Axioms from Interactions of Actors Theory

Nick Green
Real Time Study Group
Department of Computer Science
University of Wales, Cardiff
www.cyberneticsassociates.co.uk

Keywords *Cybernetics, Self-organisation, Interaction, Actors, Evolution, Learning, Spin*

Abstract *While working with clients in the last years of his life Gordon Pask produced an axiomatic scheme for his Interactions of Actors Theory which is a development of his well known Conversation Theory. These axioms are interpretable as a general theory of self-organisation and are discussed as characteristic of field concurrence and as part of the second order cybernetics canon. An application to population density is reported supported by both kinematic and kinetic simulation. Implications for cardiovascular anti-coagulation therapy and planetary evolution are discussed.*

Introduction

Gordon Pask's Interactions of Actors Theory (IA) was developed from his earlier Conversation Theory (CT). The key ideas are presented as the writer encountered them. A cosmological picture emerges of elementary, interacting self-organising processes that evolve to produce life and concepts in our brains. Pask regards concepts, in general, as any persistent self-productive looping process in any state of matter. CT requires the concurrent existence of at least two distinct precursor concepts to generate a third. These concepts resonate like chemical tautomers making them analogical to each other. CT is transformed to IA by the taking of duals and interacting Actors are produced which support participants in conversations of bounded duration. The central object is the stable concept triple which takes the form of the Borromean link. The potential of this form as a concurrent computing element and a model of continuity is discussed. The self-organising forces exerted by the concept triple are the subject of the axioms which are discussed in detail.

Lastly serial and concurrent experimental work is reported which applies Pask's Last Theorem (PLT), a theorem about differences and forces. Experiment confirms the view that weak forces lead to dense forms of self-organisation in ekistics (the theory of settlements), cardiovascular anti-coagulation therapy and planetary evolution. It will be noted, for example, that diatomic hydrogen cannot form unless Pask imperative forces act on the atoms.

In his later years Pask had effectively shown IA to be a theory of Cybernetics hence confirming the von Foerster soubriquet for him "Mister Cybernetics", the "cybernetician's cybernetician" (von Forster, 1995).

In 1994 while consulting with clients[1] Gordon Pask made a clear statement of axioms or properties governing his Conversation Theory, CT (Pask, 1976), the means by which concepts are shared, and its underlying support Interaction of Actors Theory, IA (Pask, 1993). As Bateson (Bateson, 1980) has it Nature and Mind are one. To Pask, also, Nature's tendency to self-organisation produces concepts (Pask, 1996) whether in a star or a brain. A formal statement of these axioms has never been made. By describing how IA developed and the names and properties of the axioms as discussed with Pask in due course a more formal paper and scheme might be produced.

P-Individuals and M-individuals

There are two parts to an interacting participant or Actor. First the P-individual which is a dynamic, productive and incidentally reproductive, adaptive, evolving and learning collection or entailment mesh of concepts. Dawkins' memes (Dawkins, 1976) are a restricted form of P- individual. Second the M-individual which is a mechanical or biological medium e.g. a computer, a brain or a star,

which supports the P-Individual and the strains its concepts produce. One P-individual may inhabit many M-individuals and many P-individuals may interpret in a single M-individual (Pask, 1975). To Pask Nature's eternal interactions, with associated P-individuals interpreted in M-individuals, could be regarded as conversations between participants when constrained by beginnings and ends. The constraints on the second order paradigm of Cybernetics, where one participant may be a carbon-based life form designated observer and part of the system, are made plain with the axioms. These axioms apply to all participants whether observer or not.

Pask (Pask,1990) won an award from Old Dominion University, Virginia for his Process/Product complementarity principle. "Every process produces a product, every product is produced by a process" e.g. electromagnetic waves and photons or in the case of CT applied concepts and their descriptions.

This may be written $\mathbf{Ap}(\mathbf{Con_z}(T)) => \mathbf{D_z}(T)$ where => means produces, z is a participant and T the current topic or concept from which all others can unfold as thought proceeds from within the domain or entailment mesh of the participants. So the Description, D, of Concept, T, is produced by the Application, Ap, operator on the Conversation, Con, operator on T. The dual character is denoted: $<\mathbf{Ap}(\mathbf{Con_z}(T)), \mathbf{D_z}(T)>$. Physically D is a hard carapace of repulsive force.

P and M-Individuals are also dual process/product pairs. Pask wrote this as: <P-individual, M-individual> denoting an Actor or participant to interaction or conversation. Ap, Con and D are operators in Pask's protolanguage Lp or protologic as he sometimes called it.

Concepts

A concept is derived by the conjunction, ANDing, of at least two concurrent concepts. This satisfies the marked state requirement of Petri Information transfer. Dr Bernard Scott (personal communication) points out that this is equivalent to the "irreducible to binary form" relations emphasised by Peirce, Korzybsky & McCulloch.

This may be shown graphically as in **Figure 1**.

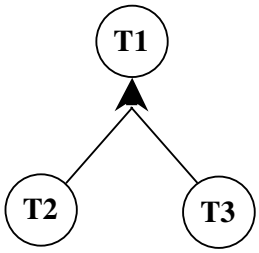

Figure 1 T1 is derived from T2 and T3

Here, for example, we might be speaking of Newton's Second Law[2]. T1 could stand for the concept of Force with T2 and T3 being mass and acceleration. To understand the modern theory of force more deeply we might prefer the topics or concepts to be assigned as sparticle, knot and string. Something more trivial seeming might be dog, lead and walk. Clearly in all these examples a third concept can be derived from any pair. There is a strict analogy between any concept pair, distinguished by differences and similarities defined by the third concept. Pask (Pask, 1976) called this "local cyclicity" and this can be demonstrated graphically as in **Figure 2**.

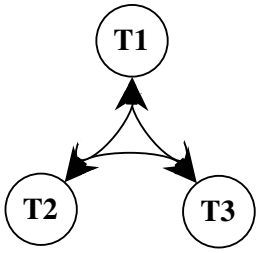

Figure 2 Local Cyclicity of a concept triple

In the case of the two examples taken from classical and supersymmetry force theory we can demonstrate consistency and coherence with, for example, dimensional analysis or probing into the observations that led to the construction of the concepts. In the case of the dog, the walk and the lead a supporting hypothesis may also be constructed. Further concepts are entailed

supporting the disambiguation of dog, walk and lead. One might show that leads are used to take dogs for walks rather than, say, connect them to an electricity supply. Supporting hypotheses of this kind are implicit in the scientific examples and can also be made explicit. The terms assigned to the topic numbers must, at least, be defined unambiguously for the appropriate context. Thence addition of concepts leads to potentially very large entailment meshes representing the concepts of one or many participants to a conversation delimited by beginnings and ends supported by an interaction which is eternal.

Interactions of Actors

It was from consideration of local cyclicity[3] in Conversation Theory that Interaction of Actors Theory was derived. Pask summoned me to the Athenaeum, one of his clubs, to show me with great enthusiasm some large drawings he had made, charmingly indifferent to the club rule: no papers in the bar. Duality and the taking of duals is a widely used technique in simplifying, for example, graph theory and electrical circuit theory. Calculations can sometimes be simplified. In graph theory nodes can be interchanged with arcs and in circuit theory inductances with capacitances and current sources with voltage sources. Further we find a three pointed "star" of resistances is electrically equivalent to a triangle of resistances. Electrical engineers call this Star Delta duality[4]. Pask took the dual with the bidirectional arcs of local cyclicity and the topic or concept nodes. Thus in one elegant transformation Conversation Theory was made dynamic. The old derivations, the sticks of what he called his "stick and ball model" (as figures 1 and 2) became formally circular, closed loop processes. The topic or concept nodes became the intersections of the fields produced by the closed, looping process. He asserted forces acted between the circular processes and that they existed in stable triples. The Begins and Ends of the application of concepts in Conversation Theory had been replaced by eternal, evolving kinetic interactions between organisationally closed and informationally open concept loops, toruses with carapaces that maintain a boundary, a distinction. An Actor is anything that acts as a result of an interaction or a transfer of meaningful information

The axioms or properties below apply to both Conversation and Interactions of Actors Theory with the exception that conversations of P-individuals have Begins and Ends and may be interrupted by other conversations and so be nested. Actors and their M-individuals interact eternally.

Concept resonance

The closed toroidal processes which comprise the concepts of P-individuals exist as stable triples in which any pair is analogous to the other and distinguished by the third. Any two concepts may generate the third because of their resonant similarities and differences.

The resonance produced by an incident field produces an output radiative field. Knot Theory was a matter of some concern to Pask. He coined the term "tapestry" making his entailment mesh structure of the concepts of a participant coherent with knot theory. Whilst loops are always permitted, indeed are the nature of concepts, the intersections of CT become crossings in IA where crossings up and down with loops define knots. The crossing up or down rule of the knots or links was not decided but a recursive and nested Borromean form seemed most likely. This seems coherent with the superstring theory interpretation of force. Here knots in strings produce the sparticles and thence bosons of current force theory e.g. Pierre van Baal and Andreas Wipf (van Baal & Wipf, 2001) who postulate Hopf linked strings (two intersecting loops) produce force. A suitably energetic hadron collider experiment e.g. Utpal Chattopadhyay and Pran Nath (Chattopadhyay & Nath, 2001) may be able to decide if the Hopf or Pask's Borromean model is most respectable. A smaller new experiment by

Long et al (Long et al, 2003) using planar oscillators at 100μm lengths has examined some of string theory predictions of the need for extra dimensions. In some cases this would result in deviations from the Newton's inverse square law at distances less than 1mm. None were found.

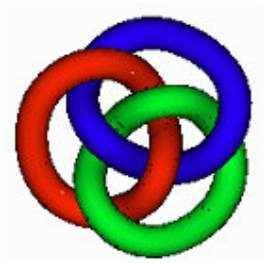

Figure 3 Borromean Ring Model of stable Concept triple

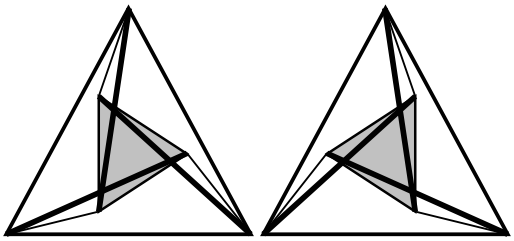

Figure 4 Plan of Equilateral Prismatic Tensegrity computing element showing optical isomerism, an enantiomorphic pair. A short proof of the 30° angle of twist is elusive.

