

Foundations of Ontology 1

Barry Smith

<http://ifomis.org>

The problem

About 30,000 genes in a human

Probably 100-200,000 proteins

Individual variation in most genes

100s of cell types

100,000s of disease types

Organism

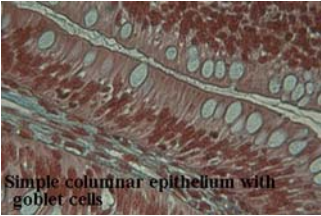


Organ



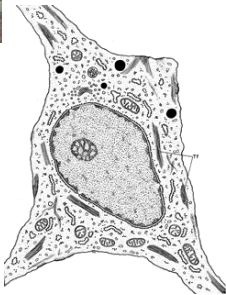
- Musculo-skeletal system
- Circulatory system
- Respiratory system
- Digestive system
- Nervous system
- Urinary system
- Reproductive system
- Endocrine system
- Lymphoidal system

Tissue



Simple columnar epithelium with goblet cells

Cell



Organelle

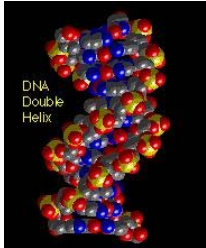


- Mitochondria
- Nucleus
- Endoplasmic reticulum
- Cell membrane

Protein



DNA



The Challenge

Each (clinical, pathological, genetic, proteomic, pharmacological ...) information system uses its own terminology and category system

biomedical research demands the ability to navigate through all such information systems

How can we overcome the incompatibilities which become apparent when data from distinct sources is combined?

Answer:

“Ontology”

Three senses of ontology

1. Philosophical sense: an inventory of the types of entities and relations in reality
2. Knowledge engineering sense: an ontology as a consensus representation of the concepts used in a given domain
3. GO/OBO sense: a controlled vocabulary

Ontology as a branch of philosophy

seeks to establish

the basic *formal-ontological structures*

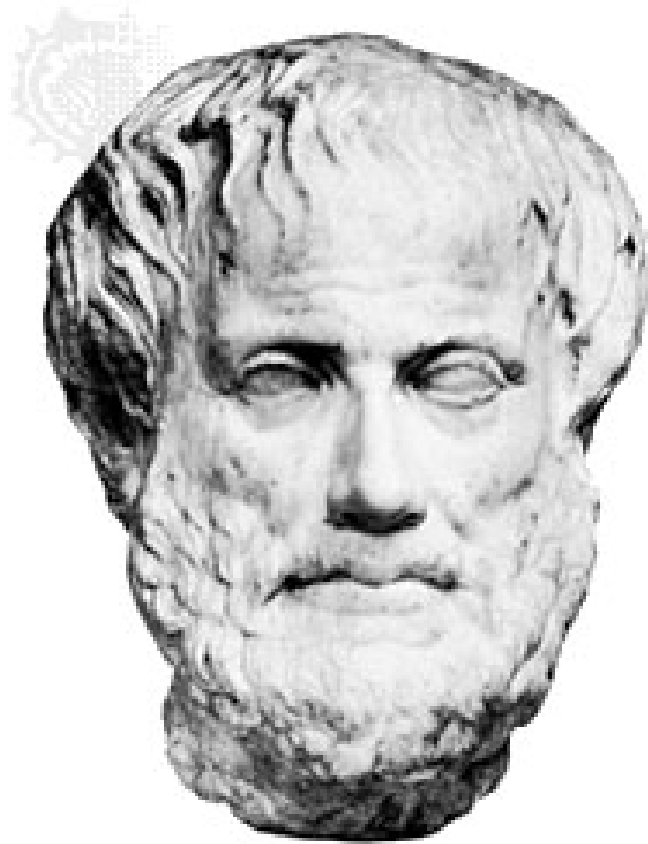
the kinds and structures of objects, properties, events, processes and relations in each *material* domain of reality

Formal ontology an analogue of pure mathematics

Can be *applied* to different domains

Material ontology a kind of
generalized chemistry or zoology

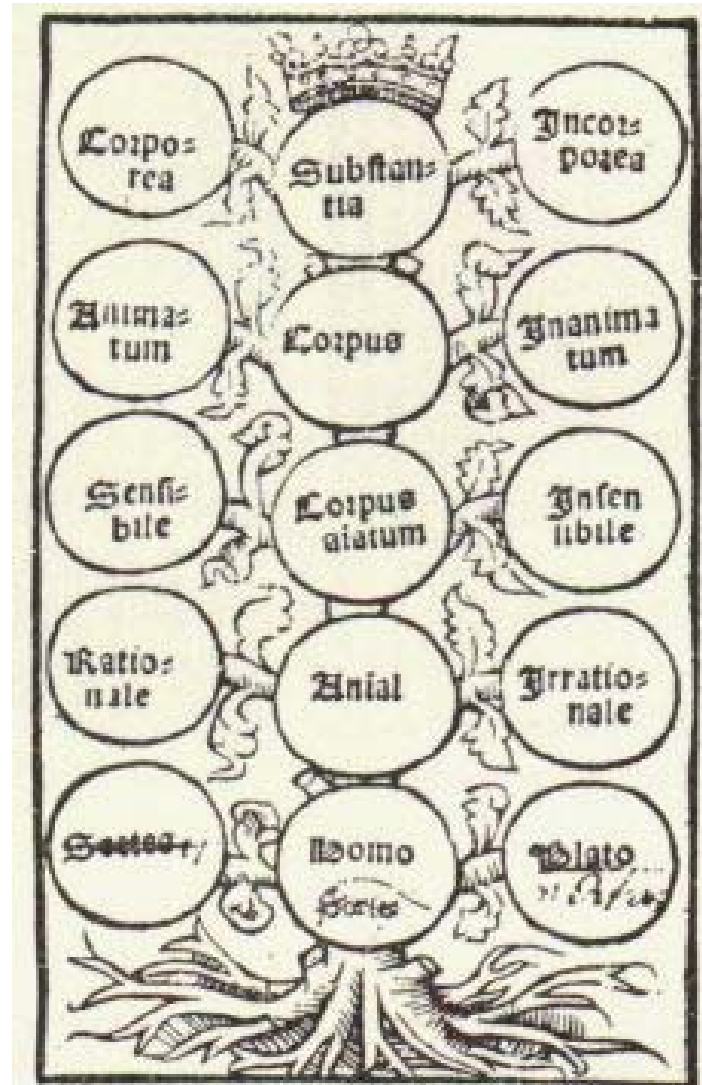
**(Aristotle's ontology grew out of
biological classification)**



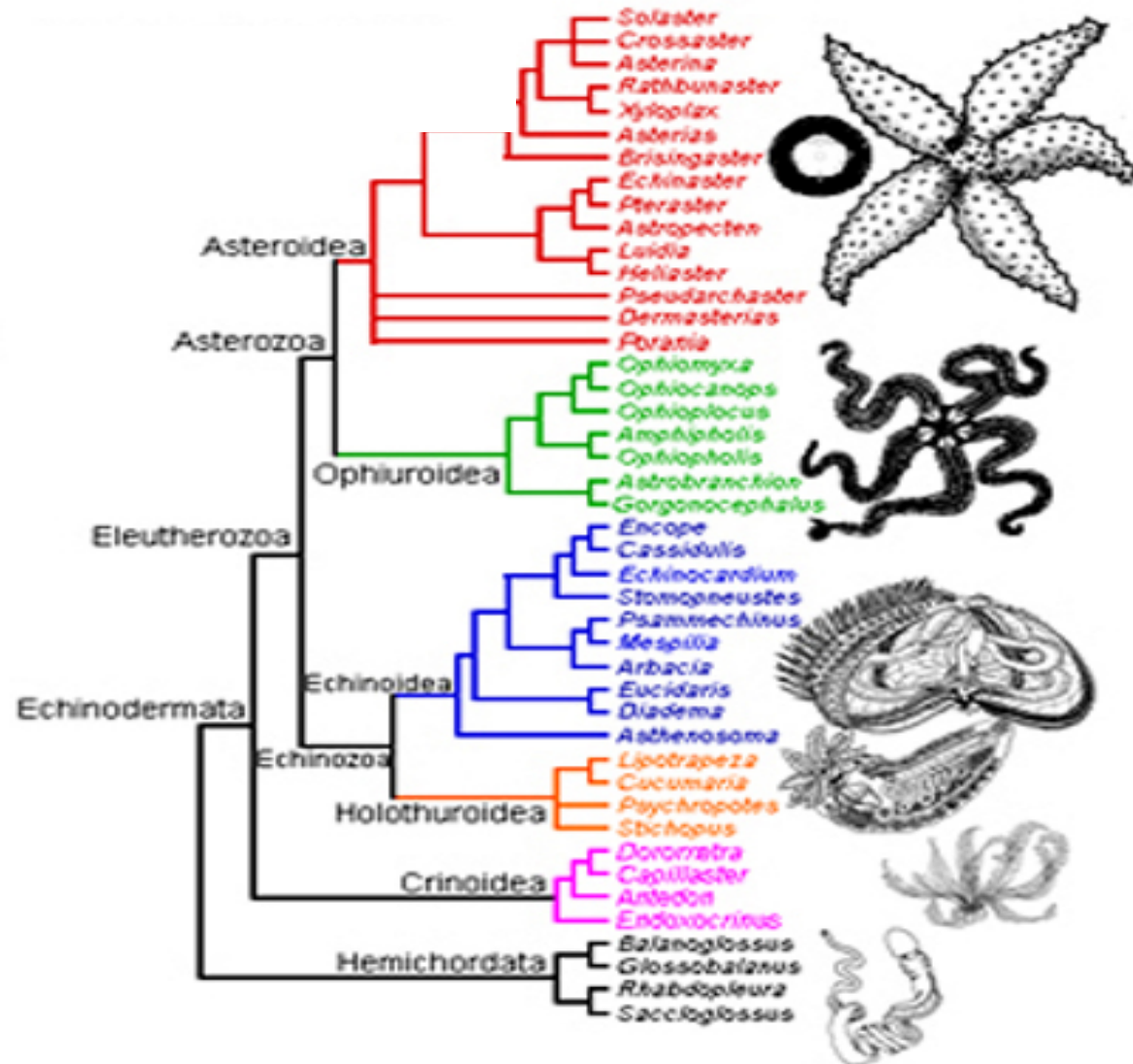
world's first ontologist

World's first ontology

(from Porphyry's *Commentary on Aristotle's Categories*)



