# Artificial Life

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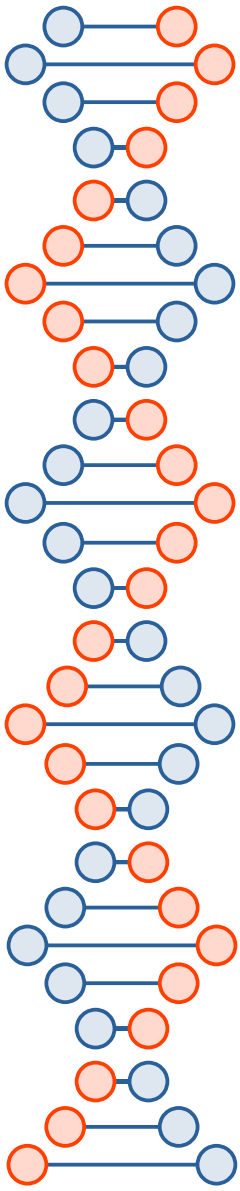http://www.nickrossiter.org.uk/process/

ANPA, Oxford, August 2024

# Synopsis

- Look at ALife (Artificial Life)
  - Ideas, workers
- Build on last year's Metabiology
  - Just one part of the ALife workspace
- Build on Whitehead's Process & Reality
  - Look at his Modes of Thought, 2 chapters on life
- Show the potential of category theory, employing Whitehead's Modes of Thought, in:
  - Representing ALife conceptually
  - Through topos and adjointness

# Basic Idea

- ALife
  - Developed by Christopher Langton in 1986
  - Three basic types
    - Soft (software)
    - Hard (hardware)
    - Wet (biochemistry)
  - To simulate biological processes
    - Those that we know
    - Those that we don't know yet
  - ALife is not just about life as we know it
  - ALife is archetypal, looking for broader definition

# Differences in approaches
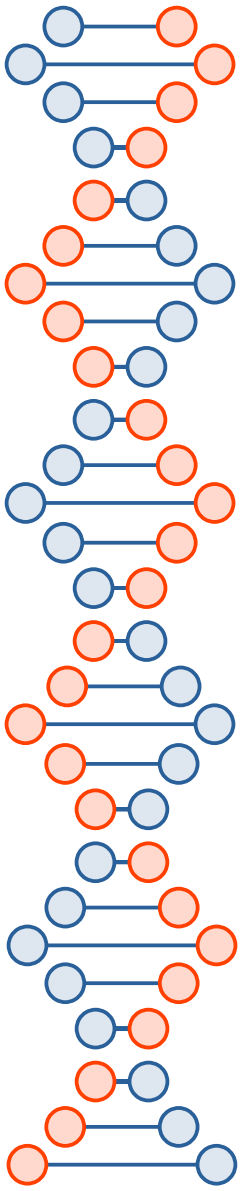
- Soft
    - Using software processes to simulate life
    - Mainly computer models
    - Metabiology as discussed last year
- Hard
    - Using hardware (chips) to simulate life
    - Partial connection with AI and  Nvidia's GPU
    - Linked to robotics
- Wet
    - Using biochemical processes 'wetware'
    - Synthetic DNA

4

# ISAL
# International Society for Artificial Life

- The vision:
    - For the field to be widely known and valued
    - To contribute to the good of human society and the biosphere
    - To understand life as it could be
- A somewhat defensive posture
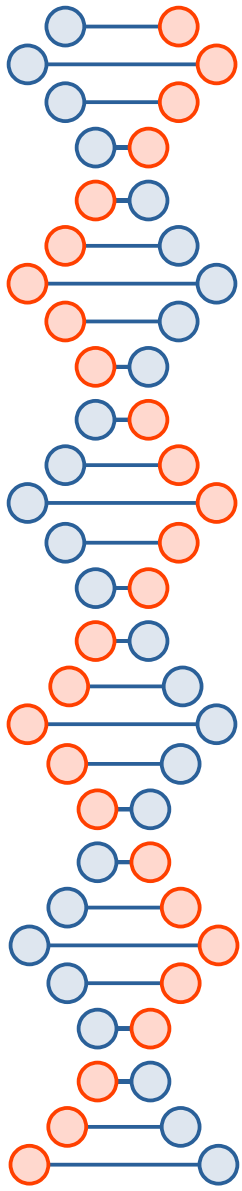- A chequered history for the subject

# Metabiology

- Handling complexity of biological systems
- Role of information processing and mathematical reasoning
- Study of evolutionary processes
- A software approach
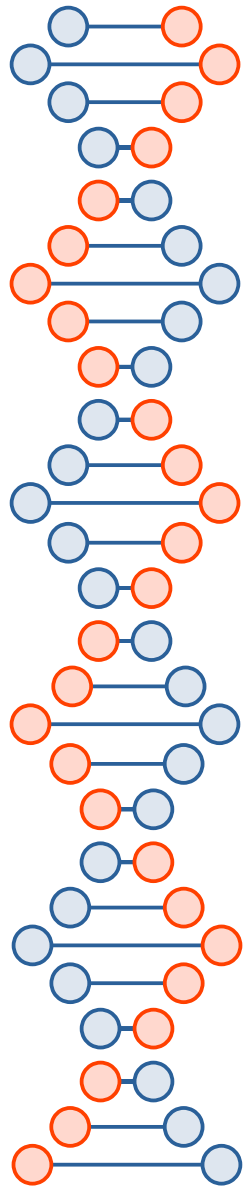
# Artificial Body

- Organ on chip

- Brain-like chip

- Cellular automata (photonic computing)

- Hardware approaches

# Organic Computer

- Artificial organic brain

- An embryo

- A biological virus

- Living neurons

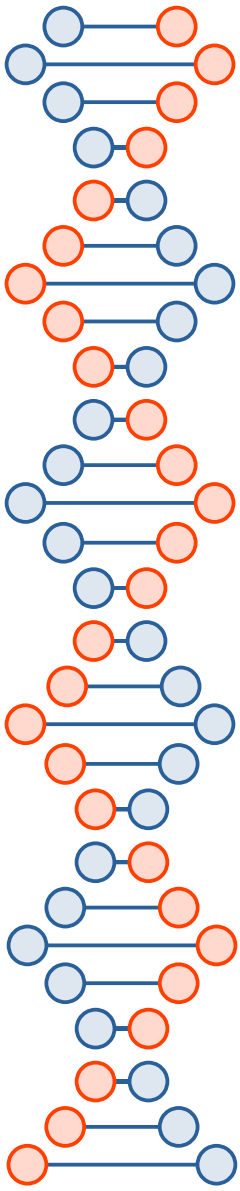- All wetware approaches

# Philosophy of ALife

- Artificial life is a young interdisciplinary collection of research activities aimed at understanding the fundamental behaviour of life-like systems by synthesizing that behaviour in artificial systems.