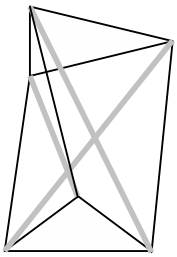

Figure 5 Isometric View

The twelve arcs of the Borromean Ring form and the equilateral prismatic tensegrity of Buckminster Fuller were under study at the time I joined Pask Associates in 1993. The tensegrity provided a tractable force model comprising three repulsions and nine attractions corresponding to the diagonal rods and tension strings. In due course these were configured as elements of a potential concurrent computer. Pask wanted a machine in which the three struts of the prismatic tensegrity were periodically excited with make and break circuits feeding solenoids. Tiny electric motors attached to each strut were more successful and less liable to collapse. The phasor sum of these vibrations produces a fourth frequency that is a mechanical four wave mixing analogue[5] (Shih, 1987). We had no theory of desirable frequencies. A variety of resonant frequencies could be inferred but a full vibrational analysis with strain gauges and spectrograph was an obvious next step. Pask felt inspiration, it seemed to me, holding the machine as its three axis vibrated and, as usual, fell apart. He was clearly looking for unusual phenomenon.

With the help of the Royal Institution a higher precision device was made with six equal mass and 15 cm length mild steel rods. There was potential danger here without a safety cage and thankfully Pask appeared to lose interest in pursuing this having made his statement, as it were, of the nature of concept triples as computing elements. This device mimics the phase conjugate mirror. Two waves are mixed in a non-linear medium. Any input wave is amplified if the two "pumping" waves are sufficiently intense, phase conjugated and reflected back converging to the input source. Phase conjugate oscillator technology is crucial to some to make practical beam weapons. The fact that the incident wave is phase conjugated has lead to the radiated wave being described as "time reversed".

One can share in Pask's delight at interpreting in rough hardware his concept triples as a dynamic computing component where the memory requirement was formally embodied as a highly restricted method of travelling backwards in time. Further precision work and miniaturisation is required to create a practical device. Confirmation that output is phase conjugated with the input wave could be a first step in validating the prototype prismatic tensegrity computer. Estimating its capacity as a storage medium for analogue waveforms for given implementation technologies might be a next step.

Concept kinematics and kinetics
Concepts nest recursively in triples within each other. As drawn by Pask they form tori like wires in a multi-core electric cable[6]. Repulsive forces are exerted by the concepts generating a carapace or hard protective shell around them as in figure 6. These forces further distinguish the domain of Interactions of Actors Theory from Conversation Theory in that Pask asserted IA to be a **kinetic** theory and CT to be **kinematic** because of its implicit begins and ends. Forces cause thoughts to change and we have the **Last Theorem,** as Pask called it, which states

"Like concepts repel, unlike concepts attract".
Pask's Last Theorem (PLT)

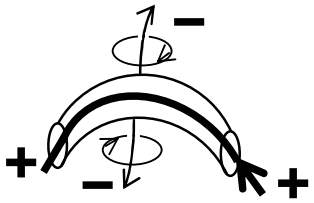

Figure 6 The Carapace of Repulsive Force around a section of a closed loop concept process from Pask 1993

This statement is intended to embody all forces: weak, strong, gravitational and electric or magnetic, which give rise to the self-organising character we see in Nature. Here '+' directs into the not void (or something) and '-' means orthogonal to and "deflects similar concepts". This deflective force is "bearing the clockwise or anticlockwise signature of the process which creates it" Pask (Pask, 1993, p. 44). In a most difficult part of the IA manuscript a prepositional operator mesh is introduced with ontologies and analogies. Ap becomes permissive application and & (or IM) imperative application. There is a discussion of unfoldment, Un, as mentation and action in this context. Un is identified with '-' and seeking out further concepts in its neighbourhood to apply. The '+' process may be clockwise or anticlockwise in orientation and may not always close or "eat its own tail" but may disappear into the void (Pask, 1993, p. 77). On page 78 he says "No aether, electromagnetic or not, is needed only orthogonality, as in the electrical and magnetic components of an electromagnetic field and, here, represented by '+' and '-'".

After stating PLT for the first time to me (Green, 2001) I asked Pask "What kind of force?" After a considered pause he said "Just a force".

Self-organisation
The properties of the axioms can be investigated and appreciated as characteristic of interaction in field concurrent n body systems, like the Newtonian solar system or the electrically charged protons and electrons of an atom or molecule. The outcomes of interaction are interpreted in the participant Actors.

Interpretation of Pask's theory of force as producing self-organisation is ongoing. Some not so obvious considerations from the classical dynamics of forces should be pointed out. First stable closed elliptical orbits are rare in n body simulations with random initial conditions but equal masses. Choreographies, by contrast, are common when masses are equal e.g. Cris Moore Sante Fe[7], Carlos Simó (~2000 but undated pre-print from Paris Observatory). These trajectories form braids and are stable in that a small perturbation produces a precession only. This may imply braids are frequent in liquids and gases between like polarised molecules. For serial computing simulation tools see Acheson (Acheson,1997). Asymmetric attractive, sticky, aggregative generation producing a non-uniform Power Law or Bakian $1/f^{\beta}$ distribution of masses (Bak, 1997) is probably necessary for the stable seeming elliptical orbits we all expect. Bak's condition of Self-Organised Criticality can be met with the non-linear aggregation of attractive uniform aggregates or Actors (see later for more, Witten and Sander, 1981). The mechanism of the stickiness (or valency) is worth further

study and may be partly tractable under serial digital simulation. Poincaré proved circular orbits in n body systems have zero probability. Later Kolmogorov conjectured orbital toroids were feasible under perturbation in non-dissipative systems. The proofs due to Arnold and Moser in 1962 and 1963 produced the famous KAM Theorem[8]. Henceforth in this paper "circular" process implies a KAM compliant process.

Whilst the laws of electric or magnetic attraction and repulsion are familiar, recall again the closed curved Newtonian process. There is repulsion without electromagnetic law in the resistance of a gyroscope to a couple. Laithwaite's[9] apparently notorious observation while sitting on a rotating office chair with a spinning bicycle wheel in his hand that rotating the seat in one direction made the wheel lighter and in the other made the wheel heavier should be recalled.

The behaviour of the asymmetric Tippe (sometimes spelt Tippy) Top[10] should be considered. Here is counter example to whatever dynamical minimisation principles (e.g. of Fermat, Maupertius or Hamilton) is operating. The top turns up-side down at some critical frequency, reversing its direction of spin and achieving an equilibrium but raising its centre of gravity to do so. Conventional minimisation principles assert themselves as the top slows down past the critical frequency and it topples, reversing spin again, with the centre of gravity minimising its potential energy as intuition and simple Newtonian dynamics demands. A picture of Bohr demonstrating the inverting Tippe Top to Fermi[11] is held by the American Institute of Physics.

Prigogine's Group[12] believes non-linear interaction produces self-organisation in irreversible dissipative processes. Simultaneous three body collisions are under investigation and spin interaction in quantum systems, for example. For Pask a spin reversed concept was formally different and by PLT attractive. Stable triples exhibit residual clockwise/anticlockwise parity.

Lastly, it is worth noting a relatively new phenomenon discovered by David Acheson (Acheson, 1993) and discussed in Acheson (Acheson, 1997). The stiffening of a soft carapace, as IA might interpret it, has been demonstrated. Around 30 inches of ordinary household flexible plastic covered curtain wire stands up straight when vertical periodic excitations are applied to the base with a mechanical vibrator at a resonant frequency. Acheson calls this gravity defying effect[13] "Not quite the Indian Rope Trick".

Interactions of Actors Axioms

- Context
- Perspective
- Responsible
- Respectable
- Amity
- Agreement
- Agreement-to-disagree (ATD)
- Purpose
- Unity not uniformity
- Faith
- Beginnings and Ends (CT)
- Eternally interacting (IA)
- Similarity and Difference
- Adaptation
- Evolution
- Generation
- Kinetic (IA)
- Kinematic (CT)
- Conservation of Meaningful Information Transfer both *Permissive* (Ap) and *Imperative* Application (Im)
- Informational openness and Organisational closure.
- Void and Not-Void

Exactly how to treat these axioms is the subject of some discussion. Pask's form of words for each axiom is particularly useful in maximising applicability to the so-called soft sciences. The aim is to be able to make statements about interacting people of form equivalent in robustness to those of conventional physical science: age of the Earth, the water will take ten minutes to boil and so on. There is no implied order of priority in these axioms. They exist concurrently as restrictions on the behaviour of all participants in their interactions and the forces acting be they strings, sub-atomic particles, atoms, molecules, plasmas, gases, liquids, solids, plants or animals.

The setting up of counting and in particular state counting or variety may prove an interesting first challenge to elegance and chosen notation. The apparent simplicity of the **Similarities and Differences** in Actors Axiom are what may be deployed. It should be noted that a difference is the feedback of first order cybernetics. Beer once remarked to me that often people in conversation would make a statement or proposal and invite criticism or responses from others by saying "Give me some feedback". This he said was, with an emphatic pause, "not correct". Beer said no more and in the context of a formal model he may have a point. It would be correct in the context of the Difference axiom in CT/IA where "teach back", the feedback to which Beer objected, is judged, implied or used explicitly to confirm a new difference acquired or successful act of learning or meaningful information transfer. This is also described as the execution of a model in a modelling facility shared by participants, within the Cognitive Reflector form of CT, to demonstrate an interpretation of the newly acquired difference by a participant. This was Pask practising as philosophical mechanic (Pask, 1993, p. 83). These are more or less formal routine, but imperative, components of transactions in every day conversation. Cognitive pathologies result from their incorrect operation e.g. vacuous holism "Can't see the trees for the woods" or pathological serialism "Can't see the woods for the trees" rather than the desirable balance of local and global versatile cognitive style. The nonsense talked about micromanagement today reflects these pathologies. The dangerously fallacious (vacuous holist) belief that knowledge of detail prevents proper management lead to a Railtrack Board with no engineers[14]. The lack of proper performance of track maintenance sub-contractors seemed unnoticed by the Board. There were tragic consequences with seven dead outside London at Potters Bar on May 10th 2002. In 2003 investigative reporting in the London Evening Standard showed track maintenance sub-contractor costs out of control. BBC investigations disclosed a similar pattern at London Underground. A therapeutic dose of Viable System Theory can cure but participants get attached to their pathologies. They are surrounded with repulsive forces. They have to "want to change" as the psychotherapist might say. Presenting an unwelcome difference the professional cybernetician may be confronted with Dr Elizabeth Kübla-Ross' five stages of grief: "denial, anger, depression, bargaining and acceptance" (Kübla-Ross, 1969). Through enquiry CT/IA can help to externalise, compare and contrast participants' perspectives in a given context and facilitate self-discovery and establish more versatile styles of cognition and learning.

Diagrams or entailment meshes showing the dependencies of participant perspectives on concepts can assist this process. These n-ary relations can unfold from a head node, topic or concept and in IA or dynamic Lp, they can depict forces acting between concepts through PLT.