Linnaean Ontology



Formal Ontology

- theory of part and whole
- theory of dependence / unity
- theory of boundary, continuity and contact
- theory of universals and instances
- theory of continuants and occurrents (objects and processes)
- theory of functions and functioning
- theory of granularity

Formal Ontology

the theory of those ontological structures
(such as part-whole, universal-particular)
which **apply to all domains whatsoever**

Formal Ontology vs. Formal Logic

Formal ontology deals with the interconnections of *things*

with *objects* and *properties*, *parts* and *wholes*, *relations* and *collectives*

Formal logic deals with the interconnections of *truths*

with *consistency* and *validity*, or and *not*

Formal Ontology vs. Formal Logic

Formal ontology deals with **formal ontological structures**

Formal logic deals with **formal logical structures**

(Epistemology deals with ways of gaining knowledge)

Formal-Ontological Categories

substance

process

function

unity

plurality

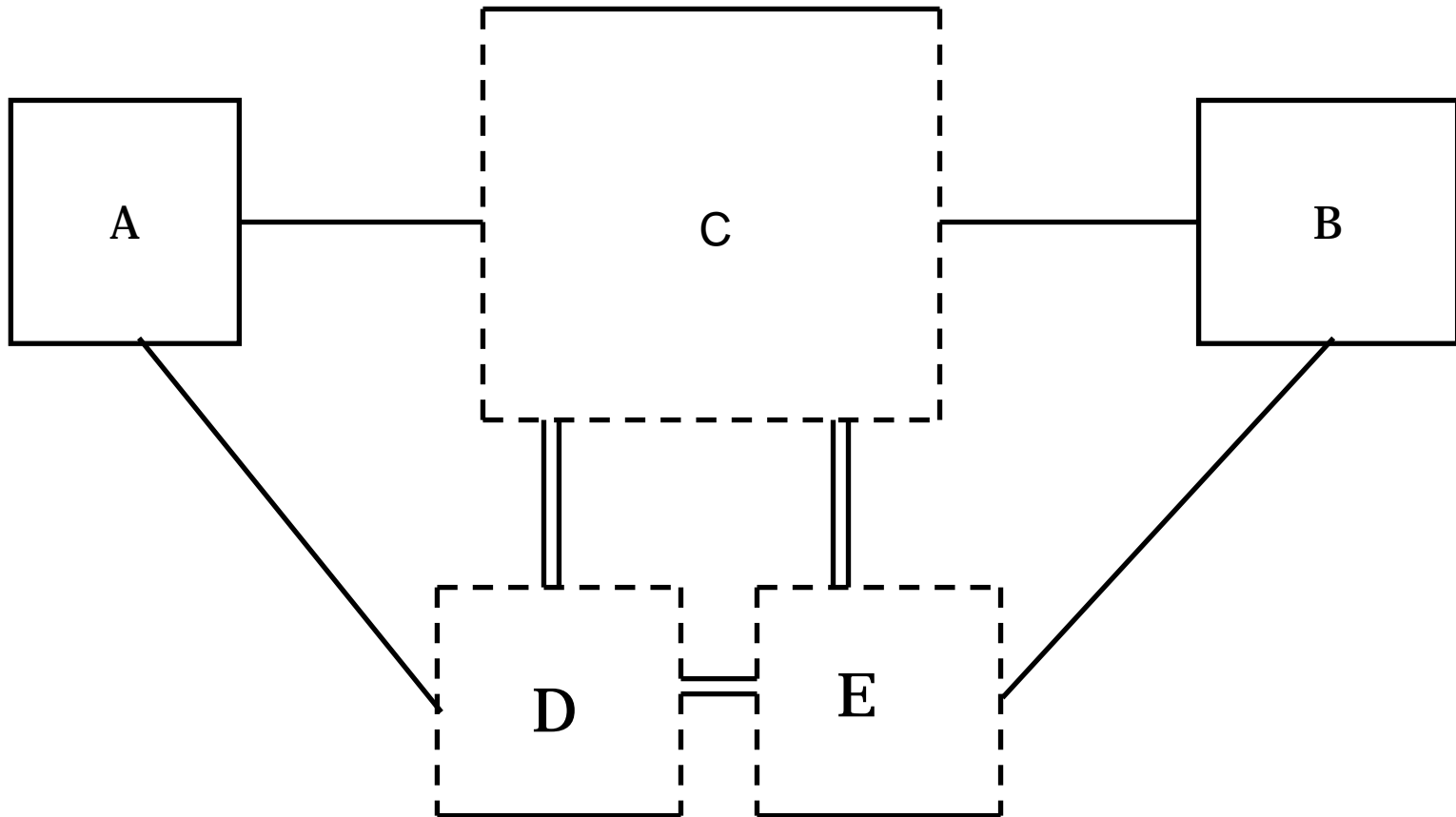
site

dependent part

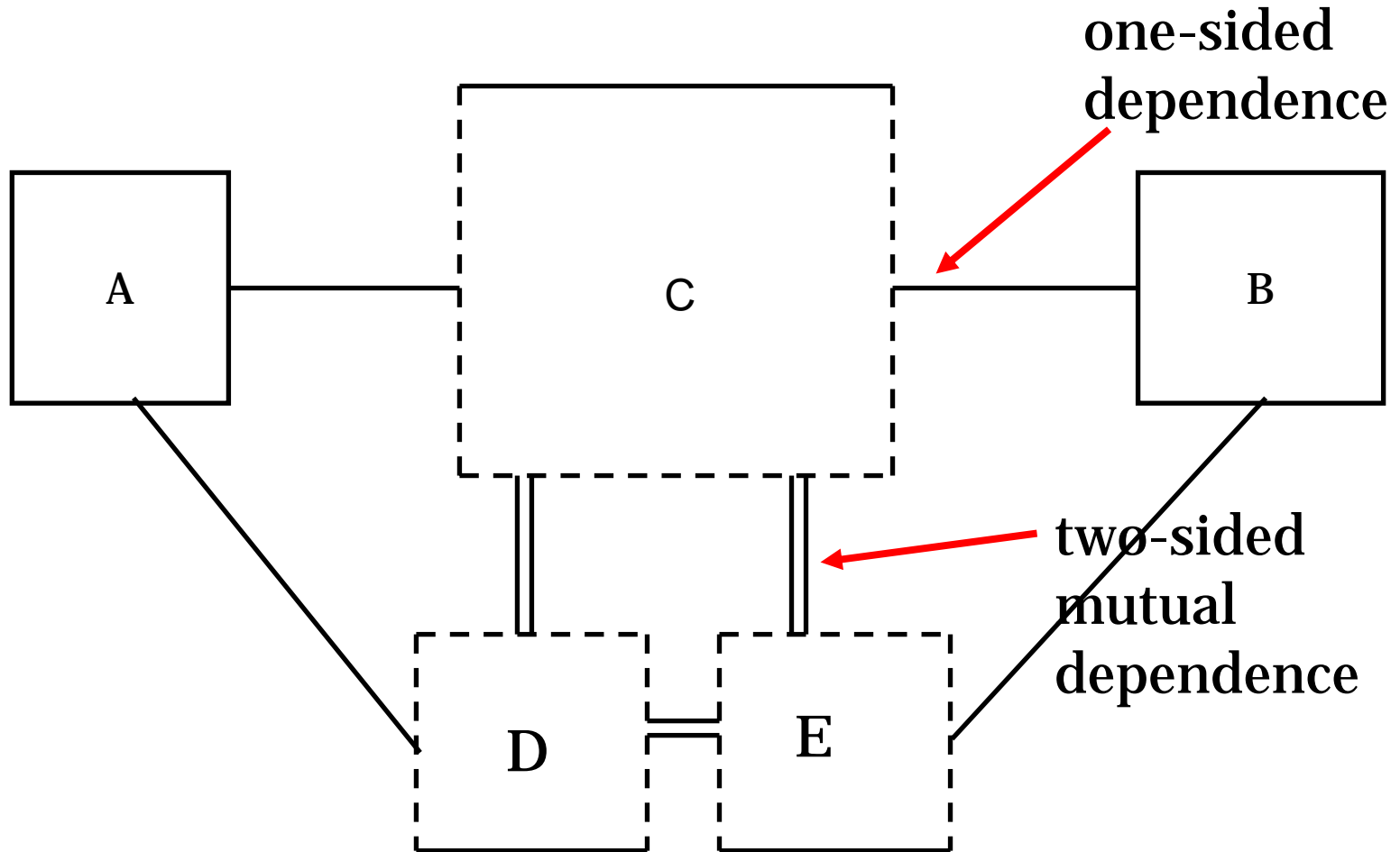
independent part

are able to form complex structures in non-arbitrary ways joined by relations such as ***part***, ***dependence***, ***location***.