- Artificial life research seeks to synthesize the characteristics of life by artificial means, particularly employing computer technology.

- Perhaps more aims than philosophy

# ALife vs AI

- ALife creates life-like processes in artificial systems, such as software, hardware, or chemical systems.

- AI replicates human-like intelligence in machines

- There is considerable overlap

- ALife is sometimes thought to be bottom-up while AI is top-down

- AI in practice today is concentrated on machine learning and pattern matching using very fast hardware
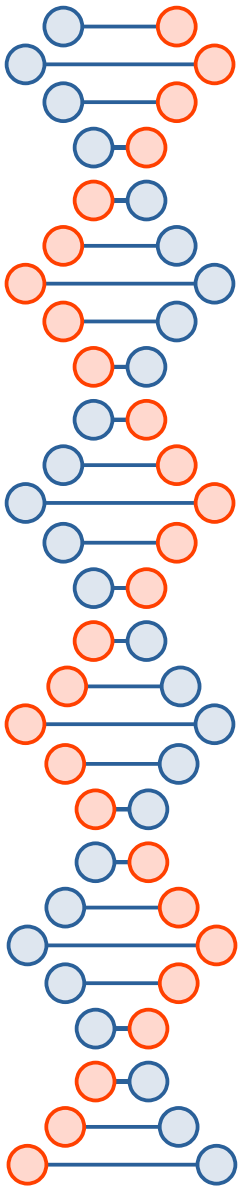
  - e.g. GPU (chips) of Nvidia

# Examples of Alife/AI overlap

- Neural nets
  - ALife models brain structures and mechanisms
  - AI uses same techniques
- Genetic algorithms
  - ALife models birth, evolution and death
  - AI uses same techniques

# Possible use of categories

- Life continuously changes its own components and states at each moment through interaction with the external world, while maintaining its own individuality in a cyclical manner.

- Such a property, known as *autonomy*, has been formulated using the mathematical concept of *closure*.

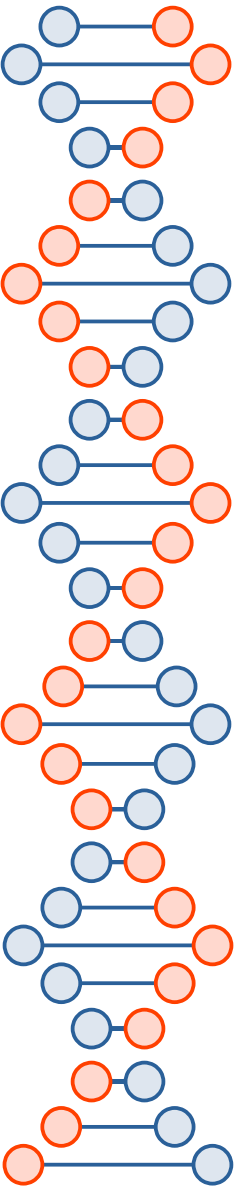- Use of monoids by Ryuzo Hirota, published ALIFE (2023)

# ALife vs Nature

- The Oxford English Dictionary currently excludes humans from its definition of nature, describing it as "the phenomena of the physical world collectively; esp. plants, animals, and other features and products of the earth itself, as opposed to humans and human creations."26 Apr 2024

  - "the breathtaking beauty of nature"

- So Alife is bigger than nature

  - As an all-encompassing term

13

# Nature (Natural)

- Nature is a cornerstone of traditional philosophy

- Whitehead in Modes of Thought -  Lecture 7

  - Alfred North Whitehead. "Nature Lifeless." Lecture Seven in Modes of Thought. New York: Macmillan (1938): 173-201.

  - Derides much of contemporary and earlier work on Nature, particularly by Newton

    - Deficient in both analysis and abstraction

    - Details are often poorly worked out

    - And abstractions are inappropriate

  - Dislikes:

    - Positivism

    - Descartes dualism

14

# Whitehead – Nature Alive

- A Mead Project source page

  - https://brocku.ca/MeadProject/Whitehead/Whitehead_1938/1938_08.html

- Originally published as:

  - Alfred North Whitehead. "Nature Alive." Lecture Eight in Modes of Thought. New York: Macmillan (1938): 202 -232.

- Establishes process as essential concept

# Various Processes – Prehension

- The notion of life implies a certain absoluteness of self-enjoyment

- This must mean a certain immediate individuality, which is a complex <u>process</u> of appropriating into a <u>unity</u> of <u>existence</u> the <u>many data</u> presented as relevant by the physical processes of nature

- Life implies the absolute, individual self-enjoyment arising out of this process of <u>appropriation</u>.

- I have, in my recent writings, used the word '<u>prehension</u>' to express this process of appropriation. Also I have termed each individual act of immediate self-enjoyment an '<u>occasion</u> of experience'

16

# Whitehead – Three Characteristics of Life

- Thus the characteristics of life are absolutely

- 1) Self-enjoyment, 2) Creative activity, 3) Aim.

    - Self-enjoyment is prehension

    - Here 'aim' evidently involves the entertainment of the purely ideal so as to be directive of the creative process.

    - Also the enjoyment belongs to the process and is not a characteristic of any static result.

    - The aim is at the enjoyment belonging to the process.

# Whitehead – Aim and Feeling

- But even yet we have not exhausted the notion of creation which is essential to the understanding of nature. We must add yet another character to our description of life.