Amity and **Faith** have caused much concern. Amity simply means availability for interaction. It is a nearest neighbour criterion for least noticeable difference or distinction in an observation. In the human context we may say "willingness" to interact where will implies a shared **Purpose** or **Unity** which is

not Uniformity. This in turn may lead us to use the term love, certainly where **Generative** interaction (or aggregative growth) is implied. Graham Barnes' (Barnes,1994) celebrated primer linking Psychotherapy to second order cybernetics "Justice, Love and Wisdom" can be seen in greater relief and in all its unbounded applicability when this clarification is made. Justice is defined here as "reflective balance", wise homeostasis applied in the manner of Rawls (Rawls, 1973) or, indeed, Rescher (Rescher, 1966).

Faith is a property of the duration of an assertion and persists until a contradictory counter example is found. It is the method of argument used to establish these axioms. These axioms only hold if no counter examples can be found in the context of Interaction. This does not imply completeness. New axioms may be found and existing axioms may be condensed into a single more powerful axiom. To interact or do a proper experiment, for example, faith is required. We cannot forecast the outcome, whatever we may claim, otherwise the experiment or interaction would not be worth conducting. It may be seen as a kind of concurrent Halting Problem or unknown signal identification with noise. It is never clear how long to cancel or average noise before a useful signal may emerge.

Responsible, Respectable distinguishes classical and quantum observability and controllability. A respectable Actor is classically observable, can be heard, seen etc. A potentially responsible Actor may require excitation or heating to fulfil a Heisenberg condition of respectability or observability. More usually excitation is needed to produce some desirable characteristic response. Pask saw these induced excitatory stresses and strains as analogous to the tautomeric forms of structural chemistry.

The IA forms are more facile in application and the ethical status of observation can emerge naturally, despite the somewhat unnatural Victorian resonance. The Home Office Minister appeals to us to instruct our children to show respect, which is fine if reciprocated by his Department's accountability, which is another form of the observability criterion. Simply put, lack of accountability is formally not respectable. With the Kalman (1961)[15] approach a system is controllable if there is some finite set of inputs which can produce a desired state. Observability of a given internal state requires a finite number of observations from which that state can be estimated. Given the Conant-Ashby (Conant & Ashby 1970) Model Regulator Theorem we can use requisite variety and insist observability precedes controllability to make a proper model.

The transfers of meaningful information implied require agreement or reproducibility according to the IA axioms. The Kalman criteria help us see what might be available for further rigour in the responsible (perhaps better response-able) and respectable (perhaps better respect) axiom definitions. There is an ethical position associated with these axioms that, surprisingly, stands up to further examination. When a test mass is released into an n body system it follows a path of minimum action (putting on one side what appears to be the transient maximum of the Tippy Top phenomenon). In a society we can interpret this as optimum action and therefore local and globally optimum (Bounais, 2002 and Pineau, 2002). The ethical implications of local/global optimisation or minimisation of action, the transformation of imperative to permissive or discretionary application, should be considered further.

It may not be widely agreed that altruism is a property of matter but that language supports it cannot be denied. Can language be applied without altruism? Suppression of language, censorship, stealth, privacy are the beginnings of the short termism or restricted local optimisation, which is not altruistic and not

respectable or responsible. If we speak of meaningful information transfer between self-organising systems then we may expect an ethical content. An application to the longer term, a eudemonic utility, as Stafford Beer might put it, as opposed to a hedony - the relatively short term gain which has recently lead to pension funds being plundered on a wide scale. Appropriate real time or concurrent engineering could make fraud of this kind impossible or, at least, far less likely to succeed. We might say of a Dawkins' gene that it cannot be selfish unless it can keep secrets.

The ethical content of interaction whilst implicit for Interacting Actors seems to lessen as Permissive Ap and Begins and Ends enter the picture. We note the notion of "optimal" is difficult in physical nature but where optimal trajectory in an n body system asserts itself, in real time and kinetically, there is implicit optimisation and thus ethical minimisation of action. In serial digital kinematic simulation accurate serial[16] digital computation with its begins and ends is implicitly error prone. The meaning of optimal in this sense might change with intention or purpose e.g. it may be quicker, more ethical with action minimised, to get to Mars by waiting for a better planetary alignment. Oddly, perhaps, determining the applicability of ethics or optimisation of action and purpose might yield fundamental theorems in concurrent computing. The failure to distinguish serial/parallel and pseudo concurrent (task scheduling) from true field concurrence is paralysing to development in computing. Shannon Information Theory's dependence on the Ergodic Hypothesis encourages this[17]. Turing's definition of Computability - what a bank clerk can do with a pencil, some paper and unambiguous instructions - similarly assumes seriality is competent for Universality. Ashby's more fundamental measure of Variety is not, in principle, sequentially constrained. The one line demonstration of Requisite Variety via the simple integration of bandwidth implies seriality. However the substitution of parallel communication channels presents no difficulty. Note Kolmogorov (Kolmogorov, 1956) shows the equivalence of Shannon Theory to continuous signals when observed with bounded accuracy. The substitution of parallel digital channels by true field concurrent (implicitly synchronised and dependent) continuous fields renders no difference to which Shannon, Turing or Ashby might object[18]. Thus Variety can be applied to the true concurrent case also.

Chaitin in personal communication confirms knowledge of Requisite Variety as a teenager. The purely Turing sequential proof of his Algorithmic Information Theory[19] that the length of incompressible algorithms are bound by their incompressible output follows freely from Ashby's Law of Requisite Variety. We have constraints exposed here that might yet yield a concurrent theory. Pask was adamant that Data Compression did not imply automatic theory building at least in the concurrent case. We seem to have the necessary ingredients for a concurrent theory. How to proceed is not decided.

Permissive and **Imperative** application of a stress-producing concept may be distinguished by freedom of choice: when the strains of concepts internal to a P-individual lead to autonomous action rather than action forced by another participant. We see clearly how delicate the balance between permissive and imperative application necessarily is. Perhaps like a random number generator permissive application is an ideal. Freedom of choice evolves, argues Daniel Dennett (Denett, 2003). Can permissive Ap ever be eternal? Further the hierarchy of force: weak, strong, electric and gravitational may yield to a nested homeostatic model of the balance of imperative forces. But what exactly is a permissive application? The outcome of what we call autonomous thought, no doubt, but is free will implied? The “no doppelgangers” clause so often applied by Pask implies no two concepts are the same because they are formed in unique contexts with unique perspectives. This provides an actor with unique

responsibility. Is this enough to guarantee free will? Wittgenstein says free will exists because future actions cannot be known now (Tractatus 5.1362), a position shared by Pask in his indeterminacy of foci of thought or attention and the indeterminacy of truncation and unfoldment given its origin (Table 4 Pask, 1993). We might say free will is environmentally determined. When thought forces are weakly perceived, distant and outside the nearest neighbourhood context, they form a background of noise. A stochastic resonance may occur, however, lifting out a concept under enfoldment. This will ensure unique action but not freedom of choice. Our willingness to accept responsibility for freedom of choice is seen as evidence by Pask (p.83 Pask, 1993) of sentience and eternal mystery. Could it be permissive application is only possible in contemplating the eternal and infinite? But that position uses a variety[20] argument that Pask would not approve at least in our private research dealings. Avoiding responsibility by claiming imperative constraints, which are, in fact, permissive, on choice or free will may be at the heart of much management failure today. The Beer model of Autonomy (Beer 1972) may provide a practically tenable position adumbrated by D. J. Stewart's (Stewart, 2000) Tern Theory and its intervention ratios with their supporting dimensions of imparity. An equilibrium between imperatives would seem a necessary initial condition for permissive Ap.

Pask claimed **Void** and **Not Void**, or "something" as not void may be called, were required distinctions in IA. A connected void of some kind distinguishes an M-Individual. In CT although voids may be invoked they are not required. The begins and ends of CT may be seen as abstractions of the void/not void. If begins and ends are real on/off phenomenon with characteristic rise times or even actual void/not void crossings an interesting question arises. Is Gibbs ringing seen around the begins and ends when the closed, periodic processes in a signal are counted with Fourier spectral analysis (ii.e. wWhen $\mathbf{Con}_z(T)$ is applied with **Ap** in a CT with begins and ends)? Voids are small with suitable dimensions around 10^{-35} m., the Planck length[21]. Are they found, perhaps, at the centre of superstrings? Are they the wormholes that join a Deutschian multiverse (Deutsch, 1997)? These are the tests they must pass to be part of a relevant physical canon.

Recall Concepts are made up of voids and "something" with '+' force (thought) directing into the not void. At the level of CT the Gibbs effect, an exponential decaying distribution of high frequency components (the circular processes that must be summed to produce a steep rise time, an "on"/"off" or begin/end) may be seen. Pask claims indeterminacy around the truncation and selection of an unfoldment force, '-', (mentation) allowing some smoothing and reduction of these undesirable frequency components. At the level of Interaction of Actors, in which the void is a necessary component, the convolution of a 0, 1 void/not void support with a test signal can cancel the Gibbs ringing. Careful choice of initial conditions can yield the necessary phase cancellation with a test signal[22]. The possible elimination of CT's Gibb's phenomenon by a wavelet convolution with the discrete punctured void/not void space that IA supports and requires underlines the depth of Pask's approach. This constitutes an outline proof of the value and power of the Begin/End, Void/Not Void axioms distinguishing CT and its IA support[23].

Agreement can be seen as trajectories between bodies in phase lock coupling or copying as in Wiener self-organisation (Wiener, 1961, p. 201). The "attraction of frequencies" as he called it in the second edition. It is interesting to note that this attraction only occurs in the parallel-coupled case and a serial coupling leads to instability or a spectrum of many frequencies. A deeper understanding of PLT immediately suggests itself wherein repulsion may cause unfoldment of concepts (mentation thence action or thought) but attraction may simply cause aggregation, learning or addition of a new concept. The push and

pull of thought, as it were. We might also notice that in his last paper Pask (Pask, 1996) used the von Foerster (von Foerster, 1981) redundancy measure, R, of self-organisation - itself motivated by the McCulloch condition of Redundancy of Potential Command.

$$R = 1 - H/H_{max}$$

where H is current bandwidth or entropy and H_{max} peak bandwidth or entropy

This condition, the minimisation of bandwidth and the maximisation of autonomy, motivates learning and the acquisition through agreement of new and useful concepts. The usual Paskian distinctions from CT/IA of similarity and difference apply here. The philosophical mechanic's cognitive reflector protocol can be applied to produce externalisation, in a medium shared by at least two participants, of a behaviour induced by one participant as a result of a communication act. The response by the second participant, with whom there also exists the analogical dependence of meaningful information transfer or communication, constitutes agreement. **Agreement to Disagree** is clearly the recognition by a pair of participants that this condition has not been achieved. It denotes the differences between participants. **Begins** and **ends** are implicit here. These bounding singularities are indicated here by a rapid change in radius of curvature of a trajectory or an encounter with the void (possible Gibbs effect and frequencies dependent on the magnitude of the force applied.) The precise nature of this interface where forces produce begins and ends needs further work.