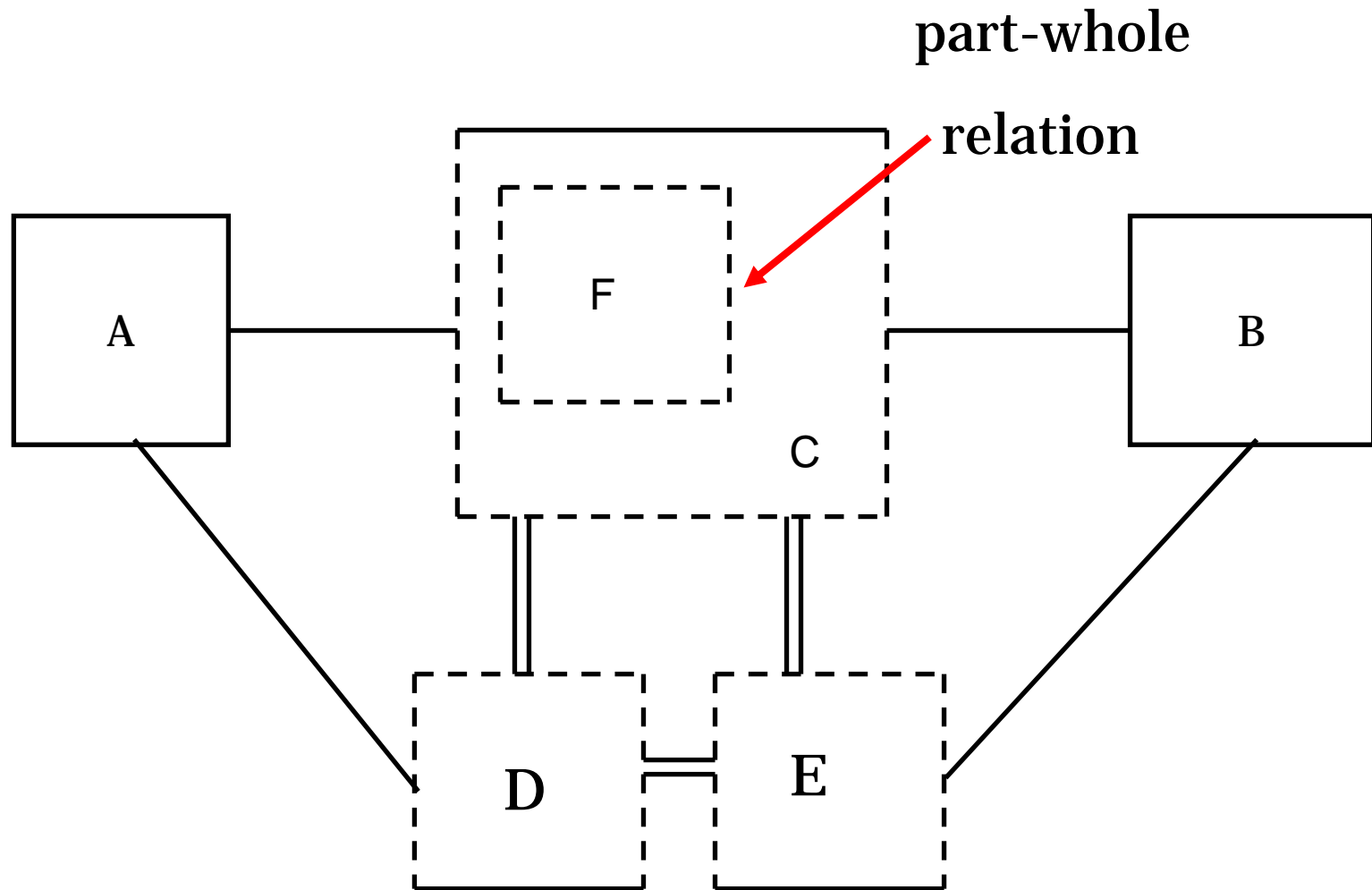
Example of a Formal-Ontological Structure