- This missing characteristic is 'aim'. By this term 'aim' is meant the exclusion of the boundless wealth of alternative potentiality, and the inclusion of that definite factor of novelty which constitutes the selected way of entertaining those data in that process of unification.

- The aim is at that complex of <u>feeling</u> which is the enjoyment of those data <u>in that way</u>. 'That way of enjoyment' is selected from the boundless wealth of alternatives. It has been aimed at for <u>actualization</u> in that process.
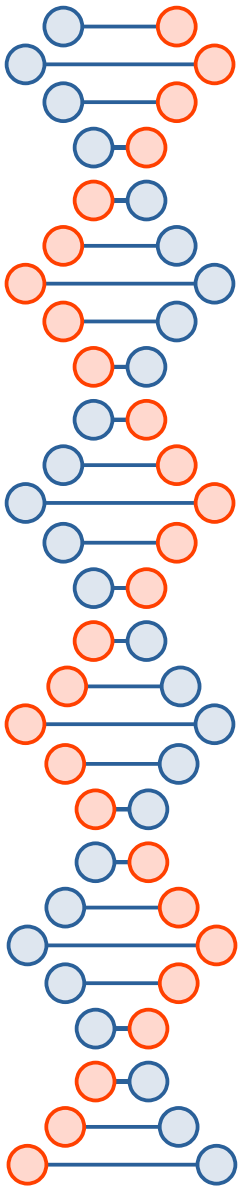
# Maturation of Whitehead's Thoughts

- Modes of Thought 1938

- Process and Reality 1928

- So what's changed?
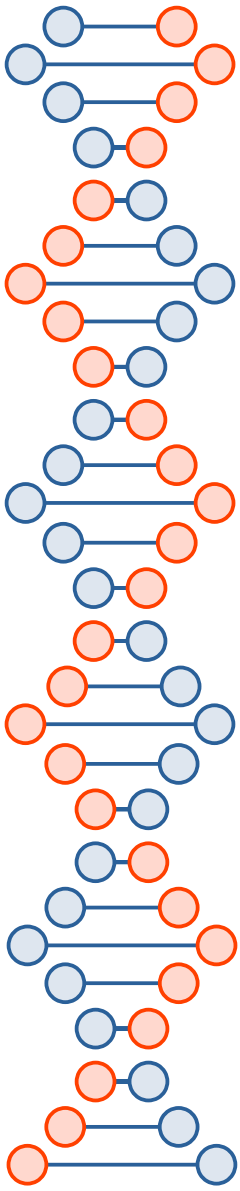
# Recap Whitehead P&R 1928

- Develops the idea of feelings
  - Based upon concrescence
    - of prehensions from
      - Ingression of eternal objects/ actual entities
- No explicit <u>concrescence</u> in 1938
- Feelings are developed into those prehensions that become <u>actualizations</u>
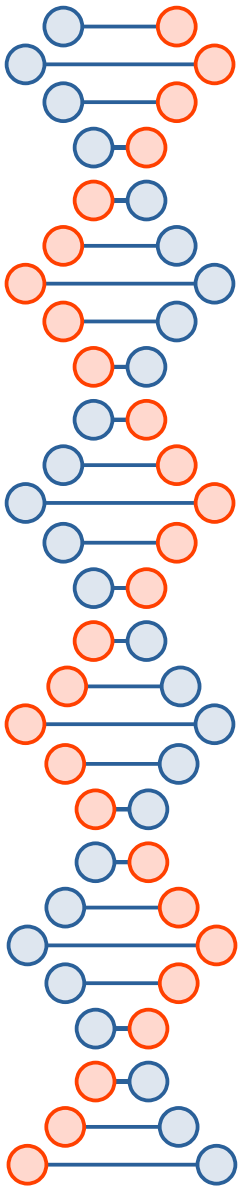- Feelings are the concrescence of prehensions
  - But the concrescence is more by choice than  by viability

# Transitions
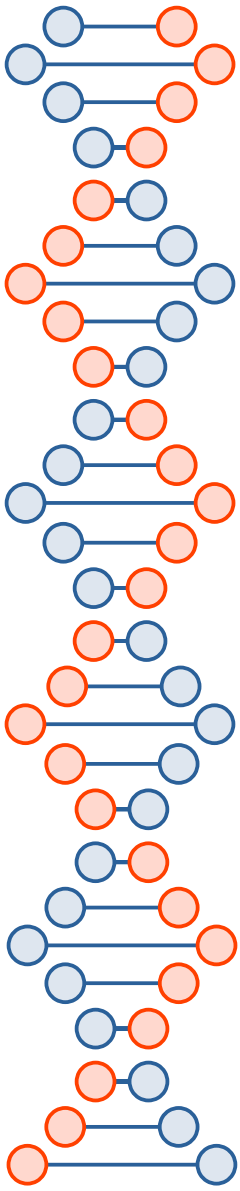
- Feelings are sentient, not necessarily conscious.

- Prehension (being) does not necessarily lead to a concrete new entity (becoming, via concrescence)

  - Emergence

  - Evolution (Darwin)

# Entities – Whitehead's View

- Real (exist)

- Individual (atomic)

- Particular (singled out, identity)

- Can be joined together as a nexus (union of similar entities, ordered society, togetherness)

- "Every entity should be a specific instance of one category of existence" PR p.20 (classification)

- Can be seized by prehension (product or coproduct relatedness) to give a subjective form
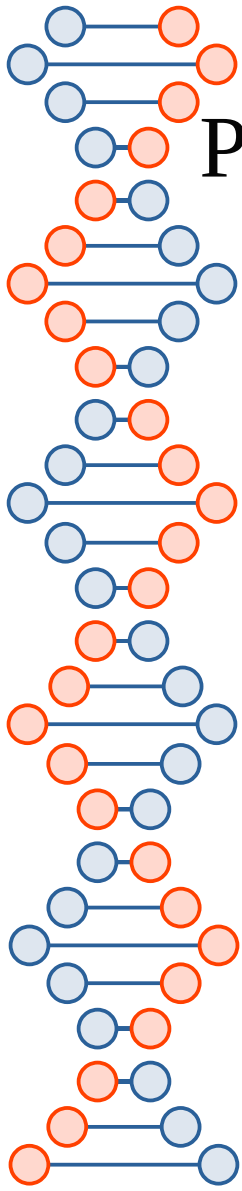
# Prehension – More Concrete Definition PR p.23

"(xi) That every prehension consists of three factors: (a) the 'subject' which is prehending, namely, the actual entity in which that prehension is a concrete element; (b) the 'datum' which is prehended; (c) the 'subjective form' which is how that subject prehends that datum."

