle A_2, \alpha\rangle$. In any case, the two P-Individuals, A_1, A_2 are distinct prior to displacement and are coalesced at the moment of displacement. For unconstrained innovation, the "team" is presumably a "think tank" or a "T group" or a "Free Innovation Group"; the inventor becomes an "ideator".

(k) The context varies in the course of displacement. Its magnitude may be roughly appraised if the mental operations are referred to a conversational domain. It is greater than the concepts attached to nodes in the intersection of EntSet I (where I is A_1's

aim, the X focussed context) and EntSet J (where J is A_2's aim, the Y focussed context). It is less than the concepts attached to nodes in the union of EntSet I, EntSet J.

(l) Innovation, according to Schon's theory, satisfies the conditions set out in Scheme 1; we show this by outlining Scheme 2 (below) and placing it in register. The important distinction between Problematic Enquiry and Speculative Enquiry tallies with the distinction (Chapter 5 and Chapter 6) between "discoving an analogy with topics given" (Problematic Enquiry) and the "analogy first" construction (Speculative Enquiry). This distinction is chiefly obtrusive in clause 5 of Scheme 1.

Displacement, according to Schon's theory may either be interpreted as "successful displacement" (when it adumbrates all of Scheme 1), or as a process that satisfies clauses 5 and 6 of Scheme 1. Both interpretations are legitimate; their relative utility depends upon the purpose in hand.

SCHEME 2

Clause in Scheme 1	"Displacement" Conditions or Events
1	Two (or more) contexts and perspectives X, Y.
2	*SC*i in X, *SC*j in Y.
3	Awareness postulates and observations in *The Displacement of Concepts* (not described in this overview).
4	For some *SM*; *SC*i (*SM*) *SC*j is possible, and may be likely.
5	Production of *SD* to support *SM*.
6	Resolution (the several special cases) and generation of two or more contexts/perspectives required in (1).

3.2. Cultural Innovation

Barnett approaches innovation from an anthropologist's position and derives empirical support from various cultures; notably, from detailed studies of the American Indian Shaker cult (a deviant but devout religious group, founded in the mid-1700s near New York). However, the underlying theory of innovation is applicable to individual as well as societal transformations.

The basic mechanism is similar to displacement, and by token of Scheme 2 and the preceding identifications, it is compatible with the conversation theoretic hypothesis. Compared to Schon, the detailed argument put forward by Barnett (1953) is tortuous, complicated, and difficult to exhibit for stage by stage analysis. The complexity is essential for two main reasons.

(a) Since the theory is primarily societal, it is expedient to distinguish several types or subprocesses of innovation (for example, "assimilation" and "projection") and various phases of innovation (for example, "identification" and "incorporation" and "analysis"). Expediency becomes a necessity insofar as innovative cultural transformations involve a great deal of other-than-innovative activity from which they cannot be meaningfully extricated: thinking, learning, adaptation; symbolic, normative, and ritualistic modifications.

(b) Again, because of the societal interpretation, it is necessary to enrich the paradigmatic situation. When talking of invention for instance, it is reasonable to deal in terms of analogies between two topics with the caveat (frequently stressed in the earlier pages) that n-fold-analogies ($n > 2$) and analogies-between-analogies are often intended. Little is lost by this piecemeal approach, and the relevant processes are much more easily represented. In contrast, it would certainly be unrealistic to cite generalised analogies involving two topics as exemplars of cultural transformations. As a result, any cogent argument must comprehend very elaborate clusters of innovation.

No attempt is made to summarise the full force of Barnett's argument (the burden of which is carried by Chapter VII and VIII of *Innovation, The Basis of Cultural Change* and by an *Appendix on the Nature of "Things"*). However, it is possible to accomodate the basic theory as compatible with Scheme 1 under the following identifications.

(A) The primary units are configurations ("Barnett configurations" *BC*) which themselves relate several concepts. A configuration may be conceived as a whole since it is a stable entity, or analysed in a context into its parts. The *BC* are identified either with stable *understandings* of a concept class in a P-Individual, or with P-Individuals. In all cases that involve innovation (in contrast

to the other cultural transformations of learning, and so on), either identification is apposite. Thus, the P-Individuals of clauses 1, 2 and 3 in Scheme 1 are *BC* (henceforward, just A_1 and A_2) without commitment to their locus of execution (several *BC* in one brain or a *BC* distributed over several brains).

But A_1 consists in a replicative collection of other *BC*s (some but not all of which may be factor P-Individuals in their own right); call them BC_1^1, BC_1^2 .... Similarly, for A_2 there is a collection of *BC*s, say BC_2^1, BC_2^2 .... At the least, a BC_1^i may be a stable $\underline{\text{Proc}}^0$i, namely a concept; generally, it is a cluster of concepts, the constituent $\underline{\text{Proc}}^0$i in which must be extracted by analysis in a given context. If such an analysis is carried out for $\underline{\text{Proc}}^0$i (alias BC_1^i) in A_1 and for $\underline{\text{Proc}}^0$j (alias BC_2^j) in A_2, then the relations R_i, R_j brought about by executing $\underline{\text{Proc}}^0$i and $\underline{\text{Proc}}^0$j are interpreted in distinct universes (X, Y).