Ontological Structure



Ontological Structure



A Network of Domain Ontologies

Basic Formal Ontology

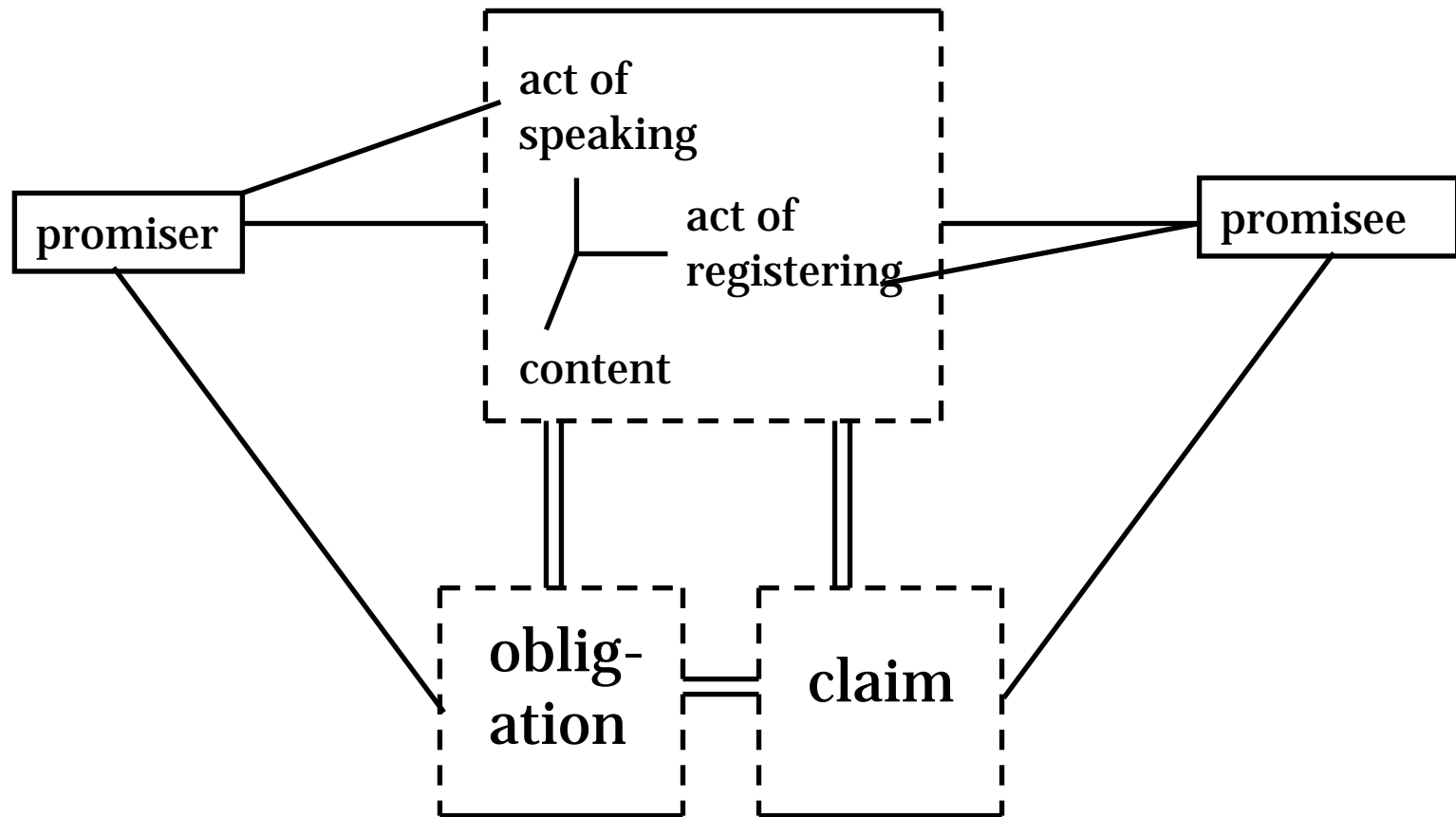


Material (Regional) Ontologies

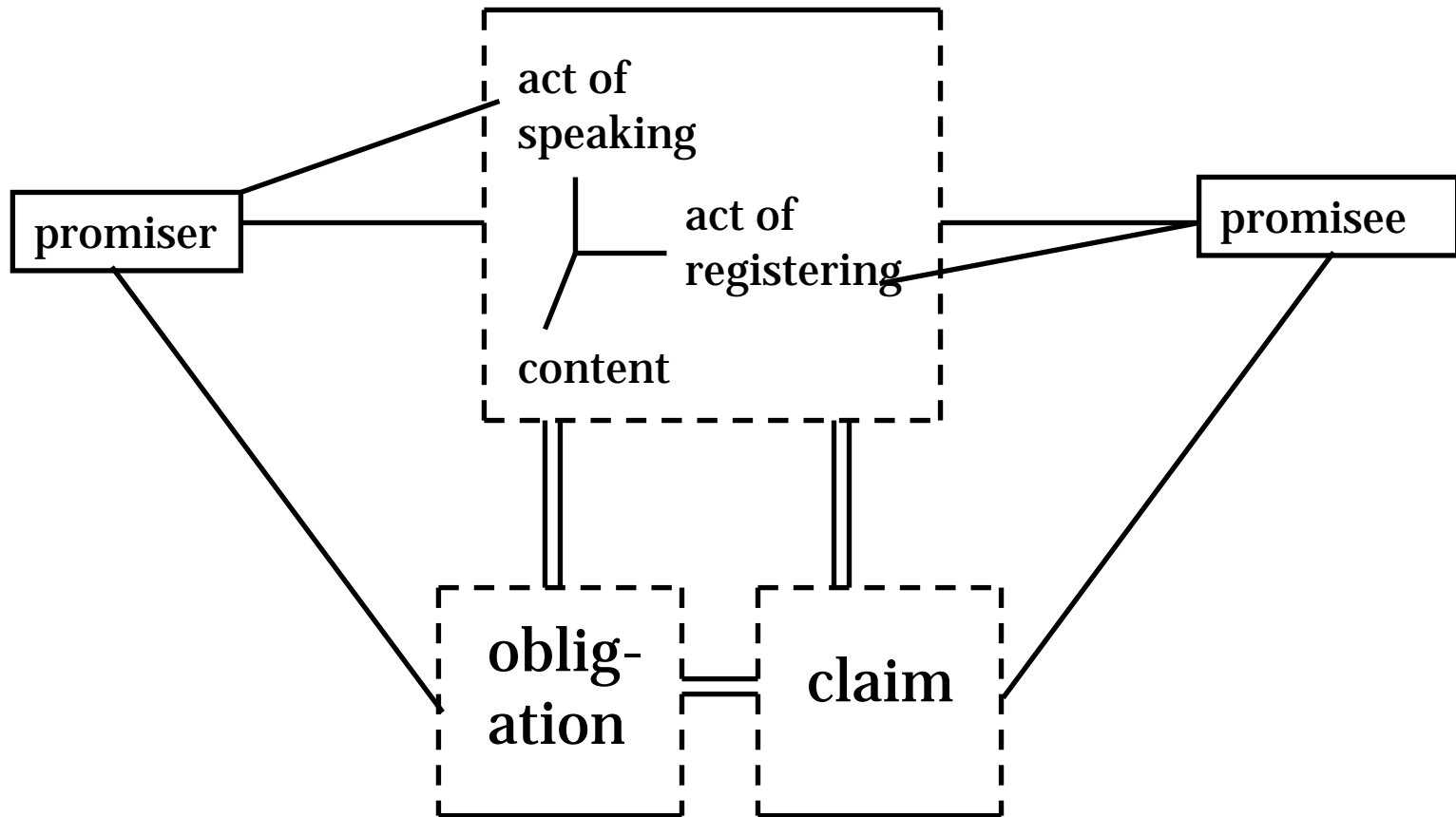
In formal ontology

as in formal logic, we can grasp the properties of given structures in such a way as to establish *in one go* the properties of all formally similar structures