Adaptation, **Generation** and **Evolution** are deeply intertwined, as indeed are all the axioms, but key features can be distinguished. Adaptation is a dynamical change perhaps elastic in character. From Ashby (Ashby, 1952) adaptation is the propensity to re-establish equilibrium or homeostasis. If asked to give an example of a simple adaptive system Pask once offered a "cushion". It seems quite reasonable to suggest Newton's Third Law "To every action there is an equal and opposite reaction" is a manifestation of the adaptive principle. In the n body environment Le Chatelier's Principle seems best to capture the adaptive principle: "A system will shift its equilibrium to oppose external change". The communication of difference seems a pre-condition for adaptation to occur. The interpretation of this phenomenon in terms of PLT in which an attractive difference produces an identity maintaining repulsion to a difference needs further work.

Generation is seen as growth by attraction and thus aggregation. There is a fuller discussion of this with supporting experimental work at the end of this paper.

Evolution requires meaningful information transfer or learning. The System Four of Beer's Viable System Model (Beer, 1972) embodies this most clearly but the inheritance of phylogenetic learning is more primitive. The ontogenetic learning of the Viable System comes after the evolution of a neuroanatomy[24]. For this generation is clearly required. It is interesting to note Pask's embodiment of Beer's autonomic response as an imperative application of self-organising forces. System Five ensures the more permissive applications of System Four is bounded by the Identity Imperative. Alfred Wallace (Wallace, 1858), whose letter to Darwin caused publication of "Origin of Species"[25], described evolution as a negative feedback process. In the penultimate paragraph of the paper to the Linnean Society Wallace states:

> *The action of this principle is exactly like that of the centrifugal governor of the steam engine, which checks and corrects any irregularities almost before they become evident; and in like manner no unbalanced deficiency in*

the animal kingdom can ever reach any conspicuous magnitude, because it would make itself felt at the very first step, by rendering existence difficult and extinction almost sure soon to follow.

In his paper the frequent use of the term variety as in "variety of species" and, as above, the term "unbalanced deficiency" (as extinction producing violation of homeostasis) are striking to the cybernetician. Bateson (Bateson, 1976) calls this "probably the most powerful thing that'd been said in the 19th Century".

Ten years later Maxwell (Maxwell, 1868) wrote "On Governors" but the discussion is restricted to Watt, Jenkin, Thomson, Foucault and Siemens who all produced centrifugal regulatory devices. Maxwell seemed unaware of Wallace's claims for the centrifugal governor, unifying electricity, magnetism and light was achievement enough, after all. Nowadays we speak of negative feedback. The term was not used until 1927 when Dr Harold Black[26] used a phase shifting loop back, patented in 1937, to cancel amplifier valve noise for the American Bell transcontinental telephone system.

The usefulness of an Evolutionary axiom cannot be denied provided it is interpreted as a negative feedback bound on the viability of a growing population and its associated extinctions, begins and ends. The Difference axiom can thus be applied with additional distinctions to Generation and Adaptation to yield Evolution.

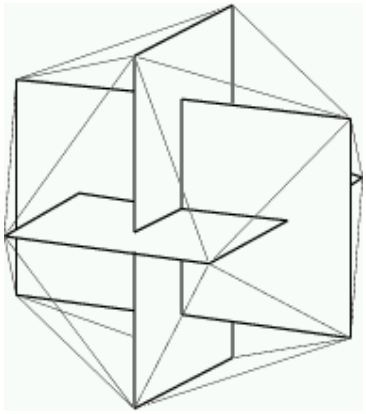

Figure 7 The Borromean link Intersection of three golden rectangles

Per Bak's challenge (failed by John Holland's Genetic Algorithm) to calculate a distribution of species extinction might be an interesting problem to attempt with IA assumptions.

The use of "viability" was strongly endorsed by Pask (Pask,1993, p. 70) with an affirmation of the depth of Beer's Viable System theory (along with his C.T., Lp and I.A.). "Foundationally Cybernetic in type as competent and very general if not universal theories" he wrote, "against a background of badly considered, pretentious and often meaningless general theories, greatly publicised and advertised by empty rhetoric." Many years ago Beer asked me after lunch what I wanted. I said "Freedom". I asked him what he wanted. He said he wanted to understand "cosmic repulsion" and we discussed Mach's Principle (the determination of local momentum relative to global momentum and the possible rotations of the universe). Now repulsion is embodied in PLT and the carapace theorem of autonomy. They may have claimed not to know much about each other's work but they certainly worked in the same garden. The unification of their approach is still elusive. However Beer (p. 187 Beer, 1994) takes us through the remarkable fact, Figure 7, that joining the vertices of the orthogonal intersection of three golden rectangles produces an icosahedron. After pointing out that "true Borromean circles" (Linstrom & Zetterstrom, 1991) are impossible Dr Peter Cromwell remarks that the boundaries of the golden rectangles are linked in the Borromean manner[27]. A sketch proof would let the vertices of the rectangles define the external radii of an elliptical toroid then let the three orthogonal penetrations be such that the internal major axis equals, or is greater than, the external minor axis. This produces the Borromean link shown in Figure

8. One link must be opened and closed to achieve this (as a Paskian '+' force questing for closure). Thus Pask Concept Triples and Beer Icosahedral Syntegrity have a topological equivalence supported in a void/not void with some minimum of number of void/not void crossings to permit closure. A host of new results and applications seems possible. Outside a void/not void support the transformation destroys half the vertices of the golden rectangles and a triangular tiling of a symmetrical Borromean ring produces an octahedron. ("Boiling the Platonic kettle"? -the Platonic icosahedron was associated with water and the octahedron with air.) Most profoundly the orthogonal form of the Borromean[28] stable concept triple can be seen as a cybernetic statement of continuity around a void.

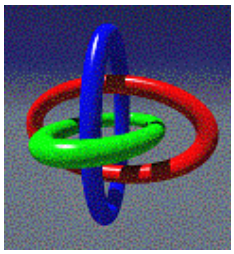

Figure 8 The Orthogonal Form of the Borromean link-isometric view.

A general theory of pain/pleasure regulation or algedonics (Beer, 1972) might help as an example of the evolution, differentiation and specialisation of function in self-organisation. This might help us define life, for example. Stafford Beer (Beer, 1998) suggests this in the urging of our profession to deepen its understanding of the role of hormones. "Molecules of Emotion" as Candace Pert, the pioneer of endorphin receptor chemistry, calls them in her book of that title. Could it be hormones support a permissive interface to the operation of an imperative force as, for example, when flooded with adrenaline in choosing a destination for fight or flight?[29]. Pask observed "Meaning is Emotion". He regarded his work as potentially generative of Beer's Viable System Model (Pask, G. 1993, p. 70). Mapping Figure 8 into an orthogonal three dimensional tessellation plane as an automaton with six nearest neighbours will produce an icosahedron.

Context and **Perspective** can be easily defined as the neighbourhood and your position in it and can be literally interpreted with no special caveats. Derrida's criticism of J. L. Austin (who holds speech acts depend on context) that context changes as utterances are made[30] are routinely handled in IA/CT by teach back differences. One might urge, as Obe Wan Kenobi in Star Wars, "Feel the Force, Jacques." A change in context means a change in resultant force vector, a test of sensitivity of the critic and his least noticeable difference. Getting used to the idea that there is real force in communication is a challenge to us all.

From the early work in CT participants in conversation shared an entailment mesh pruned or unfolded in ways different for each participant with their unique contexts and, indeed, perspectives. This is a powerful first step in hermeneutics and the potential use of the axioms as a toolkit for teaching Criticism; indeed the Critical Theory and Hermeneutics community should be advised of their depth and apparent robustness. The miracle of the communication of a similarity to a constructivist might well yield to the context and perspective differences of the achievement of agreement. A more rigorous definition of context is now possible thanks to the work of Jones et al (Jones, 2002). We are all bound to the context of the Universe (or Multiverse - to comply with Deutsch). In defining our context we are seeking which concepts or parameters are applicable. Jones et al's Gamma test measures the variance of nearest neighbours in hyperspace for continuous smooth models. When this variance is at a minimum we have a definition of the useful context. Outside the context forces produce background noise only. This is an extremely important result for Time Series analysis. It can select which Actors or parameters determine outcomes and are hence part of the local context. One application is in establishing the least obtainable error by a neural net after training on a data set. Effectively this is a kind of solution to the

Halting Problem for neural nets training on smooth data. It avoids the problem of over-training by advising when training can stop.

Unity without uniformity can be interpreted as an expression of identity, the System Five of Beer's VSM, wherein distinct parts cohere persistently. It is thus also an expression of **Purpose**. Purpose is the convergent or perceived outcome of a process, it may be another word for product. Nevertheless purpose, the product of a difference in a control or metasystem, is important in the emergence of Cybernetics and a key to its interdisciplinary success. The recognition that control is a reflexive process, a conversation or interaction, wherein who is meta cannot be established except where purpose or identity is maintained is part of the CT/IA paradigm. The purpose of self-organisation to minimise heat loss with redundancy, intelligent thermal lagging as it were, is coherent with Le Chatelier and the state changes of plasmas, gases, liquids and solids as they cool. So we see IA is also a theory of process and its product dual. To underline this in discussion with a Whitehead scholar I suggested the monumental classic "Process and Reality" could be retitled "Product and Reality". This was stoutly, if somewhat vacuously, resisted. Analysis of participant beliefs can be painful using I.A. The blend of facile and profound can surprise and delight but criticism is probably most effective if restricted to utterances that violate the axioms.

The question of identity is not dealt with in IA except in establishing the repulsive carapace of the successfully self-organised system. The System Three and Two processes of Beer's viable system are not distinguishable. Adaptation is implicit throughout the circular process but identity only comes as the requisite force produces a particular unfolding. Whilst there may be no doppelgangers an attractive difference is implied (PLT:"...unlike concepts attract"). However when two participants are attracted and meet, a hard carapace separates them. This can only be explained by unfoldment: I may be an expert on force, you may be an expert on mass. We both share a great deal of similar concepts yet we still retain our hard repulsive shells. Reductio ad Absurdum we both share the identical concept of a hard shell so by a tautology we repel. This does not constitute an adequate exposition of the mechanism. There is a great deal about orthogonal forces producing action under unfoldment in Pask (Pask, 1993) which may need further analysis to resolve this question. Interestingly ATD (Agreement to Disagree) maintains attractive differences.