(B) At the least, R_i and R_j are simple. In general (herein lies the complexity as well as the verisimilitude), they are analogy relations to begin with. For example, *BC* may be a Schon analogy *SC*u(*SM*)*SC*v.

(C) The context in which BC_1^i and BC_2^j are isolated and juxtaposed may be set by external means; for example, if an A_1, A_2 conversation is referred to a conversational domain, or if a problem is specified by external boundary conditions. It may also arise autonomously in the course of A_1, A_2 dialogue.

(D) Barnett uses a special term "Barnett Analogy" (*BA*) to designate both the juxtaposition and its resolution. Thus, *BA* is an L^1 operation (a $\underline{\text{Proc}}^1$ in the present theory) which may be approximated by the *DB**, *PB** construction of Section 3.1, augmented by a pivotal *SD* in a universe U. However, at this stage, there are two important differences between the elementary sort of displacement so far investigated and the action of a *BA*.

First of all, the *BC*s upon which *BA* operates may be inherently complex; configurations such as the resolutions *BC* = *SC*u(*SM*)*SC*v or *BC* = *SC*s(*SM*)*SC*t, so that *BA* gives rise to various structures; for example,

$$BC_{12}^1 = \langle SCu(SM)SCv(BA_1)SCs(SM)SCt\rangle$$

$$BC_{12}^2 = \langle SCu(SM)SCv(BA_2)SCt(SM)SCs\rangle$$

(which are analogies between analogy relations), or to diminuitive

forms of which $BC^3_{12} = (SCu(BA_3)SCs)$; $BC^4_{12} = (SCu(BA_4)SCt)$; $BC^5_{12} = (SCv(BA_5)SCs)$, are some examples. Moreover, in interesting cases at least one, and possibly several, *SC* are displaced to *SD*. Such colligations are called *hybrids*.

The other difference, a source of equally legitimate complexity, is that the *BC*s arising in the process are, or may be, viable P-Individuals. Of the two differences, the latter underlines the cautionary comments of Chapter 5, Section 11. Although *BA*, qua operation, may be expressed in the manner of Section 3.1(d), this formulation is approximate; it is a scarcely legitimate shorthand. Barnett's use of hybrid is singularly apposite. The resulting configuration does resemble a resonance hybrid (using the jargon of elementary chemistry) and like a resonant, in contrast to a tautomeric molecule, may only be accurately pictured within some more comprehensive (in the chemical case, quantum mechanical) frame of reference.

If the emergent *BC* is complex and is stable, it is itself a P-Individual, and in this case the formation of a hybrid is not only a complex displacement, but is also an example of "Conversation Breeding" (Scheme 1, clause 6). Barnett makes the point explicit by noting that innovation is (symbolic) *evolution*. The power of his theory, as well as much of its complexity, resides in the fact that evolutionary processes are accommodated within the theory.

The price paid for such an encompassing construction is that several situations have an air of strangeness about them. For example, it sounds odd and almost like a conundrum to say that a concept (or the relation it brings about) is both the same as some other concept and also different to this other concept, given a particular *BA*. This difficulty, at least, may be surmounted by recognising that stable *BC*s are P-Individuals (A_1, A_2; that the similar-or-different concepts are part of different *BC*s (A_1's repertoire and A_2's repertoire); that A_1 and A_2 have distinct perspectives (or, where the notion is applicable, distinct aims); and finally, that the distinct points of view (A_1's and A_2's) may be resolved as a syntactic similarity and a semantic difference (Dist (x, y)) if A_1 and A_2 coalesce in the process of breeding further *BC*s.

3.3. Innovation as "Bissociation"

Koestler's masterly *Act of Creation* (1964) contains the clearest statement of a theory compatible with our own. There is a very

close similarity between the theories of Koestler, Barnett and Schon (the wealth of examples obviously spring from distinct sources), but Koestler is far more explicit about the dynamic character of the entities involved and comments at greater length upon the role of consciousness in the creative process. Part of the argument appeals to historical and conceptual reality, and part of it (the latter half of the book) is couched in terms of a process oriented physiological allegory. That is, unconscious activity and so on are tacitly identified with the operation of functional subsystems in a brain which is differentiated (on the one hand) as more or less automatic and (on the other) as more or less phylogenetically archaic. "Allegory" carries no pejorative overtones. It merely stakes out a salutory distinction between unique and multiple causality. Thus, the posited mechanisms *may be* responsible for the psychological effects; on some occasions, they probably *are* the causative agents. But so may many other mechanisms act in this capacity. Like Hebb (1949) when he speaks of "cell assemblies" or "phase sequences" as the progenitors of psychic events, Koestler is using one possible mechanism in order to tell a true story about ubiquitous mental happenings, which may, or may not, have a direct connection with physiological processes.

With that qualification, the unitary constituents of Koestler's theory are matrices (*KM*) and an operation between matrices called "Bissociation" (in contrast to a comparable operation upon one matrix, which is *association*). "Matrix" is a rubric given to various coherent and rule obeying mental activities (from Bartlett's (1932) "schemata" to "skills"). Certainly, a "matrix" tallies with a class of stable Proc^{0}i (concepts that are undergoing execution with respect of one universe of interpretation). Matrices denoted *KMX* (in X) and *KMY* (in Y), where X and Y are distinct (no conjunctive derivation has been established to unite them), and thus belong to two P-Individuals A_1 and A_2 (separate people $\langle A_1, \alpha \rangle, \langle A_2, \beta \rangle$ or more usually as roles or perspectives entertained by one person $\langle A_1, \alpha \rangle, \langle A_2, \alpha \rangle$).