- This is a data relationship, either X or +.

- A pullback (or pushout) category:

  - (c) is (a) $X_{(b)}$D (D is a third entity)

  - (c) is the subjective form

- Cartesian closed (X) (or Cocartesian closed (+)) category
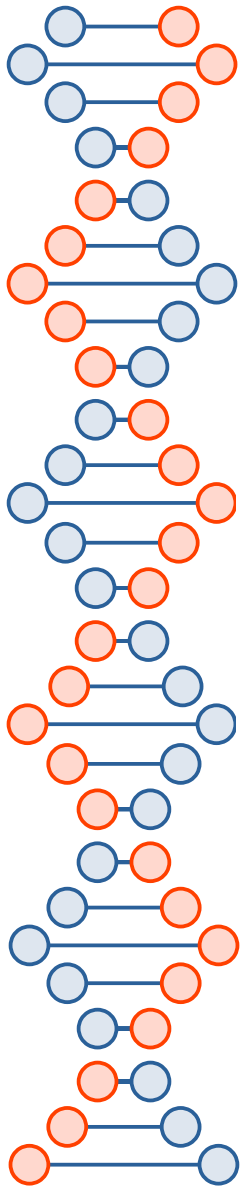
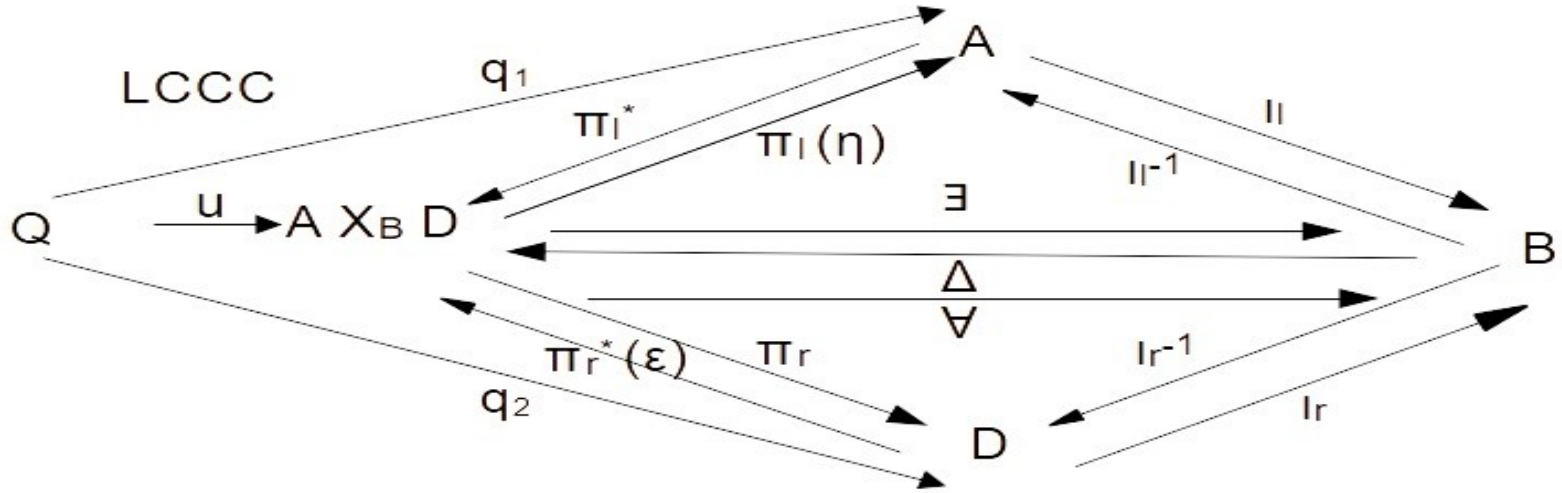# Category CPB: the Limit Diagram of a Category C: the Pullback $A X_B D$
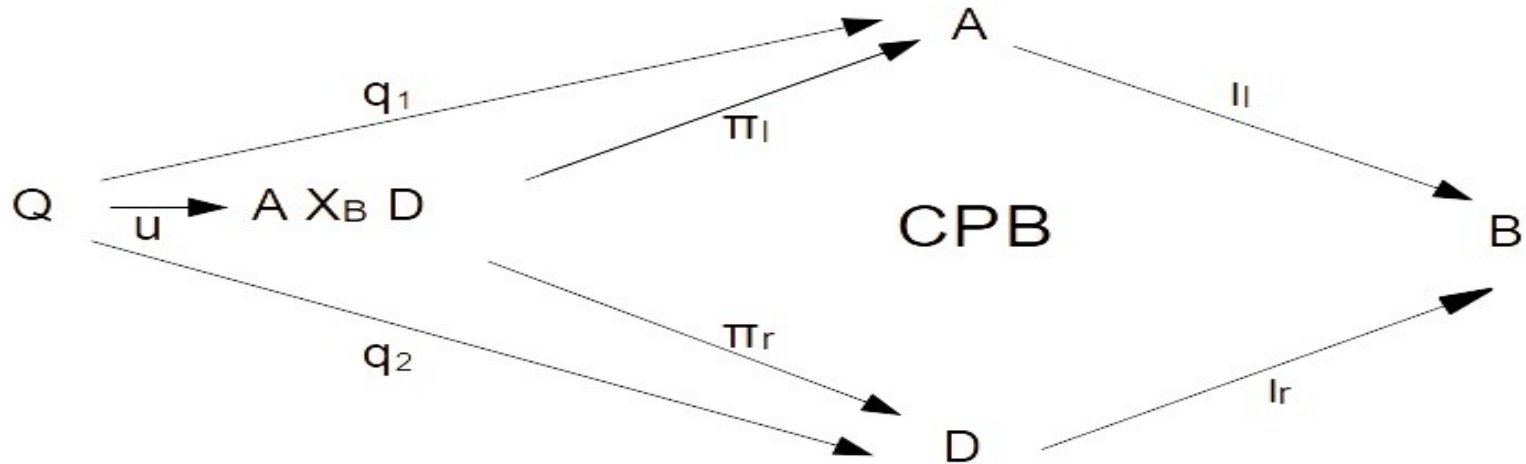