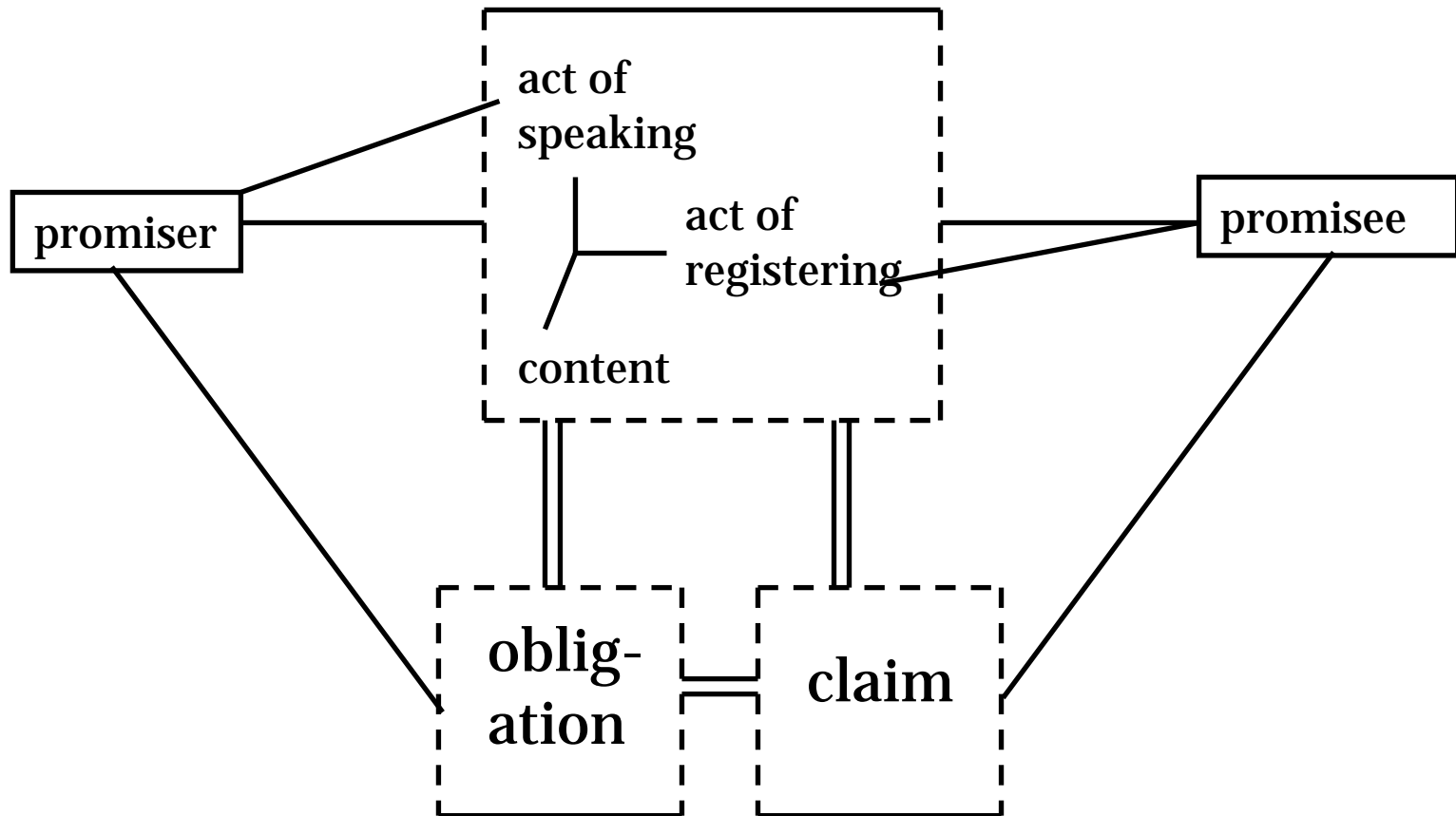
Material Ontology of Social Interaction



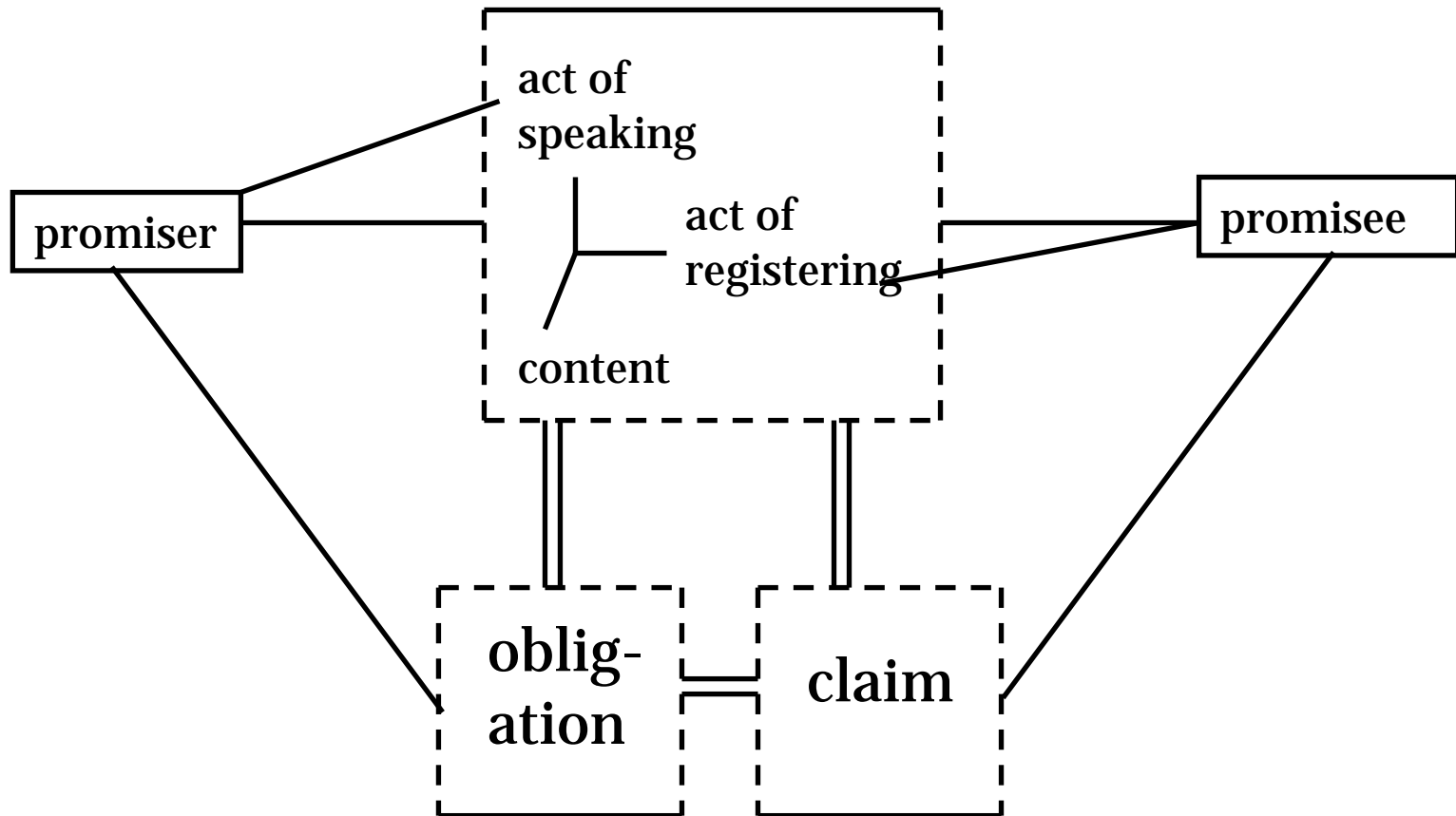
A Window on Reality



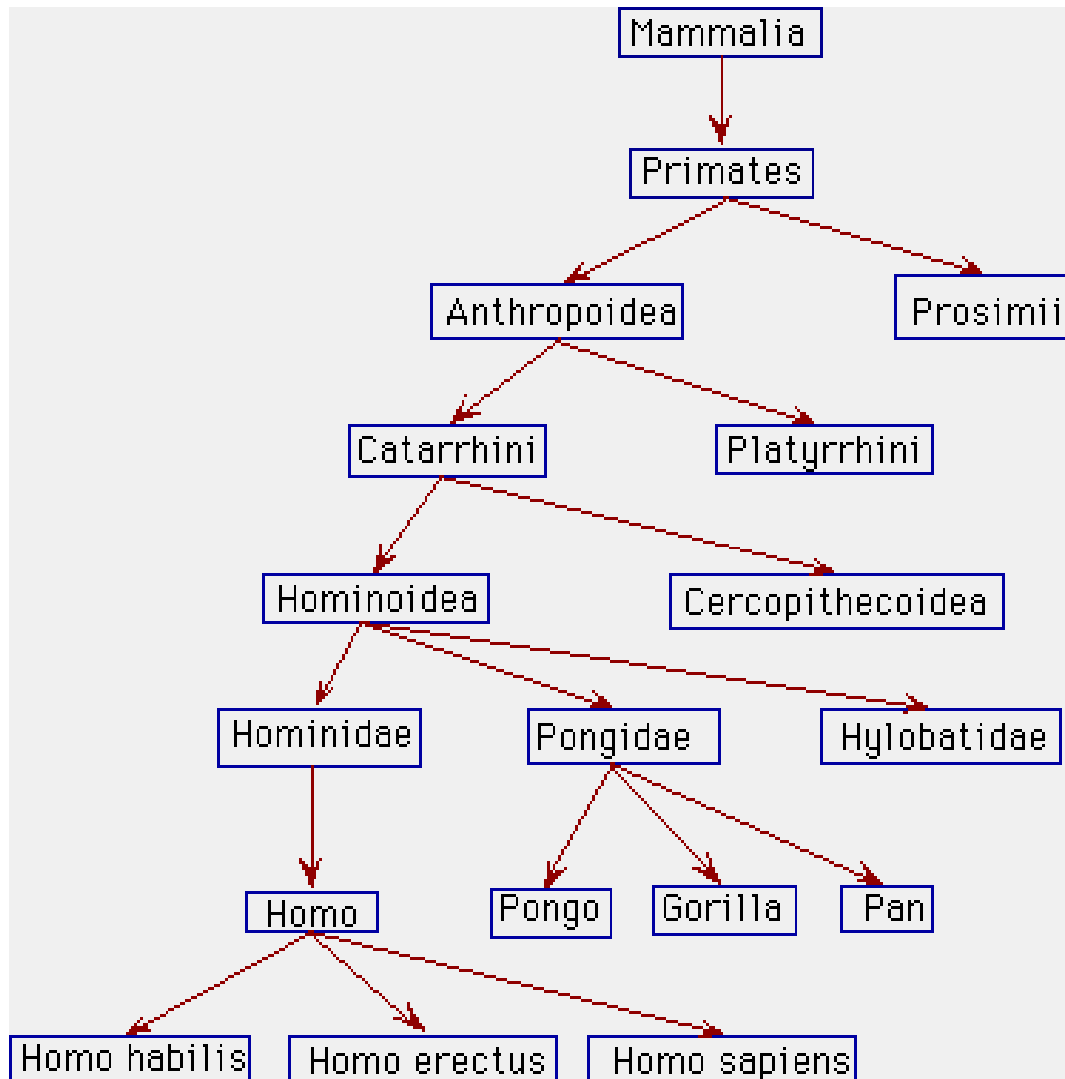
Universals



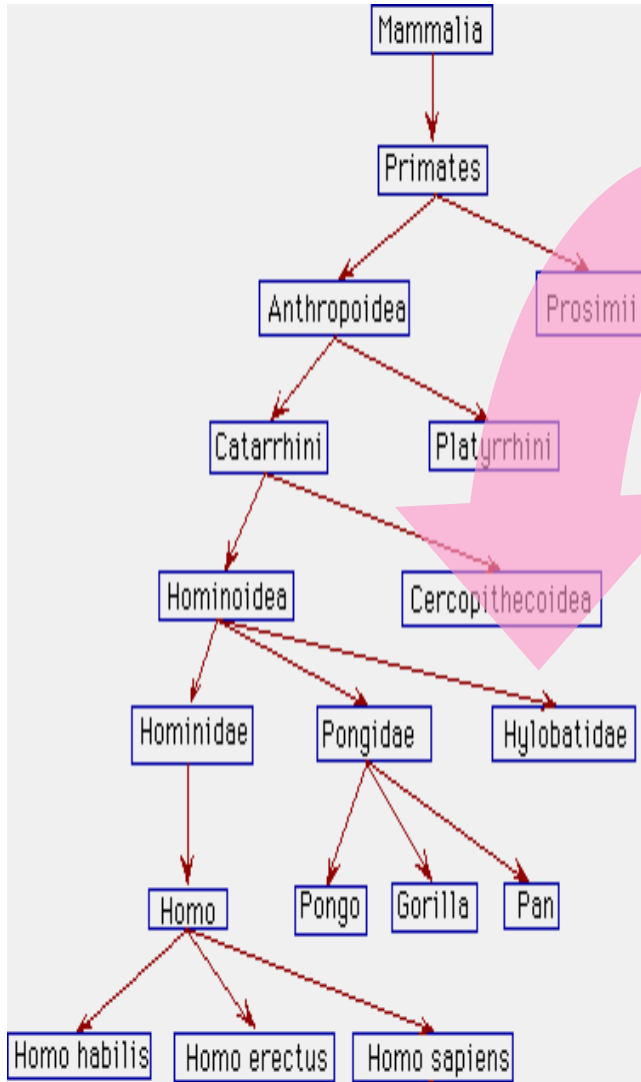
Instances



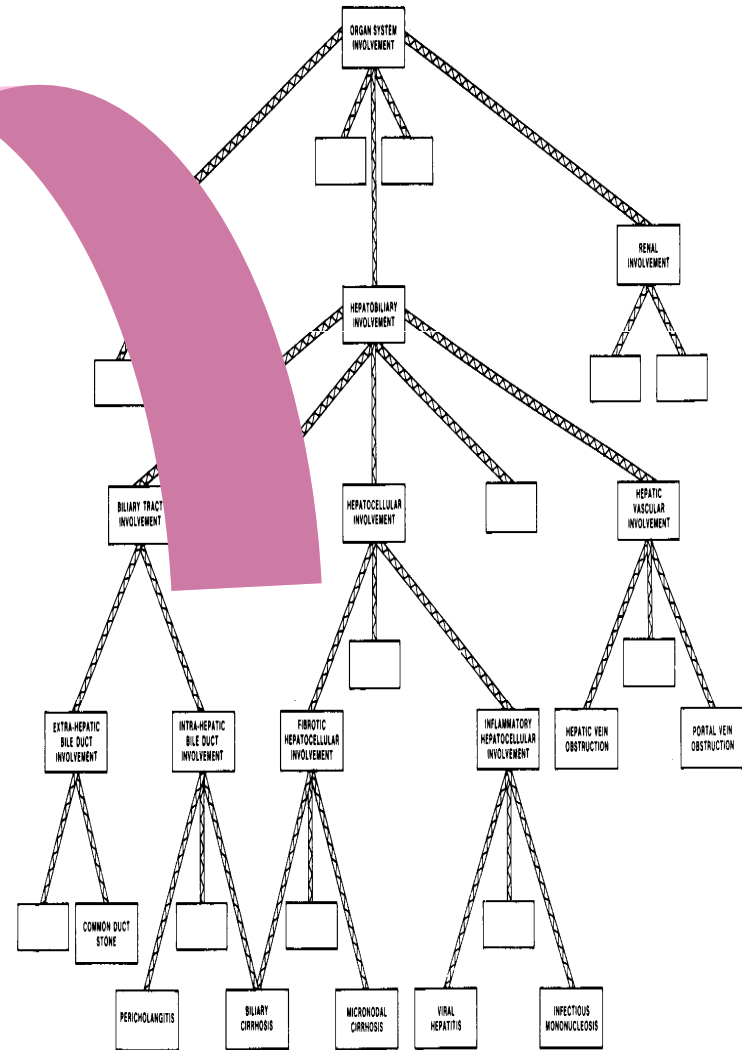
A Window on Reality



Dependence Relations

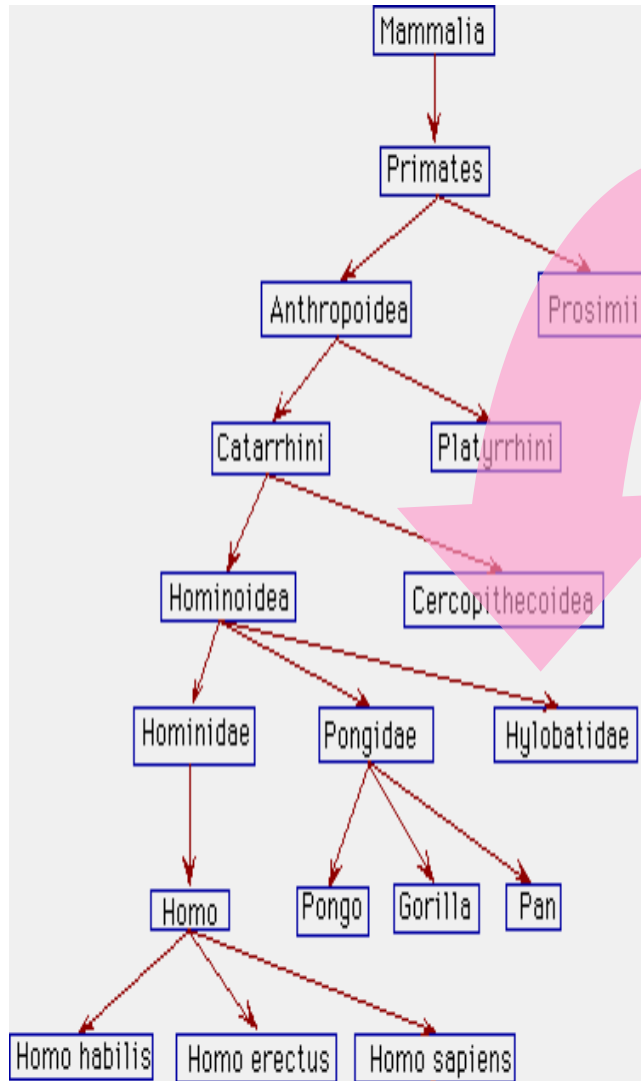


Organisms

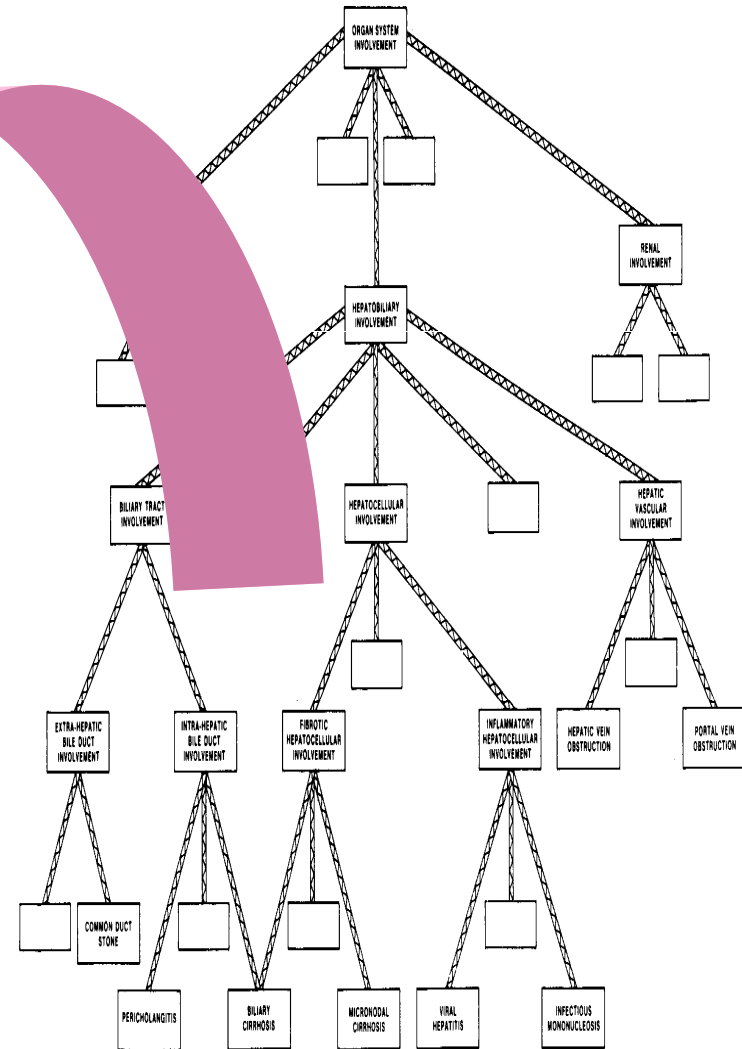


Diseases

A Window on Reality

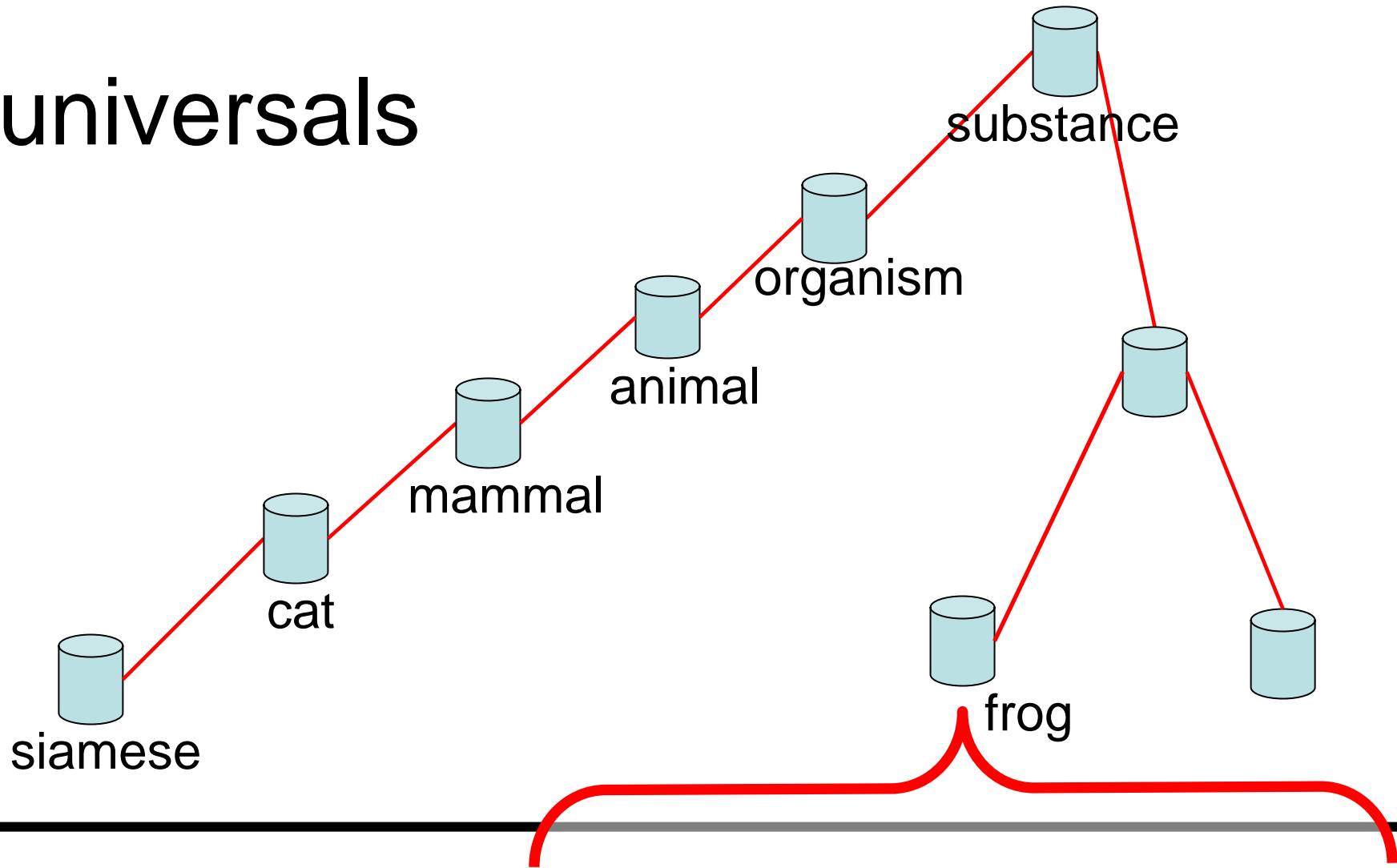


Organisms



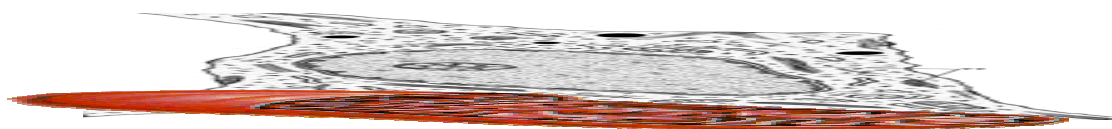
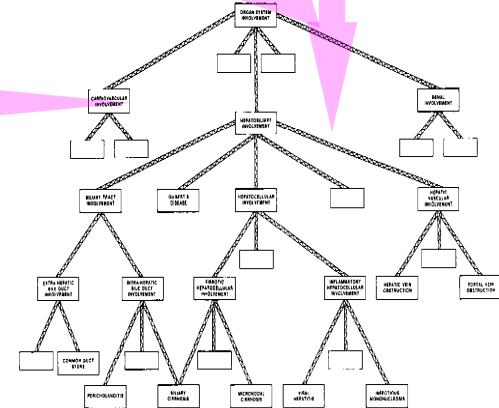
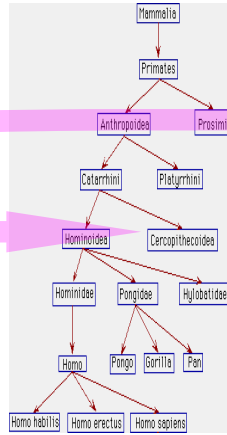
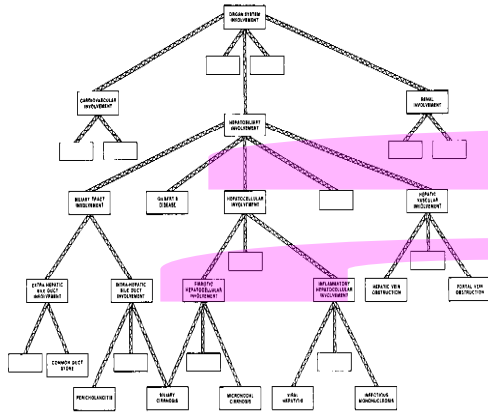