Cognitive operations involving only one P-Individual (within or upon *KMX* or *KMY* in isolation) are either run of the mill learning processes (imaged by one-aim-at-once transactions) or the constructive act of *extrapolation* (Chapter 7). Koestler classes all of these operations as *associative* operations.

Bissociation, the crucial process, involves the coexistence of two

P-Individuals A_1, A_2 as matrices *KMX* and *KMY*; their subsequent coalescence to yield a novel or displaced concept and the modification of concepts that exist in the repertoires of A_1 and of A_2. Koestler identifies the phase of analysis (where some $\underline{\text{Proc}}^0$i stands out from *KMX* and some $\underline{\text{Proc}}^0$j stands out from *KMY*) with the "Conversation Breeding" of Scheme 1, clause 6 and the juxtaposition of the P-Individuals (or the *KMX*, *KMY*) as conversational participants. He identifies the phase of coalescence with the action of a mechanism such as the *DB*, *PB* approximated transformation of Section 3.1(d) or Section 3.2(D). The outcome of coalescence is either *nothing* or a further and *novel* matrix *KM**. These words are not Koestler's but the "translation" appears to be justified by the previous discussion and by Scheme 3 which places Koestler's terminology in register with Scheme 1.

SCHEME 3

Clause in Scheme 1	"Bissociative" Phase
(1)	Two or more contexts, in perspectives generated in (6) below; *KMX*, *KMY*, or A_1, A_2
(2)	Proc^0i in *KMX* and Proc^0j in *KMY* are subject of A_1, A_2 dialogue, possibly yielding agreement over common meaning.
(3)	The process is unconscious until *KMX* and *KMY* are differentiated. At that point, there is consciousness of a similarity and a difference between Proc^0i in *KMX* and Proc^0j in *KMY*.
(4)	Bissociation of *KMX* and *KMY* is possible and may be likely or necessary.
(5)	*KM** is produced to support any other-than-void bissociation.
(6)	If *KM** (or the bissociation) is stable, it may constitute a further context, as required in (1).

Bissociation may be induced externally by deliberate intervention to juxtapose *KMX* and *KMY*. Telling a joke that juxtaposes two or more bizarre sets of rules has this calibre, so does a funny cartoon or the illusion figures, or a comical play (for example, in a Feydeau Farce the juxtaposition of men in wardrobes with the universe of crown princes, anarchists, and fashionable eccentrics).

The psychological concomitant of this event is stress, and it

may lead to laughter or evaporate in a cathartic process. But it may also lead to the production of a novel "matrix" *KM**, which (side condition) can be replicated and stabilised.

That is, something (*KM**) may be created by the joke. If this condition is satisfied, then the bissociation is productive or resolved as an innovation.

Koestler stresses humour because it is inherently important and also because its symptoms are unequivocal and reflexlike (we cannot tell by inspection if someone thinks a story is beautiful; we can tell by his smile that he considers it amusing). However, he emphasises that humour is only one of the concomitants of stress (the same play may induce fear, joy, laughter or sympathy). Moreover, plays can be constructed as comedies or tragedies; the same is true of any work of art.

Turn now to the issue of spontaneous creativity (invention or whatever). Koestler accounts for spontaneous creation in terms of various mechanisms and at a chiefly descriptive level discusses their experiential concomitants. His argument is:

(a) *KM*s are continually active (essentially the "man must learn" requirement of conversation theory).

(b) The distinction between universes is not absolute (this we paraphrase by saying that Dist (x, y) depends upon an interpretation of what may be known within some thesis to which the participant subscribes; and saying also that the distinction is relative to a Fuzzy Universe).

(c) The main mechanism fostering innovation genesis is *reculer pour mieux sauter* (roughly, taking a step backwards in order to make a better leap ahead). The "leap ahead" is innovation. The "step back" is conceived as reference to distinct modes of brain activity, perhaps characteristic of the limbic system or any other phylogenetically ancient structure, rather than the neocortex. This contention may be too specialised (it is part of the physiological allegory), but our theory predicts that innovation genesis and the possibility of bissociation are often heralded by awareness of different and conceivably more primitive rules; the activity of *KM*s (say *KMU* or *KMV*) that do not enter into consciousness because their activity is asynchronous. Consciousness occurs at a point of partial or local synchronicity.

(d) The innovator is commonly unconscious of (unable to com-

municate with some other sentient being, about) both *KMX* and *KMY* until such moment as resolution is attempted. After that, there are two possibilities. If resolution is unsuccessful, then *KMX* and *KMY* will alternate, temporarily, in consciousness, like the alternating perspectives of an ambiguous picture. If it is successful, *KM** will emerge as an innovation.

On translation: *KMX* and *KMY* are, or belong to, two P-Individuals A_1, A_2 with initially independent execution. As such, they are asynchronously executed. There is thus no information transfer (in Petri's sense) and, at that instant, A_1 and A_2 are not conscious, with each other, of anything in X or Y (though they may be conscious of an alternation of *KMX* and *KMY* or conscious of their distinction and their similarity, separately).