The subjective form of Whitehead is the product $A X_B D$

$A = (a), B = (b), (c) = A X_B D$; D is introduced for P&R

In Modes of Thought, D is introduced by Whitehead himself as Aim

# The locally Cartesian closed category LCCC

Adjointness in the functors between the product $A \times_B D$ and $B$



The hyperdoctrine of Lawvere (1969): $\exists \dashv \Delta \dashv \forall$

Adjointness

# Adjointness gives Viability

Whitehead:

- Prehension gives relatedness (being)

- Concrescence gives viability of relations (becoming)

Categories:

- Pullbacks give relations

- Adjointness gives viability

# Nexus – Defining Characteristic

- A nexus enjoys `social order':
  - where (i) there is a common element of form illustrated in the definiteness of each of its included actual entities, and

  - (ii) this common element of form arises in each member of the nexus by reason of the conditions imposed upon it by its prehensions of some other members of the nexus, and

  - (iii) these prehensions impose that condition of reproduction by reason of their inclusion of positive feelings of that common form.

- Such a nexus is called a `society' and the common form is the `defining characteristic' of the society. The notion of `defining characteristic' is allied to the Aristotelian notion of `substantial form'.

# The Colimit Diagram of Category NEX: the Pushout DC $+_{INH}$ S
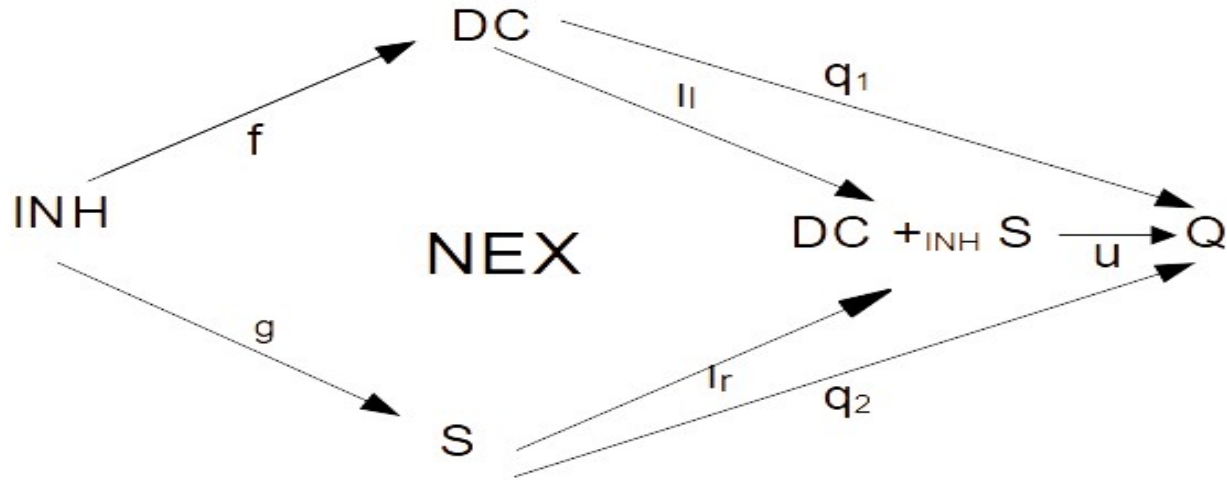


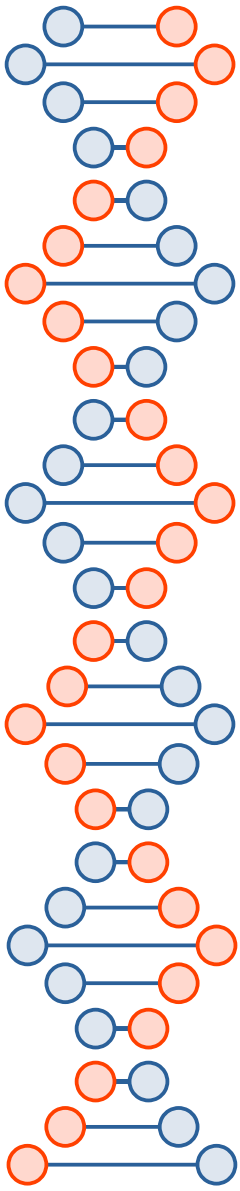S = Society, DC = Defining Characteristic, INH = line of inheritance

# Category of the Ultimate PR p.21

- "The ultimate metaphysical principle is the advance from disjunction to conjunction, creating a novel entity other than the entities given in disjunction.

- The novel entity is at once the togetherness of the 'many' which it finds, and also it is one among the disjunctive 'many' which it leaves; it is a novel entity, disjunctively among the many entities which it synthesizes.