The term **distinction** is widely known from Spencer-Brown (Spencer-Brown, 1969) and might be included for its power in setting up closure and minimal difference. We know, for example, $A \neq \overline{A}$ but what that means except as denoting a minimal difference is not clear. It is enough, however, to make it a required axiom though it may more properly be called a value, albeit subject to careful definition. It may be enough to regard it as the boundary of void/not void indeed the wavelet model of void crossing can be seen as analogous to the Primary Arithmetic. Here the magnitude of the force would define the Primary Algebra. The unification of the memory model in equations of the second degree is obviously required. Distinguishing $\overline{A}|B|$as the two pumps in the non-linear medium may satisfy the four waving mixing model.

The carapace distinguishes Pask Self-Organisation more than anything else. The repulsive force at the surface of the stresses and strains comprising an entailment mesh is produced as an invariant aspect of unfoldment of a concept which itself is compliant with PLT. Since Pask asserted that this structure could be found in stars we have to identify how that might be in solids, liquids, gases and plasmas (the earth, water, air and fire of antiquity). We are accustomed to regard hardness as a property of the solid state or condensed matter. However in all

cases of the uncondensed states of matter there exist circular convection currents. For existence these require gravity fields and variations in density. The anisotropy of diffusion in these cases is enough to regard the orthogonal force at the boundaries of a convection or circulation cell as the repulsive carapace force. The propensity to knot can be seen in vorticity, the powerful vertical currents at the centre of a tornado (whirlpool, waterspout, cyclone etc). This is the '+' force of Pask self- organisation. In general shear or curvature in fluid or gas flow induces relative vorticity. Clearly more rigour is required at the Planck scale of the sparticle and M-Brane but Borromean orbits are postulated for certain nucleons (Bhasin, 1999) e.g. ^{11}Li where two neutrons are thought to form a "Borromean Halo"[31]. A fuller investigation of Borromean linking and their star/delta supports is indicated.

A sixty-degree architecture for void/not void might be hypothesised. The close packing of spheres would seem to demand it. Sal Torquato et al (2000) however cast doubts on our ability to do this with rigour. He shows that experiment still cannot confirm Kepler's conjecture (part of Hilbert's 18th problem) now proved by Thomas Hales, outlined in Hales (Hales, 2000)[32] of 74.05% packing ($\pi/3\sqrt{2}$), but unconfirmed by experiment which persistently finds around a 64% packing fraction. Torquato reminds us how difficult even the simplest seeming scientific endeavour can be. Error inhabits all that we do. The presence of John Conway will be seen in the "many valuable discussions" which lead to this fascinating paper from Princeton that characterises the study of randomness as "still in its infancy".

At the macro level looking down on a pan of boiling water the hexagonal tiling of Rayleigh-Benard convection cells (Narasimhan, 1999)[33] can be seen. In noting the 60 degree geometry supporting the adjacency of three cells, we see a stable triple. Acheson (Acheson, 1990 p. 313) offers Drazin and Reid's method of heating a 2mm layer of corn oil in a clean pan sprinkled with cocoa as another means of observing this phenomenon. Olive oil and Bisto powder work just as well. The circular dynamic character of a convection cell only asserts when the buoyancy force (caused by the decrease in density of the hot liquid, plasma or gas) is greater than the force of viscous drag and rate of decrease of temperature. The Raleigh number characterises this condition of what we can now regard as IA self-organisation in non-condensed matter. The Rayleigh number is a dimensionless quantity defined

$$Ra = g\beta\Delta TL^3 / \alpha\nu$$

β is the coefficient of thermal expansion, ΔT the temperature difference between the hot and cold ends separated by distance L, α the thermal diffusivity and ν the kinematic viscosity of the fluid.

When $Ra > 1708$ convection will occur and an organisationally closed informationally open stable actor or concept can exist. This is one precise condition for self-organisation in gases and liquids. Continuity and incompressibility are assumed but despite this the work done in convection is close to a Carnot Cycle, a definition of entropy, information and the von Foerster redundancy measure of Self-Organisation. Further refinements are necessary to deal with (self-organising) surface tension forces at a free surface.

The sixty degrees architecture of convection cells also tries to assert itself geomorphologically. The phenomenon of columnar jointing, seen with the optimal but very rapid cooling of lava, can form hexagonally sectioned columns. Possibly the most prominent example is at the Giant's Causeway in County Antrim, Northern Ireland. The equilateral sixty-degree architecture was regarded by Pask as a characteristic of a minimising spatial self-organisation, see also Hales (Hales, 2000). This planar "hexatic" phase as it can be known is seen, for example,

within the 12 nearest neighbour close packing of spheres, benzene and graphite. With a "pentatic" component local tiling in three dimensions is enabled producing Beer icosahedral syntegrity, Buckminster Fuller tensegrity and the fullerenes. How might these structures assert themselves in planetary ecology, for example, in carbon, oxygen or sulphur cycles? Where are the forces working in Lovelock's Gaia Principle or plant and animal internal homeostats? The Gibbs Chemical Potential, μ, could be of assistance here,

$$\mu = (\partial G / \partial n)_{p,T}$$

where G is the Gibbs free energy, p is the pressure and T temperature in degrees Kelvin[34].

When the number of particles, n, is replaced with generalised space co-ordinates, or distance, an actual force results. There could be interesting implications for the chemistry of complex systems, in cell biochemical pathways, for example. The triple structure though not apparently assertive in the valency of elements does assert when molecular space is triangulated in the Delaunay-Voronoi manner, here using the delta dual of the concept triple[35]. This might suggest a single distinction may customarily be shared by three pairs of different concepts. Note, however, Terrestrial Chemistry is a special case often at 25°C and one atmosphere pressure. These are just two parameters out of many to comply with the Weak Anthropic Principle required for observers with a carbon-based consciousness, John Barrow and Frank Tipler (Barrow and Tipler, 1986). The exochemistry of Harvard's William Klemperer[36] provides an intriguing environment for matter in the Universe. In space chemistry occurs around 10K and 10^{-16} atmospheres. Here hydrogen occurs as H rather than H_2. Such prototypically organised forms as xogen (protonated carbon dioxide- $HOCO^+$), dicarbide (C_2), ketene (H_2CCO), cyanoethynyl (C_3N) are claimed to be identified by NASA. It is time to reconsider a Miller-Urey[37] type experiment at lower temperature and pressure. In terrestrial chemical self-organisation the pressure and temperature parameters imply in IA terms a greater density of imperative force equilibria. Thus in space we see the new exotic forms self-selecting and persisting.

The terms **Organisational Closure and Informational Openness** (OCIO) are nowadays widely accepted as defining of a system e.g. Maturana and Varela (Maturana and Varela, 1980). The IA scheme is coherent with this approach indeed Pask's (Pask, 1993) Chapter 7 "Interknitting" is largely given over to an analysis of this approach and illustrated by analysis of the Rituals of the Tsembaga. OCIO is supported but not required given a suitable supply of Actors who self-organise. One suspects that Pask is making a ritual nod at the profession and discharging his duty considering his findings to be more deeply applicable. Similarly Pask's acceptance of Second Order Cybernetics is trivial, achieved simply by labelling one of his participants observer in his standard IA or CT scheme[38].

The IA axioms are widely applicable. The applicability of an early version of Pask's work to psychotherapy, for example, of both individuals and organisations is shown by Barnes (Barnes, 1994). The IA scheme is designed for concurrent application so it should shed light on concurrent computation. Various hardware configurations continue to be considered. No confusion with quantum computing should be permitted where current proposals limit concurrence to the quantum registers in an emulation of the conventional serial digital computer. IA was in part a mission to Artificial Intelligence (AI) research to map a physics of self-organisation into common sense. It may yet come to the rescue if AI is to become more than attempts at advanced von Neumann machine programming.

Sceptics may say "Why speak of 'Respect' when you mean observable, why speak of 'Responsibility' when you mean interactive response or 'Faith' when you mean tenacity or duration of observation?" No great damage is done we hope but applicability is greatly facilitated. In particular the putting of the so-called "soft sciences": psychology, sociology, politics etc. and law on a sounder basis. One capable of producing sharp values (as distinct from Zadeh fuzzy values) of a precision equal to any obtainable in the so called hard sciences of Physics or Chemistry. But remember the error bars on forecasting the boiling time of the kettle, of the age of the earth and, indeed, to the close packing of spheres. We recognise the need to make assumptions and restrictions on idealisations equivalent to those made as the Euclidean becomes the Newtonian thence the relativistic, quantum and non-linear in science. The violence that poverty, scarcity and ignorance or lack of requisite difference breeds should be easily demonstrable from the Ekistic Density effect (see below). The means by which housing might be designed to encourage permissive application of self-organising force might be made formal. IA can offer a deeper understanding of the intractability of "schizophrenia" to Double Bind Theory, the Public Health implications of hypocrisy, its implications for secrecy about sexual behaviour, for example, and the multiple risks of irresponsible unaccountability.

A Bourbakian approach to axioms for Cybernetics may begin to be feasible. For IA to make a contribution the prepositional anti-mesh linked by an analogy mesh to a characterising and ontology mesh of the Actor (Table 3 Pask, 1993) needs a deal more work!

There seem to be immediate applications in putting Criticism on a more rigorous basis indeed making Criticism into a science. The hermeneutic requirements of Post Modernism seem fully satisfied. Others may care to challenge that. The applications of these axioms to Beer's Principles of Organisation (Beer 1979, 1985) and Pask's own "Properties of Self-Organised Systems and their consequences for a company" (Green, 2001, footnote 11) may also form an interesting objective for future research.

De Zeeuw's observation (de Zeeuw 2001) that IA makes it possible to search for Theory suggests Pask's goal of a dynamic proto-theory may have been achieved. As de Zeeuw so wittily observed at CybCon 2002 IA enables one to say things like "Love makes the World go round." The axioms provide a route to a robust seeming proof. One wonders where this might lead us. It seems apt to identify constraints on the applicability of IA both to practical questions and to the analysis of others approaches to what is seen as the fundamental in Nature.

Applying IA: The Groningen experiment

In 1995 Orit Kaufman, a student of John Frazer at the Architecture Association where Pask was Senior Tutor, wanted to apply IA to her contributory study of Evolutionary Ekistics in Groningen. We unexpectedly showed relatively weaker IA attraction forces lead to denser housing settlements. Subsequently the result was applied in cardiology and planetary accretion. It turned out to be a classic piece of Cybernetics. The book of the Groningen Experiment is to be dedicated to the memory of Gordon Pask (Frazer 2001).