(e) Resolution of *KMX* and *KMY* is treated uniformly (spontaneous creativity does not differ in this respect from induced innovation). Bissociation may be equated to the achievement of a common meaning agreement between A_1 and A_2. If successful, *KM** is a generalised analogy relation.

If the resolution results in an innovative (generalised) analogy, then, equisignificantly, there appears a novel P-Individual A (the fused hybrid of A_1 and A_2) or a novel concept is created; namely, the innovation *KM** from which *KMX* and *KMY* may be retrievable (with augmented meanings, as Schon insists) as specific precursors.

Koestler summarises some of his psychological points by comparing salient features of habitual (and commonly rigid, ritualistic or automatic) thinking with features of creative and innovative thinking, using a table for this purpose. The pertinent entries in Koestler's table are copied into Scheme 4, where they are related to constructs in conversation theory.

One last point is worth making. Nearly all the creative processes discussed by Koestler (and similar remarks apply to the other authors when they deal with creativity in one person) involve characterisation. This is especially true of the conditions (humour, laughter, pathos, agony, surprise, and so on) which are forerunners of bissociation itself. For example, members of a theatre audience identify themselves with more than one character in a play and thus enact and extrapolate the plot in their own mind. "Stepping back to leap forward" is another example, since in doing so, I see myself as I was (quite apart from the "back to the primitive mind"

SCHEME 4

Habitual		Innovation	
Association	Integral P-Individual	Bissociation	Transient multiple P-Individuals
Preconscious guidance of process (may become conscious or not)	Mental operations other than generalised analogy	Subconscious guidance of process (may become conscious or not)	Operations of Chapter 4, Section 10
Dynamic equilibrium	(Ideally) Understanding under one aim condition	Evolution	Conversation Breeding agreement by common meaning necessarily involves more than one aim operation
Variations on theme	Learning or simple extension of entailment structure	*Reculer pour mieux sauter*	Assimilation of domains into Fuzzy Structure
Repetition or mechanical derivation	Problem solving or automatic operation	Novel ideation	Analogy resolution often followed or preceded by (one aim) extrapolation
Conservative and stabilising function	Cognitive fixity	Partly conservative but also revolutionary function	Cognitive fixity in any one P-Individual momentarily disrupted by intrusion of other P-Individual

connotation) and see myself also as I am. Here, as in a member of an audience, there is an internal dialogue between the constructed personalities. This fission and dialogue is predictable, according to the present theory; for, we expect that any generalised analogy achieved by resolution of several aims or foci of attention will be founded upon an exchange of personalised hypotheses, as well as hypotheses which refer directly to the matter in hand.

3.4. Operational Creativity and Synectics

Around the mid-1940s, W. J. Gordon and several colleagues began to develop means for encouraging innovative activities on the part of individuals and groups. Much of their work during the 1950s, which is reported in Gordon (1961) and Prince (1970), took place against the background of industry (in a division of Arthur D. Little, Inc., and at a later stage in an independent organisation, Synectics, Inc.) and dealt with technical invention and innovative solutions to managerial or administrative problems. However, both authors stress the (indisputable) relevance and efficacity of synectic methods in education.

Like the other creativity theorists, advocates of synectics (from the Greek for "joining distinct and superficially irrelevant components") emphasise the role of analogy, of personal perspective, of juxtaposition and resolution. However, since they are concerned with operationally practical methods for conducting group sessions or guiding individual thinkers, these principles emerge with great clarity and lead to positive recommendations. For example, exemplary universes of compilation and interpretation (the "worlds" of synectic theory) are explicitly listed, as are the manoeuvres to be adopted by a group leader in order to enliven dialogue whilst introducing the minimum possible bias.

Prince (1970) tries, as I have done, to express cyclic, iterated, and often concurrent operations as easily communicated process charts; he makes precisely the same reservations (for example, that the process which is being depicted is not really serial, that it may be distributed or localised). With these reservations in mind, Scheme 5 (below) is an attempt to summarise the salient characteristics of a group activity which fosters innovation. Any group of this kind includes, amongst other participants, a subject matter expert (or, at any rate, someone having access to the facts of a

problem area), and a group leader who plays a catalytic role, as well as monitoring application of the heuristic embodied in Scheme 5. The "examination" phases involve the expert, though he is not allowed to suppress imaginative and seemingly bizarre propositions; the "choice" phases are introduced insofar as group discussion is more efficiently focussed upon one major topic at once, without prejudice to the likelihood that individual participants follow different trains of thought.

All phases, apart from selection (ultimately the leader's prerogative) and personal analogy (Phase 6, the participants brood on their own), are accompanied by lively debate, during which the participants criticise and comment upon each other's ideas. The participants are also encouraged to expand the interpretation of their dialogue, so far as possible, by mustering and citing odd bits of special knowledge; especially, if it is arcane or recondite. For example, in the protocol (from Prince 1970) on which the scheme is based, the participants embark at one point upon a discussion of electric fish, and it turns out that a particular participant is quite an authority on this subject. The purpose of the dialogue is to explore and juxtapose several worlds, or universes of interpretation, in which to adopt perspectives, to develop a common metaphorical language, to resolve the issues at hand, and to reach a series of tentative agreements. Hence, although it is crucial to have expert knowledge about the original world (geology and engineering), it does not matter whether the propositions about other universes are factually true or false, so long as they hold together in some kind of derivation.