- The many become one, and are increased by one. In their natures, entities are disjunctively 'many' in process of passage into conjunctive unity. This Category of the Ultimate replaces Aristotle's category of 'primary substance' ".
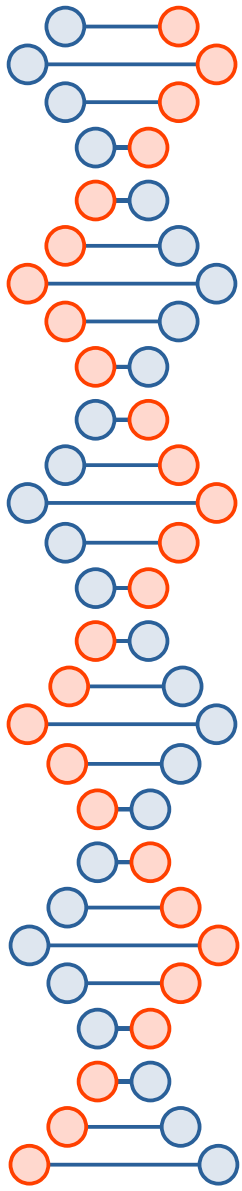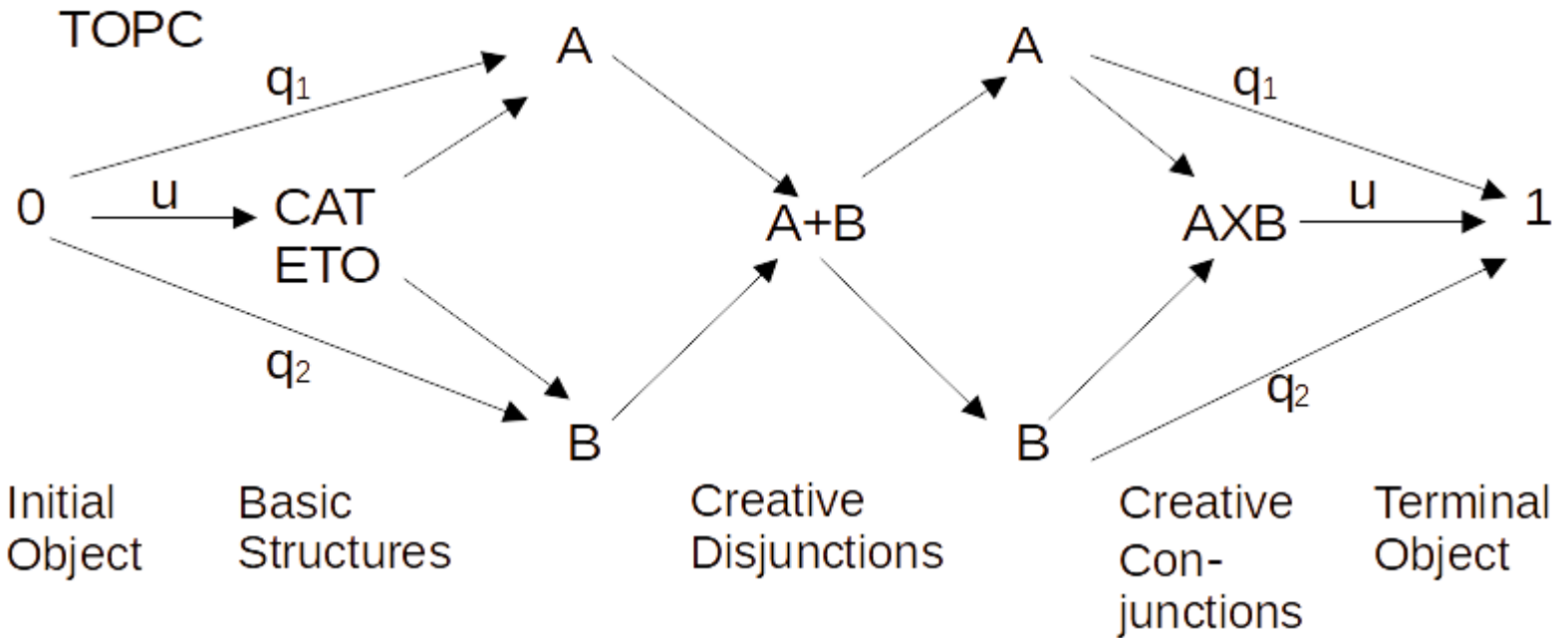
# Consequences

- Tension between X (conjunction) and + (disjunction) featured strongly in our last ANPA paper on music

- Aristotle's category of 'primary substance' is extensional
  - His secondary substance is intensional
  - Intension is an inherent part of each category through Dolittle diagrams (see our last ANPA paper on music)

- Category of the Ultimate does not appear in the later Modes of Thought
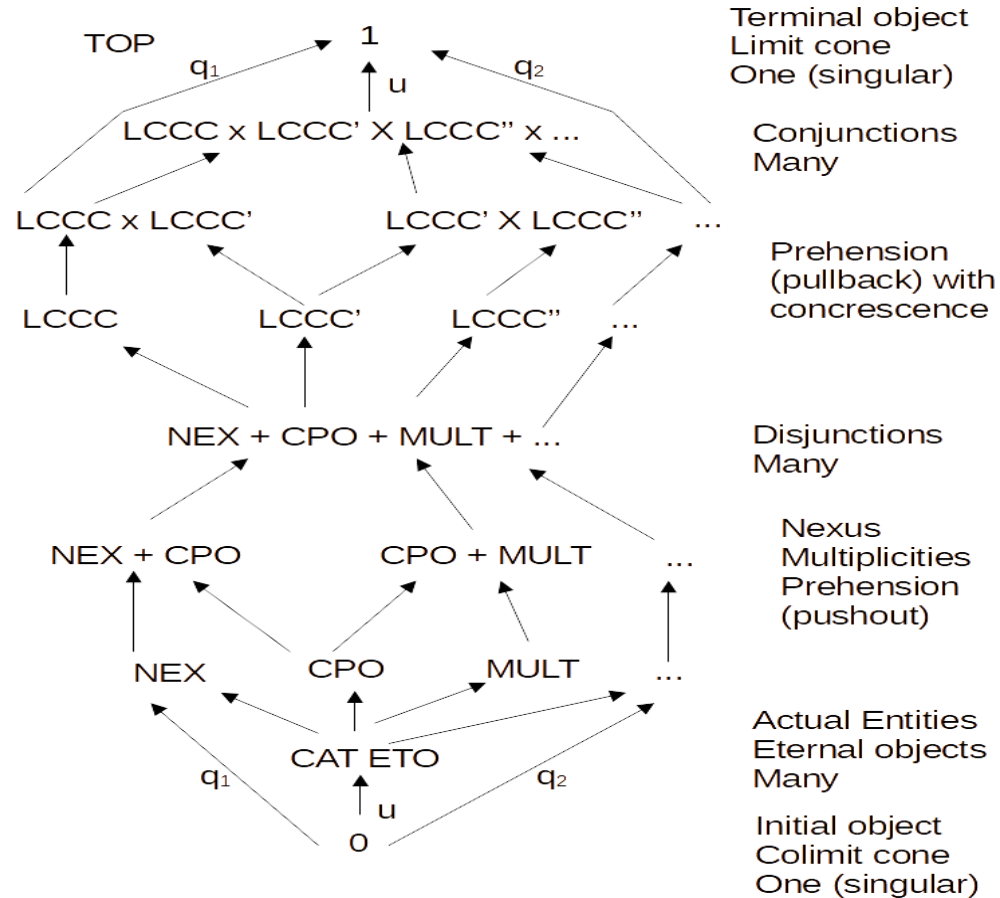  - Whitehead had not realised its fundamental nature