Generation in general, *pace* the subtleties and specialisations of meiotic and mitotic cellular reproduction, is primarily a sticky, attractive, aggregative process. This is elegantly captured in the Diffusion Limited Aggregation (DLA) model of Tom Witten and Len Sander (Witten & Sander, 1981). Sticky random walkers are released onto a fixed attractive seed from a boundary on a tessellation plane. These forces are local only and have a range of one cell. This clearly models self-organising growth. Ramified structures are seen as in moulds, brains, the nervous

and circulatory systems of animals, the xylem vessels of plants, roads, railways, rivers and streams. These can be seen as aggregations of random Y shaped forms embodied in the "star" dual of the stable concept triple.

With Kaufman serial, digital kinematic DLA simulation programs[39] were written and we constructed copper/copper sulphate electrochemical cells for concurrent kinetic simulation. From the cell we produced growth of dendritic connected settlements of copper actors at point and plate cathodes - illustrated in Kaufman (Kaufman, 1996) and Frazer (Frazer, 2001). For more elaborate electrochemical DLA techniques see Harrison (Harrison,1995).

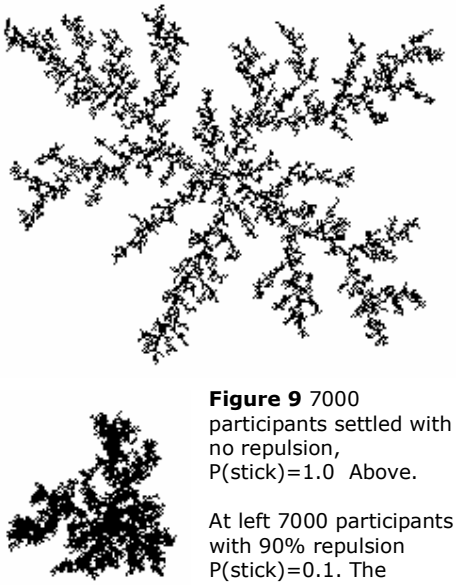

Figure 9 7000 participants settled with no repulsion, P(stick)=1.0 Above.

At left 7000 participants with 90% repulsion P(stick)=0.1. The participant density is more than 4 times greater.

The electrochemical simulation uses a plate sacrificial copper anode (cut from copper pipe) at up to 30 volts in around M/4 aqueous copper sulphate solution. Electrodes were separated by 10-15 cm in a solution about 0.5 cm deep. A river or canal bank was simulated by a plate cathode, a cross roads, well or spring by a point cathode. Kaufman's electron micrographs (p138, Kaufman 1996) confirmed self-similar aggregation.

Our interesting discovery came with the fuzzification of the Witten and Sander algorithm. We introduced a repulsive force parameter. In the digital simulation a colliding random walker or participant is only permitted to stick if a probability of sticking threshold, fixed for a given experimental run, is exceed by a random number chosen from the half-open interval [1, 0). Further we identify the probability of sticking as the probability of attraction and we define an identity for the simulation

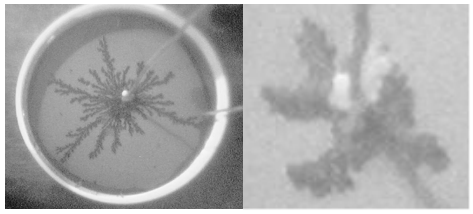

Figure 10 Left Copper DLA grown in 35 minutes at 30 volts in 2.5amp current limited 5cm diameter 1cm deep cell with circular anode and central point cathode. At right a five times enlarged view grown over five hours at around 3 volts.

P(Attraction)= 1- P(Repulsion)

Figure 9 shows the plot obtained with the modified Witten and Sander algorithm on a serial (kinematic) machine with the star dual, plan view map of participants initially attracted to a single point roughly at the centre of each mesh. In the kinetic analogue electrochemical model, Figure 10, counter ions make a more complex model of operating force but once the electrochemical potential threshold is exceeded the lower the voltage the less sticky or attractive migrating ions are. In both kinetic and kinematic simulation we found *smaller, denser structures formed with less attractiveness* (or more repulsive forces or less amity).

At this point Kaufman discovered Batty and Longley (Batty & Longely, 1994). Their work though primarily with Dielectric Breakdown Models used a

potential parameter, η, corresponding to our kinetic voltage or kinematic stickiness produced population density differences similar to those seen with our simple DLAs. Others, planning experts had seen that this approach did indeed model the growth and evolution of one dwelling to a hamlet thence to a village, a town and a city.

In settlement theory or Ekistics terms the more repulsive the short range force between settling actors, the more similar are the actors by PLT, the more dense the resulting settlement. The result seemed entirely counter intuitive but confirmation by social observation is trivial. The financially or conceptually poor tend to live in higher density housing than the educated rich whether urban or rural. "Rummaging" or shallow tunnelling behaviour explains the result: repeated random walking attempts to find sticky attraction in a local neighbourhood. The conceptually rich and variegated arrive and settle at once being most attractive and sticky. As with all randomly choosing participants some will walk back beyond the source radius and then be excluded and Ended with their viability expired. Whilst walking persists actors demonstrate Faith in achieving their Purpose. The Eternal nature of the settled actors should also be noted.

This proved to be a delightful and satisfying result elegantly demonstrated both in a serial machine (kinematic) and in concurrent (kinetic) analogue simulation. P(stick) probability is interpreted as a Similarity/Difference metric from PLT. There is also an interpretation in terms of Amity where p(stick)= Amity. The void/not void is the unoccupied/occupied cell on, in this case, the orthogonal tesselation (the random walking participant has four choices of direction). A hexagonal or hexatic tesslation (the walker has six choices) produces no distinctive difference yet seen in this context. A more complex context can be created for the growing community of actors or participants embodying concepts when each cell is assigned an attracting or repelling force of some appropriate magnitude rather than void or not/void only. The other tool, corresponding to Batty and Longley's spatial parameter, θ, restricts the release of walking participants to particular locations from a road, path or city gate, for example. This restricts the perspective of potential Actor settlers. The terrain in the Groningen Topography was modelled in this way (p.110 Kaufman, 1996)

Later the findings of this model were applied to congestive heart disease and, in particular, anti-coagulation therapy. This therapy aims to reduce the stickiness of arteriosclerotic plaques that are the aggregates in this case. The model suggested that while the incidence of heart attacks may be reduced, the incidence of fatal cerebrocardiac events might be increased. This is because of the reduced ease of digestion of the denser displaced plaque aggregate that is thought to be the pathological agent in stroke or thrombosis. A recent large Swedish study (Odén & Fahlén 2002) supports this hypothesis by concluding that lower doses of anti-coagulant reduce excess mortality. Sufferers might consider Pauling Therapy[40] which seems to exhibit only benign side effects.

This was the first experimental work undertaken demonstrating aspects of attraction and repulsion in self-organisation. Pask though unwell took a lively interest. Very early on he worked in electrochemistry to demonstrate concept growth in which a self-repairing aspect to dendrites was demonstrated, Pask (1959). Reflecting today on planetary evolution we see that a weakly attractive stickiness force is enough to make the dense rock bodies of planets by aggregation of principally siliceous dusts. Barrow and Tipler (Barrow & Tipler, 1986) p.288 state

> *The size of bodies like stars, planets and even people are neither random nor the result of any progressive selection process, but simply the*

manifestations of the different strengths of the various forces of Nature. They are the examples of possible equilibrium states between competing forces of attraction and repulsion.

This is most helpful to our central theses but IA suggests that weak force selection or permissive Ap might operate when stronger imperative forces are in equilibrium. The fractionation processes that produce variations in isotopic ratios and atomic abundances in stars and planets, for example, can be seen as naturally selective without any loss of understanding. This mechanism needs more work but whilst concepts are internal and endogenous forces operate IA can with good reason speak of perspective and context bound, respectable, responsible selection.

Relatively weak forces are doing these primary organisational tasks. For Klemperer, too, Astrochemistry is dominated by weak van der Waals forces rather than the stronger forces of Pauling covalency. Indeed in outer space without interaction from a dust support hydrogen atoms will be blown apart by the energy released with the formation of transient H_2. Here IA suggests imperative "background" force equilibria are required to select conditions suitable for the stable formation of ordinary diatomic hydrogen.

At the time of the Groningen work DLA structures were thought to be scale invariant but recent work by Benoit Mandelbrot (Mandelbrot et al, 2002) has established possible non-linear scale invariance. A shift in fractal dimension from 1.67 to 1.71 has been demonstrated for aggregates of 10^5 and 10^8 particles. This may imply in the IA model we are developing that absolutely different geometries exist for sticky non-voids and larger aggregates. Differences, for example, when sticky, attractive particles make stars, planets, meteorites, dusts, bubbles[41], foams, sols, aerosols, plants, animals, indeed, the entailment and actor meshes of CT and IA.

The Mandelbrot team may be making considerable demands on serial kinematic digital computation to measure the fractal dimension for larger structures. A "gedanken" two thousand processor parallel kinematic machine with one 10GHz processor for each random walking step would require of order ten million years run time for a 10^{22} aggregate DLA simulation. The kinetic electrochemical aggregates weighed about 1 to 0.1 gram implying $\sim 5X10^{21}$ participants and a run time of 20 minutes to a few hours at lower voltages. Box-counting determination of the fractal dimension of the copper aggregates would require electron and surface tunnelling microscopy but the procedure makes large structures tractable. For the simulation of an earth sized planet aggregation of some 10^{50} atoms is involved providing yet more motivation for innovation.

Concluding Comments

Such is Pask's IA legacy to us. He discovered a mechanics for self-organisation and a cosmological epistemology. He invented a new approach to the application of science. Unexpectedly his theory showed us the repulsive force of self-organisation could explain why the density of housing becomes high for the information poor, how anti-coagulation therapy can kill and why weak forces are sufficient to build dense planets. We have the tools to understand more clearly the evolution of physical and chemical form and function and deep axioms for a more natural human interaction.

---

[1] Hydro Aluminium, part of Norsk Hydro, Norway's largest company for Dr Bjorn-Erik Dahlberg Senior Vice President Human Resources and Environment, Health and Safety. The theme was Organisations as Lliving Oorganisms and Ecologically Sustainable Innovation.