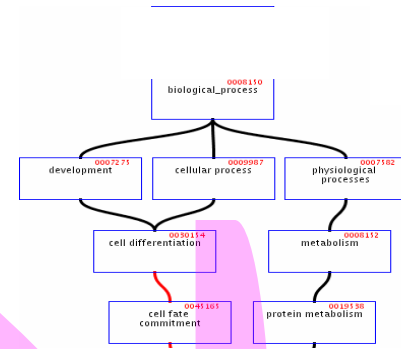
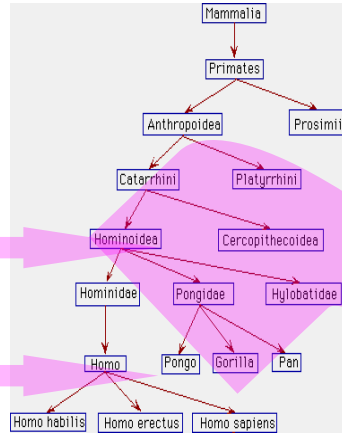
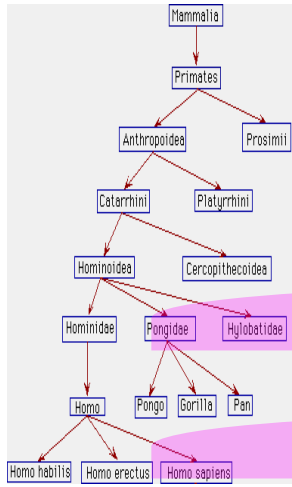
Diseases

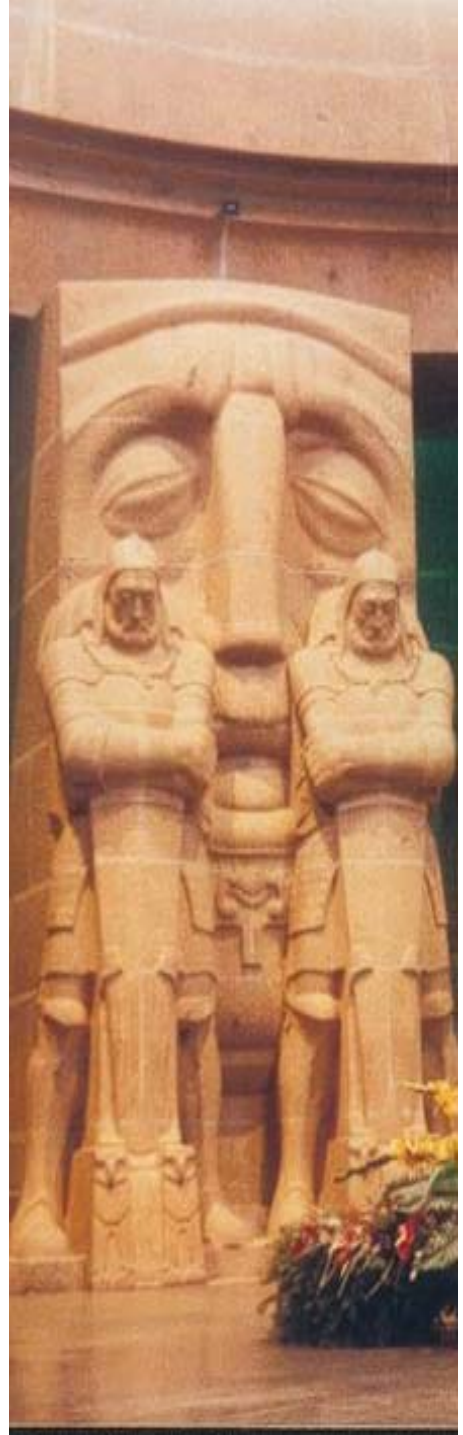
universals



instances







Many current standard 'ontologies' ramshackle because they have no counterpart of formal ontology

The Universal Medical Language System (UMLS)
a compendium of source vocabularies including:

HL7 RIM

SNOMED

International Classification of Diseases

MeSH – Medical Subject Headings

Gene Ontology

Problem: The different source vocabularies are incompatible with each other

Problem: They contain bad coding