# Canonical View of Category of Ultimate



TOPC

CAT
ETO

$q_1$   A   $q_1$

$0$ →$u$→ CAT/ETO → A+B → AXB →$u$→ 1

$q_2$   B   $q_2$

Initial Object   Basic Structures   Creative Disjunctions   Creative Conjunctions   Terminal Object

# The Topos Category TOP:Tension between times (prehension) and plus (nexus)
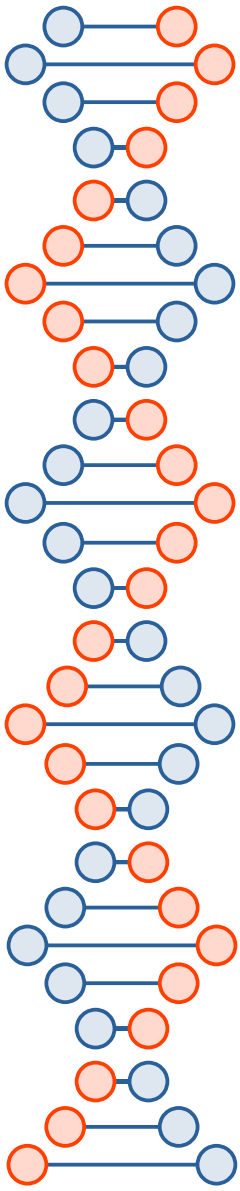
# Life as a Topos

- From Modes of Thought:

  - Life must mean a certain immediate individuality, which is a complex <u>process</u> of appropriating into a <u>unity</u> of <u>existence</u> the <u>many data</u> presented as relevant by the physical processes of nature

  - This is a topos with identity (unity) $1_{TOP}$

# Topos with Whitehead's Terms
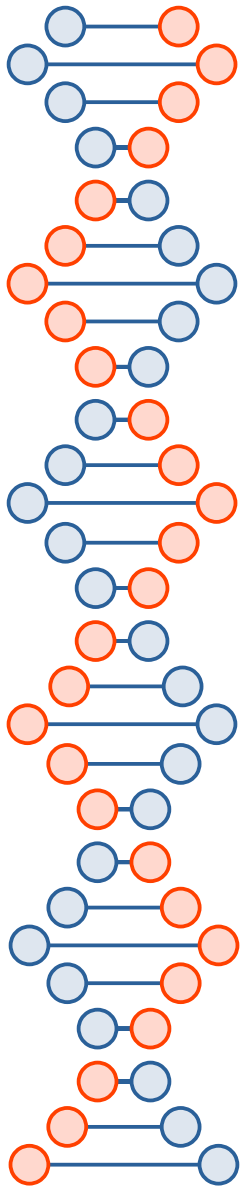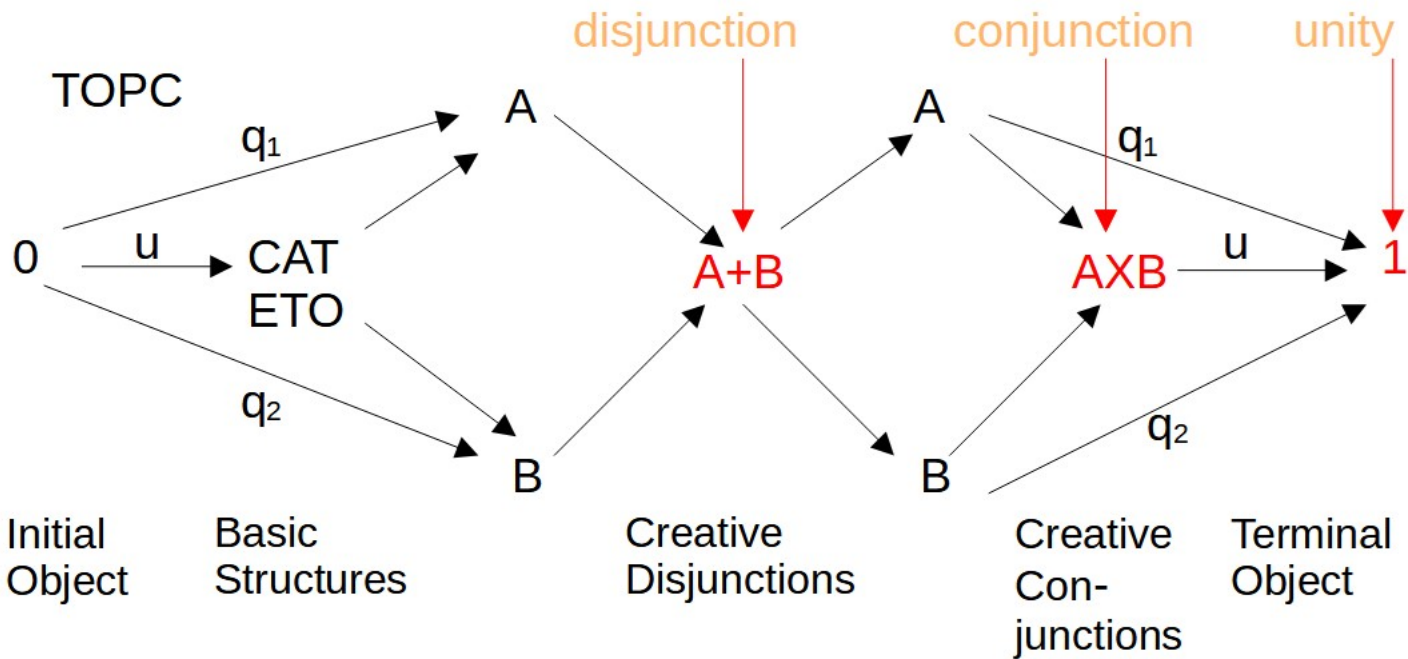
# Creativity in the Topos