[2] An analysis of Newton's Laws of dynamics from the IA cybernetic perspective might suggest the first law is a law of homeostasis, the second a law of stable concept triples, the third a law of negative feedback.
[3] My thanks to Dr Bernard Scott for pointing this out.
[4] We will use both star and delta representations of concept triples as appropriate. A further but as yet unexplored route from Computational Geometry might be to allow the resonance concept triple nodes to define an "empty circle"- a unique closed process defined by the stresses and consequent strain separations of all three concept nodes.
[5] There is a great deal about four wave mixing, phase conjugation, non-linear optics etc on the web and elsewhere. Ib Bang has a helpful introduction of this remarkable phenomenon at http://www.futureworld.dk/tech/ether/phasecon/phasecon.htm
Reflection at a spherical mirror will produce "time reversal" but without the potential for amplification implicit in wave mixing.
http://www.anu.edu.au/Physics/ACIGA/DEM/Kirk_4WM.ppt is a Powerpoint presentation by Dr David McClelland of Australian National University.
[6] Both fractal and "prismatic" recursive packing schemes for Borromean links are discussed by Slavik Jablan in "Are Borromean rings so rare?" at http://members.tripod.com/vismath5/bor/index.html from the e-Journal Visual Mathematics vol. 2 No 4 2000.
[7] http://www.santafe.edu/~moore/gallery/index.html
Applet with Moore and Simo's choreographies http://www.soe.ucsc.edu/~charlie/3body/
[8] http://mathworld.wolfram.com/Kolmogorov-Arnold-MoserTheorem.html and see also note 20
[9] http://www.bbc.co.uk/history/historic_figures/laithwaite_eric.shtml
[10] http://scienceworld.wolfram.com/physics/TippeTop.html
[11] http://www.aip.org/history/esva/html/pauli_c4.html
[12] http://order.ph.utexas.edu/index.html
[13] Hear this in Acheson's own words from a radio interview in February 1998 by Thames Valley FM at http://www.jesus.ox.ac.uk/~dacheson/intview.html
[14] Health and Safety Executive Report: http://www.hse.gov.uk/railways/pottersbar/progreport.htm
"Railtrack's decision-taking can only be strengthened by shifting the balance back in the direction of professional engineers who understand how to maintain and operate the system." Michael Fabricant MP http://www.engineeringtalk.com/news/egc/egc102.html
[15] "Controllability and Observability: Tools for Kalman Filter Design" Southall et al. http://www.bmva.ac.uk/bmvc/1998/pdf/p043.pdf
[16] Note parallel computation is precisely equivalent to serial. Prof. Aaron Sloman suggests a proof by merging processes and increasing clock speed (discussed in personal communication).
[17] The ergodic hypothesis may be stated thus: the distribution of states in an n body system at a given time is the same as the typical distribution in member bodies over their history. It is an assumption of kinetic smooth (non-kinematic, non-digital, no begins and ends or steep gradients implied) serial/parallel equivalence to concurrence. It's applicability continues to be discussed.
[18] Unless, as Pask pointed out in the mid seventies in a Brunel seminar, they were aware that strictly Shannon needed synchronisation or redundant tricks e.g. "flag waving" (as found in computing device interfaces) to correctly frame and hence decode symbol streams. This is key to understanding how clocking and the interrupt renders the serial/parallel machine crucially insensitive to fields. Compare this with the resonant response of the prismatic tensegrity element.
[19] http://www.cs.auckland.ac.nz/CDMTCS/chaitin/#B
[20] The space around points of homeostasis or equilibrium is bounded by singularities whose encoding leads to infinite varieties. It is invariably the interaction of these singularities that is the source of interesting behaviour. Freeman Dyson (personal communication) denied singularities exist. Pask was sympathetic to this in adopting the variety measure (Green, 2001, note 11) in his axioms for self-organising companies. On p. 63 (Pask, 1993) the distinction singularity in an analogy is seen as a potential generator of requisite variety. Consider taking moments around a pivot at equilibrium. A $\pm\varepsilon$ can determine a clockwise or anti-clockwise moment, the "Tipping-Point". The problem lies in a finite bounding for the coding of the ε that may become infinitesimal in the digital machine. Perhaps part of the Art of Cybernetics is devising approaches that overcome this restriction to our methods. In the field concurrent computer magnitudes are represented by field intensities and an ε will scale with all other parameters permitting singularities to exist without pathology.
[21] Nikolay Kosinov (Kosinov, 2001) in a virtuoso paper reports 12 methods of calculating the Planck length.
[22] Newcomers to this field may find Barbara Burke Hubbard (Hubbard, 1996) "The World According to Wavelets". This is a helpful overview of the new wavelet approach to Signal Processing incorporating an approach to Heisenberg Uncertainty and Quantum Mechanics. The remarks on p. 114 about the KAM Torus theorem and Weierstrauss' faith in Dirichelet's n body series converging, not shared by Birkoff and Poincaré, is a helpful introduction to turn of the last century n body research.
[23] My thanks to John Adams, ex-Pask Associates, for an extraordinarily powerful Pask aphorism: a proof of causality depends on begins and ends. The converse is also true: causality cannot be demonstrated when interaction is eternal. We are distinguishing finite and infinite communication. In mathematics counting is not seen as requiring interactive communication. There is great potential here for establishing a cybernetics producing a more rigorous treatment of nature than mathematics as we know it today.

[24] But a case can be made for e.g. a rock feeling pain. Consider an impact in the region of the elastic limit. The Thomson EMF produced by the impact would correspond to the pain signal. We might postulate a distributed System Four (Development) function to repair the crack by concretion if water is present. The rock's thermostasis will define its ability to resist icing that can promote fracture.
[25] http://www.literature.org/authors/darwin-charles/the-origin-of-species/index.html
[26] A Brief History of Feedback Control from Chapter 1: Introduction to Modern Control Theory, in: F.L. Lewis, Applied Optimal Control and Estimation, Prentice-Hall, 1992.
http://www.theorem.net/theorem/lewis1.html
[27] http://www.liv.ac.uk/~spmr02/rings/maths.html
[28] My thanks to Ben Laurie for introducing me to ideal, tight knots which are made with minimal string length. At http://www.links.org/knots/images/02-05.001-sandt2.png he shows the stadium, "waisted" Borromean link produced via simulated annealing. Could this define a form for Pask's void?
[29] At http://www.dylan.org.uk/baron-cohen.html Simon Baron-Cohen in his review in Nature 410, 520 (2001) of Dylan Evans monograph "Emotion" OUP 2001 ISBN 019285453x claims to have classified "1000 discrete emotions into 23 mutually exclusive categories". A challenge to the cybernetics of emotion. Candace Pert's "Molecules of Emotion" was published by Scribner in 1997. Estimates vary but some claim more than 300 neurotransmitter substances and some 50 hormones in humans.
[30] Discussed in Paul Cilliers' "Complexity and Postmodernism" p. 55 et seq. Routledge 1998 ISBN 0415152879
http://www.iisc.ernet.in/pramana/sept99/i1.pdf
[31] http://www.iisc.ernet.in/pramana/sept99/i1.pdf
[32] http://www.math.pitt.edu/~thales/
[33] http://engr.smu.edu/~arunn/html/convect/rbconvect/rbcon.html
[34] Philip Candela prefers $\mu = (\partial U / \partial n)_{p,T}$ where U is the internal energy and more fundamental he argues. http://www.geol.umd.edu/pages/facilities/lmdr/chmpot.htm This is not usual compare a standard approach in eg Atkins "Physical Chemistry" OUP 5th Edition 1994 page 170.
[35] http://www.cs.cornell.edu/Info/People/chew/Delaunay.html
http://www.ams.sunysb.edu/~jsbm/courses/345/ams345.html
[36] http://www.chem.harvard.edu/faculty/klemperer.html. Primarily a spectroscopist his 1997 Lecture to the Royal Institution http://www.vega.org.uk/series/vri/vri2/index.html was eye opening to the real universe of Chemistry and self-organising molecular phenomena. Note spectroscopic analysis of human interaction is potentially deeply insightful, for example, analysing Pask's versatility in learning.
[37] http://www.chem.duke.edu/~jds/cruise_chem/Exobiology/miller.html Miller-Urey produced amino acids from a hypothetical primitive reducing, oxygen free terrestrial atmosphere.
[38] In his monograph "Rheostasis" Morovsky discusses the setting of fixed points in homeostasis in general. Thus the student or experimenter in the lab with his rheostat becomes second order cybernetician.
[39] For downloadable demonstration DLA program with variable stickiness parameter for pc compats http://www.nickgreen.pwp.blueyonder.co.uk/devarea.htm
[40] www.paulingtherapy.com
[41] Joseph Plateau (1801-1883) found rules for soap film bubbles requiring three films to meet to form an edge, always at an angle of 120° and with four films meeting at the tetrahedral angle (109° 28') to form a point. This three dimensional tiling may coexist with Pask's recursive concept within a concept. Formal energy minimisation was not proved until 1973 by Jean Taylor in Annals of Mathematics (2) 103 (1976), no. 3, 489--539. http://www.stanford.edu/~meadows/math/create.html. There may be a basis here for a real-time field concurrent solution to the Travelling Salesman Problem.

References

Acheson, D. J. (1997) "From Calculus to Chaos" Oxford University Press Oxford ISBN 0-19-850257-7

Acheson, D. and Mullin, T. (1993) Nature Vol 366 pp. 215-216 (1993)

Acheson, D. J. (1990) "Elementary Fluid Dynamics" Clarendon Press Oxford ISBN 0-19-859679-0

Ashby, W. R. (1952) "Design for a Brain" Chapman Hall London

van Baal, P. and Wipf, A. (2001) "Classical Gauge Vacua as Knots" Physics Letters Vol B515 (2001) pp. 181-184
http://arxiv.org/PS_cache/hep-th/pdf/0105/0105141.pdf

Bak, P. (1997) "How Nature Works: The Science of Self-Organised Criticality" Oxford University Press Oxford ISBN 038798738

Barrow, J. D. and Tipler, F. J. (1986) "The Anthropic Cosmological Principle" Oxford University Press Oxford ISBN 0198519494

Barnes, G. (1994) "Justice Love and Wisdom" Inform Lab 1994 ISBN 9531760179

Bhasin, V. S, (1999) "A three body approach to study the structural properties of 2-n halo nuclei and the search for Efimov states" Pramana Journal of Physics Indian Academy of Sciences Vol 53, No 3 September 1999 pp. 567–575

Bateson, G. (1980) "Mind and Nature- A Necessary Unity" Bantam Books ISBN1572734345

Bateson, G. (1976) "For God's Sake, Margaret" CoEvolutionary Quarterly, June 1976, Issue no. 10, pp. 32-44. http://www.oikos.org/forgod.htm

Batty, M. and Longley, P. A. (1994) "Fractal Cities: A Geometry of Form and Function" Academic Press London

Beer, S. (1998) " On the Nature of Models: Let us Now Praise Famous Men and Women, from Warren McCulloch to Candace Pert" Informing Science Vol 2 No 3 1998 http://informingscience.org/Articles/Vol2/v2n3p69-82.pdf

Beer, S. (1994) "Beyond Dispute" John Wiley ISBN 0-471-94451-3

Beer, S. (1985) "Diagnosing the System for Organisations" John Wiley Chichester ISBN 0-471-90675-1