which often derives from failure to pay attention to simple logical or ontological principles or from principles of good definitions

Bad Coding

Plant roots ***is-a*** Plant

Plant leaves ***is-a*** Plant

Pollen ***is-a*** Plant

Both testes ***is a*** testis

Both uterii ***is a*** uterus

Bad definitions

Heptolysis =_{def} the cause of heptolysis

Biological process =_{def} a biological goal that requires more than one function

UMLS Source Vocabularies

HL7 RIM

SNOMED

International Classification of Diseases

MeSH – Medical Subject Headings

Gene Ontology

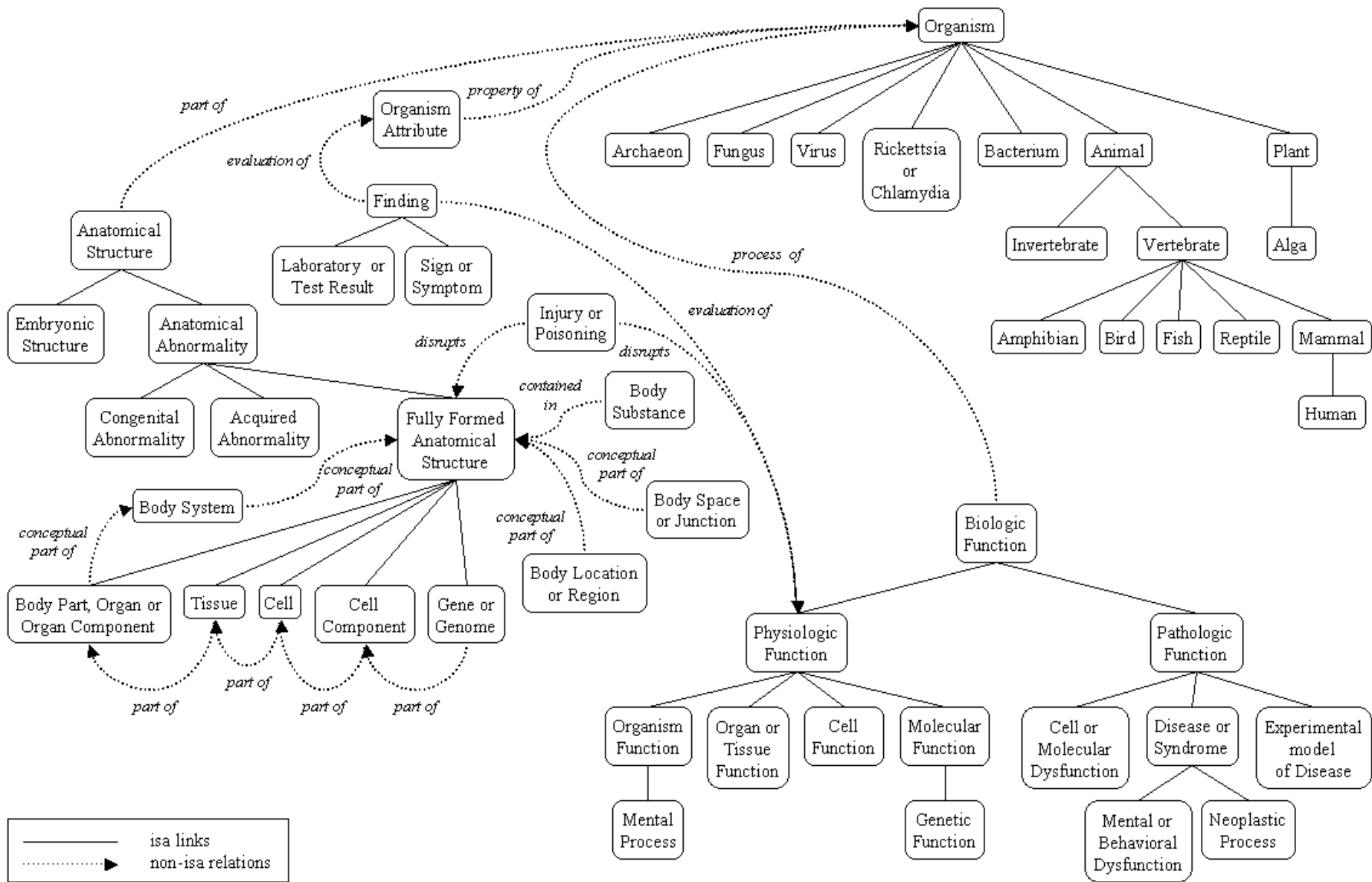
To reap the benefits of standardization
we need to make ONE SYSTEM out of
many different terminologies