- From Modes of Thought:
- Life is:
  - 1) Self-enjoyment,
  - 2) Creative activity,
  - 3) Aim
- Creativity is moving from one topos to another
  - Inter-topos (evolution, emergence)
  - F: $1_{TOP}$ -----> $1_{TOP'}$   (F is free functor)
- Or on a lesser scale modifying the extension of the creative disjunctions and conjunctions within a topos
  - Intra-topos (self-enjoyment, adaptability, survival)

# Restricted Creativity as Aim

- Restricted creativity (qualified by aim) is the adjoint pair:

  - F: $1_{TOP}$ -----> $1_{TOP}'$          G: $1_{TOP}'$ -----> $1_{TOP}$

    (G is underlying functor)

  - written as the 4-tuple  <F, G, η, ε>

  - F --| G    η: $1_{TOP}$ -----> $GF1_{TOP}$   ε: $FG1_{TOP}'$ -----> $1_{TOP}'$
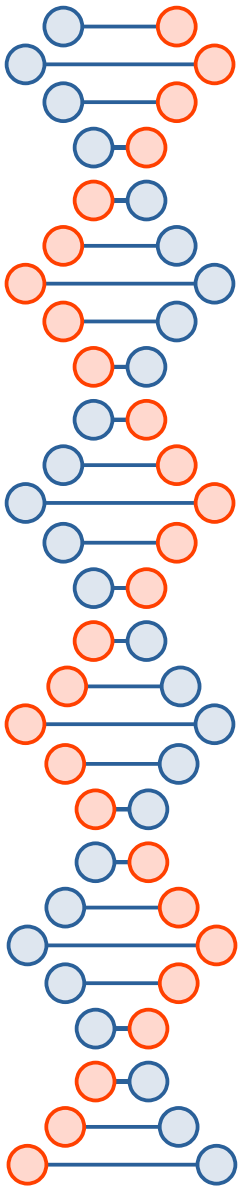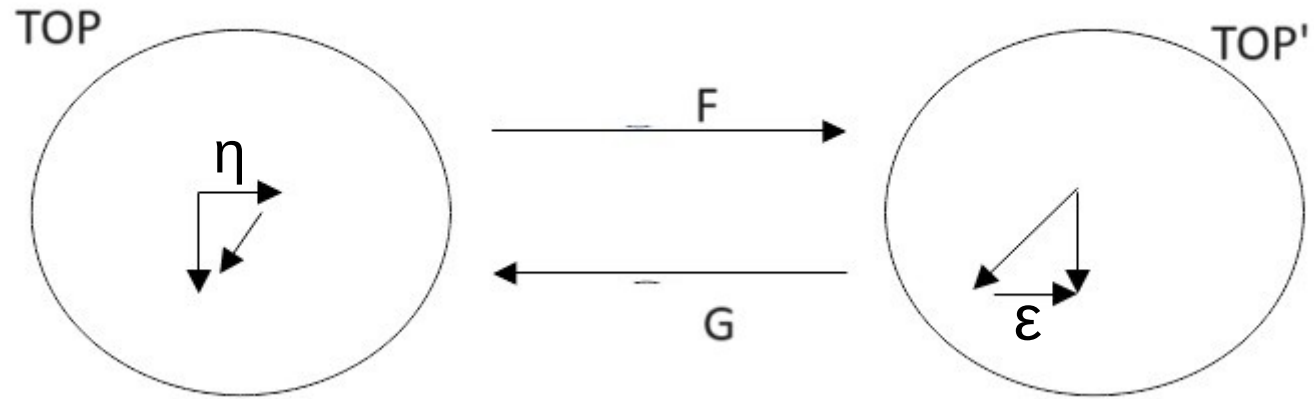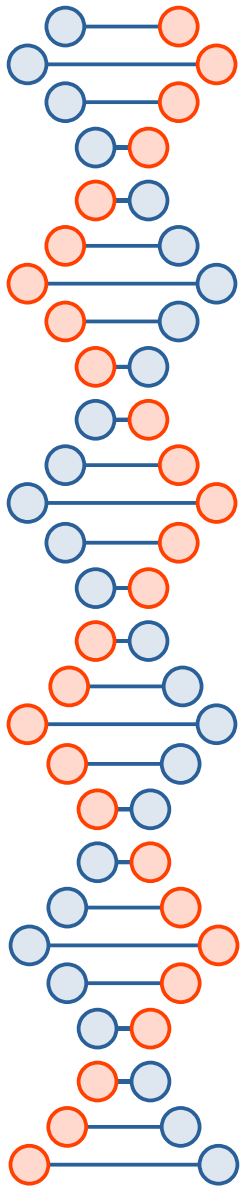    (η is unit of adjunction;  ε is counit of adjunction)

# Diagram for Restricted Creativity



$\langle F, G, \eta, \varepsilon \rangle$

# Consequences/ Questions

- Whitehead's Process and Reality provides a philosophical basis for category theory
  - This is an alternative to the classical pure mathematical/set-based basis
- Process and Reality gives a much richer realism than set theory, facilitating
  - process as a single substance
  - a much richer type system, including complex metadata in the three additional special categories
  - a move towards ALife
- Whitehead's Modes of Thought provides a more abstract view of nature than that given in Process and Reality
- The adjoint structure leads to a monad as in the music composition.
- Are humans part of nature?