The "technical" terms are mostly self-evident in the context of the scheme but one of them, "force fit," requires special comment since it has a dual connotation. On the one hand, it means bringing together concepts that have matured in distinct "worlds" or "universes of interpretation" and on the other hand, it means resolving these concepts to produce a common meaning and to model it as an analogy relation. Conceivably, the result could be a simple analogy (for example, an isomorphism between principles or systems), but usually, due to the method employed, this is a generalised and realisable analogy relation.

There is one apparently arbitrary step in Scheme 5, namely, in phase 4 the leader selects a "world" other than the original (geology and engineering) world. It is clearly necessary to ensure that

SCHEME 5

One Synectic Procedure

Phase	Operations
1.	Examine statement of problem situation; for example, problem of extracting representative core sample of oil bearing rock, without adulteration in the process, from a great depth.
2.	Elicit objectives as conceived by participants; for example, "getting oil to tell me how crowded it is in reservoir stratum".
3.	Choose one objective for scrutiny (assume the objective cited is selected).
4.	Elicit instances (of chosen objective) in distinct world; for example, since the original problem is posed in a world of geology and engineering, elicit instances of the objective in a world of biology (these range from flies crowding upon dung to a culture of viral agents in a host tissue).
5.	Select instance for scrutiny; for example, virus culture in host tissue.
6.	Personal Analogy. This is an interesting and potentially powerful method of enforcing a perspective. It consists in persuading the participants to see the chosen instance situation as though they are some element in this situation; in this case, as though each participant is a virus and part of the culture in host tissue.
7.	Elicit "book title" from each participant. A "book title" is a pithy phrase which serves as a tag metaphor for the participant's experience in the role of a virus (in this case) and summarises a paradoxical or incompatible feature of this role.
8.	Select "book title"; for example, one quoted by Prince is *Compulsive Indifference.*
9.	Elicit instance situation in a biological world or a somewhat more general world that embodies the meaning of the book title; for example, the territorial and aggressive propensities of cats, as contrasted to dogs.
10.	Select resultant instance exemplifying chosen "book title" and "force fit" it to the original objective given in the world of geology and engineering; that is, cite an analogous situation in the original world.
11.	Examine efforts to "force fit" and select plausible "viewpoint" (synectics word) or possible recommended solution; for example, the idea of calming down a crowded roomful of cats gives rise to the plausible suggestion of freezing out a rock sample filled with oil droplets so that it is not polluted whilst being removed from the boring hole.

there shall be a difference (the technique hinges upon the coexistence of distinct universes of interpretation), and it may be expedient to leave this selection to the leader. However, there is no reason, in principle, why he rather than the others must determine the different universe, and in practice, his selection is coloured by the ongoing discussion.

The cyclic and re-entrant character of the process is made especially clear in Gordon (1966), a book which is primarily concerned with synectic principles as they are applied to learning. In Appendix I of Gordon (1966), the "viewpoint" is not charted as a terminal solution (recommendation) or set of solutions (recommendations) but as the genesis of a novel objective. Moreover, there are many, almost unchartable, "internal" loops; for example, the personal analogy phase can be, and often is, either replaced or augmented by a forced "direct analogy" between the distinct worlds or universes of interpretation. Whereas "personal analogy" stresses an analogical or metaphorical universe (akin to U in Section 3.1), "direct analogy" is a straightforward recourse to the realisable universes (X and Y in Section 3.1).

With these points in mind, and noting both Gordon's and Prince's insistence that the synectic process may either be interpersonal (as depicted in Scheme 5) or intrapersonal (in either case, however, involving distinct P-Individuals), it is not difficult to see that clusters of phases in Scheme 5 are designed to bring about the events noted in Scheme 1. The identification is summarised in Scheme 6.

The phases of the synectics procedure do not, and are not meant to, capture all of the underlying heuristics (the "deep structure" of the process catalysed by the group leader). In a sense, the underlying heuristics are made evident by following the procedural suggestions and mandates; the underlying heuristics are not written out as a series of transformations.

However, on reading the literature and (at least) toying with the method, it is evident that the procedures induce cognitive transformations similar to, if not identical with, those stated explicitly in THOUGHTSTICKER (Chapter 9). The explicit statement may be useful in guiding the conversation; for example, if it is agreed that the THOUGHTSTICKER transformations (epistemic symmetry, extrapolation, and so on) are desired, amongst other things perhaps, then we feel that the leader and perhaps the participants

SCHEME 6

Comparison of Synectic Procedure and Present Theory

Clause in Scheme 1	Phases in Scheme 5 or Comments Upon Entire System
1. (Distinct P-Individuals)	Given throughout by integrity of participants and by differential perspectives as highlighted in Phases 5, 6, 7, 8.
2. (Distinct universes)	Highlighted in Phases 4 and 6 for the geological/mechanical universe and the biological/animal universe (on a par with X and Y in Scheme 2 or Scheme 3). The analogical universe of personal perspectives (on a par with U of Section 3.1) is made explicit in phases 6, 7, 8.
3. (Focus of attention)	Phases 5 and 6 juxtapose and coalesce foci established in Phases 2, 2, Phases 4, 5 and Phases 8, 9.
4. (Common language)	Maintained throughout by leader manipulation
5. (Common meaning agreement reached)	Phases 2, 3, 4 compared with Phases 8, 9, 10. Resolution is made explicit in Phases 9, 10 and is refined and reified in Phase 11.
6. Common meaning is generalised	Intention behind "generalising the perspective" in Phase 9, but the tendency to resolve by generalised analogy rather than simple analogy is part and parcel of the "force fit" operation and the events leading up to it.