Beer, S. (1979) "Heart of Enterprise" Wiley Chichester ISBN 0471275999

Beer, S. (1972) "Brain of the Firm" 2nd. Edition 1981 Wiley Chichester ISBN 047194839X

Bounais, M. (2002) "Universe as a self-observable, self-ethical, life-embedding mathematical system" Kybernetes 2002, Vol.31, no 9/10 pp1236-1248

Chattopadhyay, U. and Nath, P. (2001) "Upper Limits on Sparticle Masses from g-2 and the Possibility for Discovery of Supersymmetry at Colliders and in Dark Matter Searches" Physical Review Letters 86 (2001) 5854-5857 http://arxiv.org/PS_cache/hep-ph/pdf/0102/0102157.pdf

Chaitin, G. J. (1990) "Algorithmic Information Theory" Cambridge University Press Cambridge http://www.cs.auckland.ac.nz/CDMTCS/chaitin/cup.pdf

Conant, R. C. and Ashby, W. R. (1970) "Every Good Regulator of a System must be a Model of that System" International Journal of Systems Vol 1 No 2 pp. 89-97

Dawkins, R. (1976) "The Sefish Gene" Second Edition 1989 Oxford University Press Oxford ISBN 0192860925

Deutsch, D. (1997) "The Fabric of Reality" Alan Lane The Penguin Press ISBN 0713990619

Dennett, D. C. (2003) "Freedom Evolves" Allen Lane London ISBN 0713993991

Foester von H. (1995) "Ethics and Second-Order Cybernetics", Stanford Humanities Review vol.4 no. 2 http://www.stanford.edu/group/SHR/4-2/text/foerster.html

Foester von H (1981) "Observing Systems", Varela, Francisco ed., InterSystems Seaside, CA.

Frazer, J. H. (2001) "The cybernetics of architecture: a tribute to the contribution of Gordon Pask" Kybernetes Vol 30 Number 5/6 pp. 641- 651

Green, N. (2001) "On Gordon Pask" Kybernetes vol 30 No 5/6 2001 pp. 673-682

Hales, T. C. (2000) "Cannonballs and Honeycombs" Notices of American Mathematical Society Vol 47 No 4 pp. 440-449 http://www.ams.org/notices/200004/fea-hales.pdf

Harrison, A. (1995) "Fractals in Chemistry" Oxford University Press Oxford ISBN 019855767

Hubbard, B. B. (1998) "The World According to Wavelets" AK Peters ISBN 1568810725

Jones, A. J. (2002) "A proof of the Gamma test" Proceedings of the Royal Society Series A Vol 458 pp. 2759-2799 http://www.cs.cf.ac.uk/user/Antonia.J.Jones/GammaArchive/IndexPage.htm

Kalman, R. E. and Bucy, R. E. (1961) "New Results in Linear Filtering and Prediction Theory" American Society of Mechanical Engineers Journal. Vol 82 pp 193-196

Kaufman, O. (1996) "The Projects Review 1995-1996" p.110 & p.138 Architectural Association 1996 ISBN 1870890663

Kolmogorov, A. N. (1956) "On the Shannon Theory of Information Transmission in the Case of Continuous Signals" Institute Electrical and Electronic Engineers Transactions on Information Theory, Vol IT-2 pp. 102-108 Sept. 1956

Kosinov, N. (2001) "The New Formulas to Calculate Planck Units" Анатолия, Vol 6 pp. 176 - 179 http://www.sciteclibrary.com/eng/catalog/pages/2940.html

Kübler-Ross, E. (1969) "On Death and Dying" Touchstone, 1997 ISBN: 0684842238 http://www.elisabethkublerross.com/

Lindstrom, B and Zetterstrom H. -O. (1991) "Borromean circles are impossible", American Mathematical Monthly 98 no 4 pp 340-341

Long J.C, Chan H.W, Churnside A.B, Gulbis E.A, Varney M.C.M, and Price J.C. (2003) "Upper limits to submillimeter-range forces from extra space-time dimensions" Nature Vol 421 pp. 922-925

Mandelbrot, B., Kohl, B. and Aharony, A. (2002) "Angular Gaps in Radial Diffusion- Limited Aggregation: Two Fractal Dimensions and Nontransient Deviations from Linear Self-Similarity" Physical Review Letters **88**, 055501 (2002)

Maturana, H and Varela, F (1980) "Autopoiesis and Cognition" Kluwer Cologne ISBN 9027710155

Maxwell, J. C. (1868) "On Governors" Proceedings of the Royal Society Vol 16, pp. 270-283

Morovsky, N. (1990) "Rheostasis" Oxford University Press New York ISBN 0195061845

Narasimhan, A. (1999) "Rayleigh-Benard Convection: Physics of a widespread phenomenon," *Resonance,* Vol 4 No 6 pp. 82-90

Odén, A. and Fahlén, M. (2002) "Oral anticoagulation and risk of death: a medical record linkage study" British Medical Journal Vol 325 pp.1073-1075 (9 November) http://bmj.com/cgi/content/full/325/7372/1073#SEC3

Pask, G. (1959) "Physical Analogues to the Growth of a Concept" in "Mechanisation of Thought Processes" ed Uttley, A. London National Physical Laboratory Symposium 1958 HMSO 1959 vol. 2 pp. 877-922

Pask, G. (1975) "Conversation, Cognition and Learning," Elsevier, London

Pask, G. (1976) "Conversation Theory: Applications in Education and Epistemology" Elsevier, London

Pask, G. (1990) "Complementarity in the Theory of Conversations" in Nature, Cognition and System Carvalho, M (Ed.) Proceedings of Baden Baden Symposium 1990 Reichsuniversitiet, Groningen

Pask, G. (1993) "Interactions of Actors, Theory and some Applications" Gordon Pask and Gerard de Zeeuw Volume 1 "Outline and Overview" (Draft Last edit April 1993 Still Unpublished) http://www.cybsoc.org/PasksIAT.PDF

Pask, G. (1996) "Heinz von Foerster's Self-Organisation, the Progenitor of Conversation and Interaction Theories" Gordon Pask, Systems Research vol 13, No 3 1996 pp 349-362 http://www.nickgreen.pwp.blueyonder.co.uk/GPprog.PDF

Pineau P.-O.(2002) "An Ethical Behaviour Interpretation of Optimal Control", in Optimal Control and Differential Games - Essays In Honor Of Steffen Jørgensen, Zaccour G. (ed.), Boston: Kluwer Academic Publishers, 2002. http://web.uvic.ca/padm/people/Pineau/EthicalBehaviorApril02.pdf

Rawls, J (1973) "A Theory of Justice" Oxford University Press Oxford ISBN: 0674000781

Rescher, N (1966) "Distributive Justice" Bobbs-Merrill New York 1966

Shih, C (1987) "Theory of Four Wave Simulated Brillouin Scattering" Society for Optical Engineering (SPIE) vol 739 pp 26- 31

Simó, C (~2000) "New families of Solutions in N-Body Problems" Institut de Mecanique

Celeste, Observatoire de Paris. Pre-print http://mat.uab.es/art3ecm/simo.pdf

Spencer-Brown, George (1969) "Laws of Form" 3rd Edition 1979 Dutton New York ISBN 0-525-47544-3

Stewart, D. J. (2000) "The ternary analysis of work and working organisations" Kybernetes Vol 28 No 56 pp. 689- 701

Torqato S, Truskett, T. M. and Debenedetti P.G. (2000) "Is Random Close Packing of Spheres Well Defined?" Physical Review Letters Vol 84 No 10 pp. 2064-2067 http://cherrypit.princeton.edu/papers/paper-176.pdf

Wallace, A. (1858) "On the Tendency of Varieties to depart indefinitely from the Original Type" Linnean Society 1858 http://www.inform.umd.edu/PBIO/darwin/dw05.html

Wiener, N. (1961) "Cybernetics: or Control and Communication in the Animal and the Machine" 2nd. edition M.I.T. Press Cambridge Massachusetts ISBN 026273009

Witten, T. and Sander, L. (1981) "Diffusion-limited aggregation, a kinetic critical phenomenon" Physical Review Letters, Vol 47, 1981 pp. 1400-1403

de Zeeuw, G. (2001) "Interaction of Actors Theory" Kybernetes Vol 30, No 7/8 2001 pp. 971-983.

Tippy or Tippe Top some references to studies Weisstein, Eric http://scienceworld.wolfram.com/physics/TippeTop.html

A downloadable **Threebody simulator**, THREEBP.BAS at http://www.jesus.ox.ac.uk/~dacheson/programs/index.html see also Acheson's Vortex Research on curious self-organising vortex "leapfrogging" and his remarks on Kelvin's early knot theoretic "vortex atom" theory in "Elementary Fluid Dynamics" OUP 1990 pp168-172 including a Borromean Ring from Lord Kelvin (1869) Transactions Royal Society of Edinburgh 25, pp217-260 reprinted in "Knots and Applications" ed. Louis Kauffman World Scientific 1995 ISBN 981-02-2030-8

Choreographies demonstration applet of the recent work of Simo, Chenciner and Montgomery http://www.soe.ucsc.edu/~charlie/3body/

Further discussion of Pask and his IA axioms ongoing at **www.cyberneticsassociates.co.uk**

Acknowledgments

Figure 3 from Rob Scharein http://seemanlab4.chem.nyu.edu/borro.html
Department of Chemistry, New York University, New York, NY 10003, USA
Professor Seeman' Lab claim synthesis via circular DNA. Many Reidemeister moves are required on the many crossings of the product to establish planar isotopy with the Borromean knot

Figures 4 and 5 redrawn from Captain Ian P. Stern
http://cimar.mae.ufl.edu/CIMAR/thesis/ian_stern.pdf
MSc Thesis 1999 Department of Mechanical Engineering University of Miami
Stern analyses prisms with up to six struts (90° twist) for "self deployment"

Figure 7 is redrawn from Dr Peter Cromwell http://www.liv.ac.uk/~spmr02/rings/maths.html
Department of Pure mathematics, University of Liverpool, P.O. Box 147, Liverpool L69 3BX, England
It also appears in his book "Polyhedra" CUP 1999 ISBN 0-521-66405-5

Figure 8 is from Paul Bourke http://astronomy.swin.edu.au/~pbourke/surfaces/borromean/. Many thanks to Paul Bourke who is a visualisation researcher at Swinburne University of Technology, Melbourne, Australia.

Thanks to Dr Ranulph Glanville and Dr Bernard Scott for their help and encouragement. Dr Alex Andrew, Dr D.J. Stewart, Dr Christian Haan and have made most helpful criticisms and suggestions. Mr John Rochey-Adams contributed the very interesting and significant Pask aphorism on Causality.

Kybernetes: The International Journal of Systems & Cybernetics, Vol. 33 No. 9/10, 2004,