would gain by knowing of them as explicit meta objectives. It is quite true that overconsciousness of such information could demolish the spontaneity and emotional interplay of the dialogue. But this is not a necessary consequence, and in practice, a substantial advantage may be gained by adding explicit "deep structure". Though our own theory lays *emphasis* upon systemic aspects of thinking and creativity, it *depends* as much as any other theory upon the conative as well as the cognitive facets of the intellect.

3.5. *A Microstudy of Innovation*

The last exemplary theory of innovation comes from a study of problem solving and training students to solve problems: Elshout

and Elshout (1960). These investigators employed Guilford's "apparatus test" as their subject matter. A typical test item consists in the description or mention of an "apparatus"; for example, a chair or a razor (an "apparatus for sitting on" and an "apparatus for shaving with," respectively). The student is asked to think up and record an improvment of the "apparatus" in each test item, i.e., an improved chair on an improved razor. An improvement of *some* kind exists if the solution offered is distinct from the original apparatus but is recognisable as having the same function as the original, perhaps having other functions as well. It was found that two very different kinds of strategy are used by students: the "locating problems" strategy and "successive transformations" strategy (abreviated to *LP* and *ST*, respectively). Of these, *LP* gives rise to responses deemed pedestrian or prosaic according to several extremely plausible criteria, whereas *ST* gives rise to creative responses.

Elshout and Elshout found it possible to pretrain students to adopt either type of strategy, using one or the other of two programmed texts. In their paper, they call the prosaic solutions, minor innovations, and the creative solutions, major innovations. Here, stress is placed upon the nature of *LP* and *ST* and the differences between them. As a matter of terminology, the solutions produced by *LP* are probably *not* innovative under the present terms of reference; those of *ST* undoubtedly are innovative.

Although Elshout and Elshout do not make the claim explicitly, they appear to *have* a cogent theory of innovation embedded in the distinction between the strategy types, and it is sufficiently detailed to allow for training operations that substantially increase the proportion of innovative solutions.

The strategies in question are as follows: (Scheme 7 and Scheme 8, below). The serial form is artificial and unrealistic; for example, execution of Step *LP*1 may continue as the other steps are instituted. But certain order relations are essential; for instance, execution of *LP*1 must start before *LP*3 is instituted.

Elshout and Elshout's terminology is very close in style and meaning to our own, and it is easy to see that their theory corresponds with singular accuracy to the relevant points of conversation theory, as do their results. For example, a "problem solving procedure" (in this context, at any rate) is a concept; the learning strategies exhibited in *LP* and *ST* are regarded as

SCHEME 7

Locating Problems (*LP*)

LP 1	List the attributes of the given apparatus (possibly an indefinitely long list) by abstracting from the instance given.
LP 2	Specify the uses of the apparatus. That is, how it functions in different contexts; for example, the chair functions as an instrument for sitting on, but it has the attributes "size" and "softness" which are of different consequence if it is used in a confined space or in the open air.
LP 3	Select an attribute that under one-use-context poses a problem or produces a difficulty; for example, the chair stands up and if its "size" is "large" this fact proves embarrassing if the chair is used in a small room.
LP 4	Determine the effect of changing the *value* of the selected attribute in a manner that eliminates the context-dependent nuisance upon the functioning of the apparatus; for example, though a dumpy chair is conceivable, a child sized chair is unacceptable to adult users.
LP 5	If the selected value-change destroys the function, return to *LP* 3 and select another attribute unless no attributes remain on the list, in which case, return to *LP* 1. If the selected value-change does not destroy the function, instate the change of value; for example, "size = large" into "size = small".
LP 6	Construct a modified form of the original apparatus that incorporates the selected and functionally innocuous change in attribute value. Thus "large chair" becomes "small chair" (with some specific meaning attached to *how* the chair is smaller than it was, i.e., narrower, shorter or whatever). Select a description of this modified form of apparatus as the solution.

"higher level problem solving procedures" (learning is problem solving about problem solving, and their "level" distinction like the L^1, L^0 distinction is a matter of convenience, not fact).

Moreover, the following point, though imported and imposed as an explanatory device, is probably implicit in Elshout and Elshout's account, though they do not speak of it in these words. The difference between creative thinking as governed by *ST* and non-creative thinking as governed by *LP* is simply that *ST* demands more than one-aim-at-once, whereas *LP* makes no such demand. Of course, the student pursuing *LP* instructions might

SCHEME 8

Successive Transformations (*ST*)

ST 1	List attributes by abstraction, as in *LP* 1.
ST 2	Specify the uses of the apparatus, as in *LP* 2.
ST 3	Select a tentative attribute that poses a problem in some context or other, as in *LP* 3.
ST 4	Change the value of this attribute or adjoin some attribute (giving it a novel value), such that the apparatus is rendered *dysfunctional.*
ST 5	Attempt to transform the structure of the apparatus so that it *does* function with contradictory values of the selected attribute (which may or may not be possible). For example, if the selected attribute is "posture" a chair that "stands up" occupies room space. Changing the value of the chair's "posture" so that it "lies flat" renders the chair dysfunctional. It may or may not be possible to invent a chair (such as a collapsible deck chair) that accommodates both values of posture.
ST 6	If the attempt to transform the apparatus is unsuccessful, return to *ST* 3 unless the attribute list is exhausted (in which case return to *ST* 1). Otherwise, if the attempt is successful, specify the modified apparatus and submit its description as a solution.

divide his attention. *LP* does not prohibit this. But the student who learns and obeys *ST must* do so.

The distinction occurs at Step 4 and Step 5 in *ST*. The fact is, an apparatus (in our jargon a model, albeit a mental model) cannot be simultaneously functional and dysfunctional in the same universe. On the other hand, the posited dysfunctional apparatus must work in some universe; it can neither be a stroke of caprice nor a fatuous construction. Hence, Step 4 in the *ST* instructions tacitly calls for the construction of two a-priori-independent universes; one in which the original apparatus works, and one in which the dysfunctional modification works. Further, the resolution to be attempted at Step 5 requires the contemplation and comparison of the two universes, each with its distinct focus of attention or aim selection.

Informally, we have found that students required to solve problems of an open ended type and given instructions that tally with those in *LP* and *ST* report that the comparison at Step 5 involves

the interplay of personalised as well as problem oriented hypotheses. The student conceives himself, for example, as a user of the different pieces of apparatus, or as the progenitor of different theses about them. Generally, the emergence of the transformation which resolves the incompatibility is sudden; the student is conscious of the apparatus to be tendered as an innovation as a crystallised whole. He is not (clearly) aware of all the steps that lead up to the crystallisation, though by token of the fact that he can obey *ST* instructions or recognise his mental process as *ST* rather than *LP*, he is able to describe a series of commands he gives himself, or the constraints he applies in order to achieve this result.

This much is predictable in terms of the macrostate variables d_0, d_1, and d_2. There is a point (Scheme 1, clause 3) when d_0 is high, but its value approaches zero at "crystallisation". The act of reaching a common meaning (Scheme 1, clause 5) by hypothesis, due to concurrent autonomous operation, is associated with high d_2 (there is no awareness of "steps"). But, insofar as *ST* is described as a Fuzzy Procedure, d_1 is low. The student, under these conditions, knows how he innovates even though $d_2 > d_1$, he is unaware of the results until ($d_0 = 0$) they are reified as an artifact or a solid idea.

3.6. Other Possibilities

Similar spirited comparisons can be extended to other theories rich enough to posit a process underlying, and somehow peculiar to, creativity. For lack of space, the matter is not pursued, but the reader may find it rewarding to examine the creativity theories of Bateson (1972), Maslow (1954), and Fischer (1969, 1974) in the light of the foregoing discussion. These are chosen, as far from exhaustive or exclusive examples, for two reasons: first, each is a beautiful and well-attested statement; secondly, the theories stem from different departments of cognitive science.

Bateson's view of innovation emerges in part from social and anthropological studies, and in part from individual psychology. The doctrine of "deutero learning" and "higher than deutero-learning" establishes a positive connection between "ordinary" and "creative" thinking; specific mechanisms, such as the cultural "double bind" and its several analogues, set the stage for innova-

tion (or, in the present jargon, for "many aim" operation). Various hierarchically organised homeostatic mechanisms are compatible with the picture of coalescence and resolution drawn in this chapter, and the fundamental evolutionary component is compatible with conversation breeding.

Maslow's theory is set in a less encompassing framework, a species of transactionalism, but once again, it contains the full complement of processes, and these are compatible with the identifications so far mooted. Similar remarks apply to Fischer's theory, which is stated in a series of quite widely scattered papers. Its background is mixed: first, an eclectic but basically mentalistic psychology, and secondly, the area of neurophysiology and psychopharmacology. In "translating" Fischer's concept of a perception-hallucination continuum (in which creative productions occupy a special place), it is necessary to "translate" simultaneously the mechanisms of symbolic evolution which underlie this continuum. Further, it is necessary, and apparently legitimate, to identify Fischer's concept of "private" and "public" verification of the images so produced with the notion of modelling (intellectual or factual) in correspondingly "private" and "public" universes; to note, as Fischer does, that the status of a *creative* image (our "idea") is aleatory. Concordance between the model of an image and of an individual (or the societal status quo) is undecided at the instant of inception.

4. MERIT IN IDENTIFYING THEORIES OF INNOVATION

We embarked upon this chapter with the promise of unification amongst theories which, taken alone, have points of disparity. This promise has been fulfilled by exhibiting a common systemic core adequate to accommodate variously described processes. The essay might be justified on these grounds alone, but some other advantages are also gained.

The present theory forms a natural bridge between the many person situations (Chapter 6), the many aim situations (many person or just one) which seem to engender innovation, and the process (Chapter 9) of "learning to learn". Differences of degree exist; these aspects of reality may be usefully discriminated. But the underlying process is the same throughout. It involves "Conversa-

tion Breeding" (a comprehensive type of symbolic evolution), the juxtaposition of aims or perspectives and their resolution by the coalescence of P-Individuals in a common-meaning agreement. Since P-Individuals, the major working units of our theory, may be localised or distributed over several brains and since several may coexist in one brain, the perplexing differences between societal and personal innovation mostly evaporate.

In return, our theory is buttressed by a body of evidence. Chapters 7, 8 and 9 gave some examples of innovation observed in THOUGHTSTICKER and the "learning to learn" experiments. But since under these circumstances cognition is laboriously externalised, the instances are rare and miniscule: a picayune body of data quite inadequate to support a serious hypothesis. So it would remain after many repetitions of the experiments. For data about realistic innovation are garnered over years from different cultures, and the most dramatic instances are best observed beyond the laboratory (as Minsky remarks, in order to study "intelligence" examine the cognition of someone who is superlatively intelligent; by the same reasoning, creativity is best studied amongst people or systems or groups who have an outstanding creativity record). Now the data supporting the other theories usually *are* of the required kind; they are far more convincing than a few laboratory transactions. Insofar as the other formulations can be placed in register with the present constructs, much of this data is put at the disposal of our theory and is held to lend it inductive support.

5. PREDICTION AND PRAGMATISM

Obviously, we claim to predict the form of an innovative process. The tricky question is whether or not it is possible to foster creativity, and if so, by what means. To some extent the question has been answered in the affirmative. In Chapters 8 and 9, we cite procedures for encouraging various ingredients of innovation; for example, these listed under "aim initiation" or the overall heuristic of THOUGHTSTICKER, which induces a resolution behavior akin to Elshout and Elshout's "successive transformation" tactic. It was noted in Chapter 9, Sections 3 and 4, that these methods are not bound to pieces of machinery, however convenient the machinery may be; by token of this, principles extracted from

usage of the operating system have been used successfully to approximate the same result in entirely non-mechanised studies of "learning to learn". Elshout and Elshout obtained similar results in the context of the "Apparatus Test"; Gordon and Prince, in the practice of synectics.

The scope is wider than these parochial examples suggest. First, the recommendations arise from the essence of a theory; they are not just arbitrary or empirical suggestions. Next, the theory has been identified with the systemic core of other theories for which recommendations as diverse as the areas of interpretation already exist. So, for example, it is possible with Bateson's and Barnett's theories to stipulate cultural organisations conducive (say) to "aim initiation" (one ingredient of innovation), and to infer that innovation is more likely to occur if these organisations are realised together with means to guide the other ingredient processes. Or, in the psychophysiological interpretation of Fischer's theory, it is possible to argue that certain brain states increase the likelihood of innovation; at least, that these states will stimulate appropriate subprocesses.

6. RELEVANCE IN EDUCATION

Often and probably rightly, innovation is cited as desirable as an end in itself. If that is agreed, then there appear to be rather complicated training operations which encourage innovation; either the mechanical or non-mechanical expedients of Chapters 7 to 9. It is of interest that these operations tally well with the conditions held to be fecund in this respect by process oriented theorists; in contrast, they do not tally well with the manoeuvres of simple minded encouragement which (however attractive they are in terms of potential cost benefit) have proved disappointing (see, for example, the very clear and candid review of one such endeavor by Torrance and Gupta 1964).

Suppose, however, that innovation is not so universally valued, that children or adults should not be specifically "trained to innovate". After all, a number of career oriented educationalists honestly take this point of view.

It would still be agreed, in most quarters, that "learning to learn" and "group competence" *are* important parts of the educa-

tional system (if not of the curriculum). For example, even if the object is to produce technicians and specialists as the main product, they will benefit from versatility (a component of "learning to learn") and are likely to be better citizens if they understand each other rather than acting as robots. Moreover, it has been argued (and the case appears to be indisputable) that an efficient educational system, be it for generalists or specialists, *depends upon* "the art of learning" disseminated amongst the students. This is so for the following reasons: (a) That rapid learning with sensible retention is achieved (in practice) only by utilising the valid analogies in a subject matter, discovering them and checking their proper comprehension, both of which entail the "art of learning"; (b) because only a small fraction of the environment is an academia where knowables and do-ables are coherently structured. Most learning must (for most people) take place outside an institution, on the job or in the street; a moiety of the time spent in an institution should, therefore, be devoted to indoctrinating the "art of learning" (from unstructured surroundings), just as time is spent inculcating the other basic skills of communication, arithmetic, and so on.

Whichever point of view is adopted — namely, "Innovation is good in itself," or "Innovation should not be generally encouraged when we need specialists or hodmen," or "I am indifferent to innovation or not, but education should be, in some sense, efficacious" — the comments in this chapter and the last are still very much to the point. It has been argued that the processes called "innovation" and "learning to learn" and "learning to participate in a group" have a common component and that, operationally speaking, their encouragement is a matter of adopting the same class of tactics and methods. I do not think, whatever is done, we can guarantee that someone will prove a brilliant inventor/artist/politician. But we do have the inklings of how to achieve a less grandiose, though no less laudable, goal: that this person will learn to make sense of and savour his intellectual or concrete environment, its past and its future; that he will learn to love his neighbour and simultaneously aspire to ambitions which (I do believe) have no limit whatsoever.