→ UMLS Semantic Network

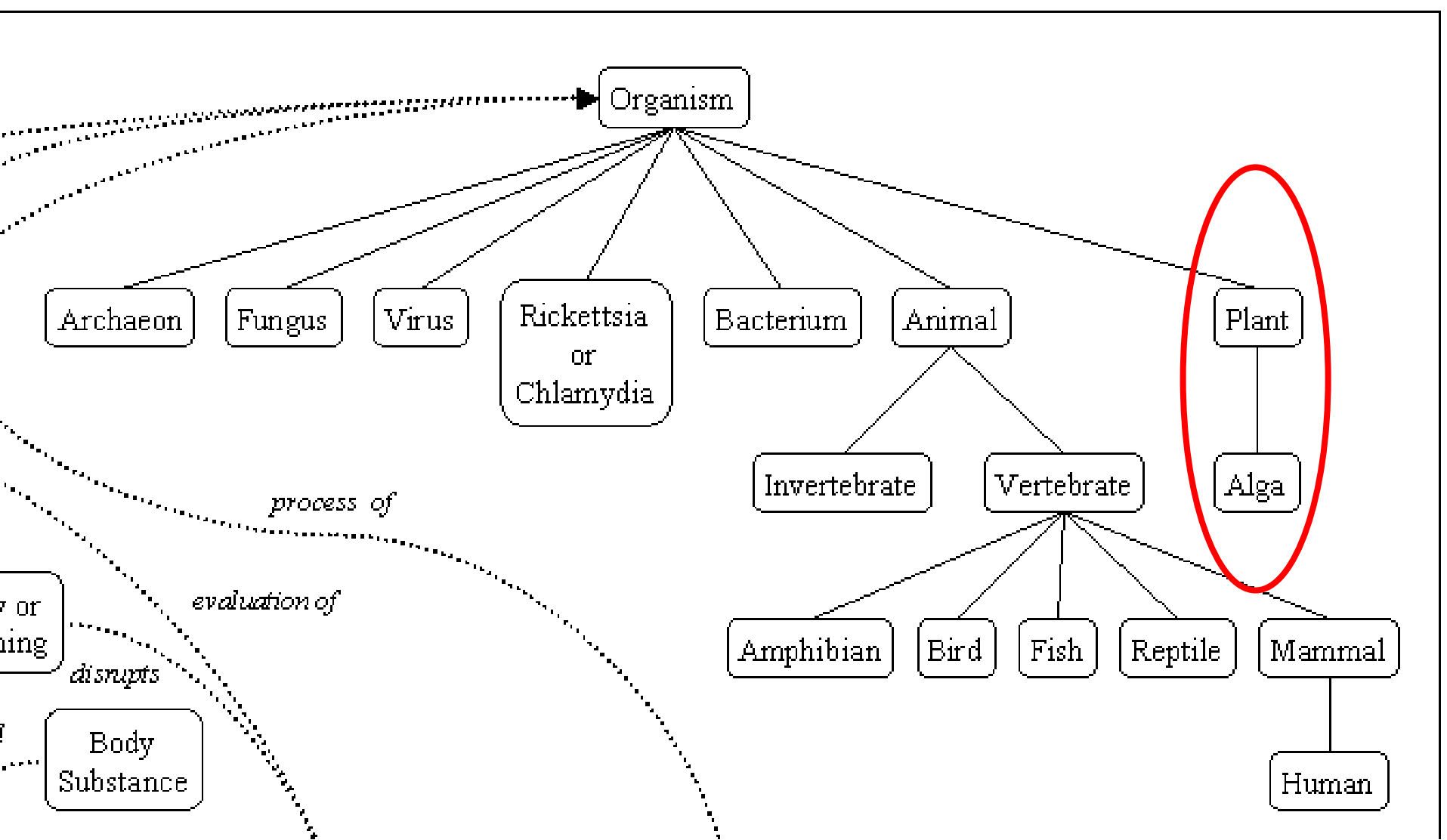
nearest thing to an “ontology” of the UMLS

134 Nodes, 54 Relationship-Types between
these Nodes, forming a graph with 6000
Edges

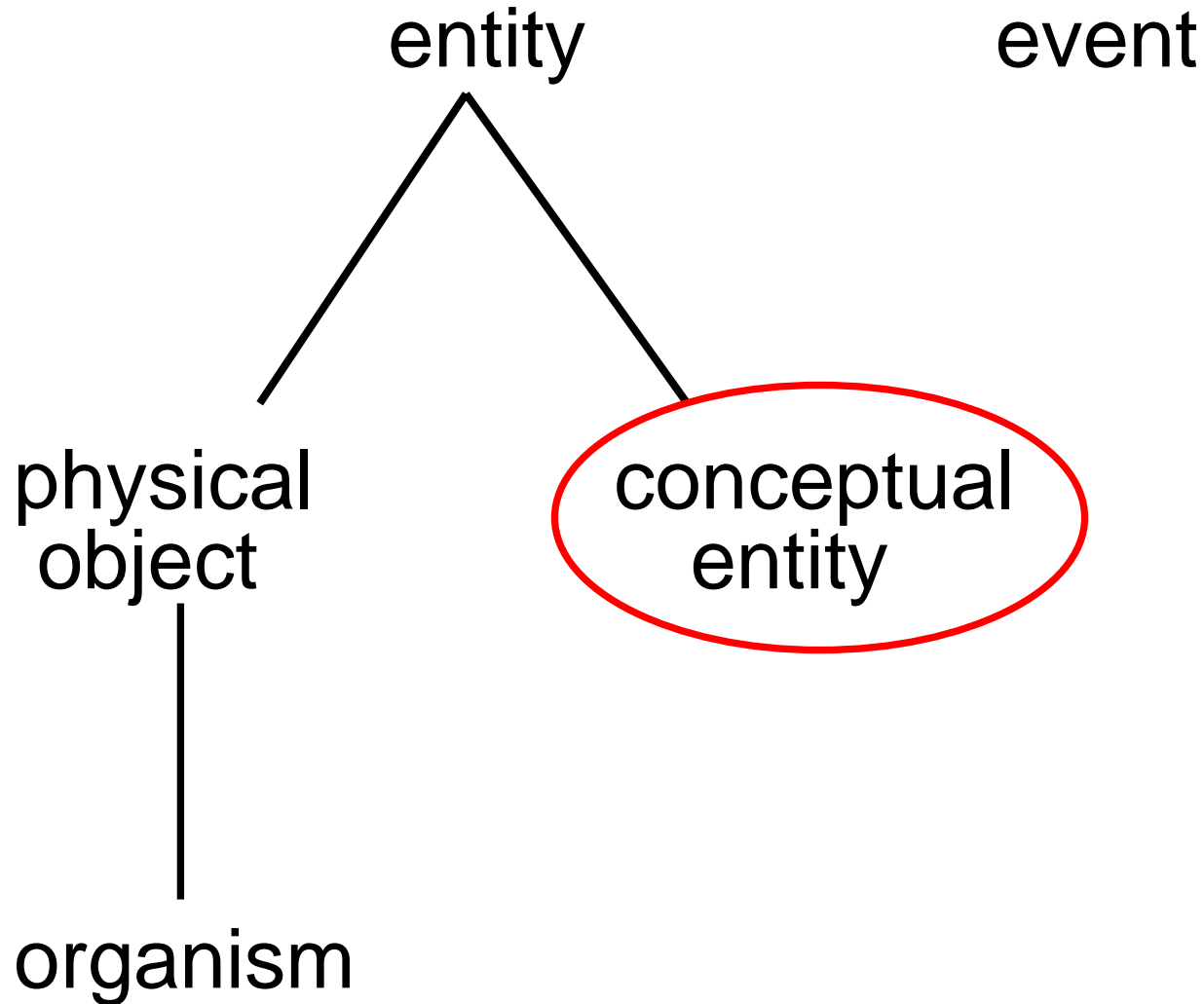
(built by linguists ...)



Fragment of the UML Semantic Network 42



UMLS Semantic Network



conceptual entity



Organism Attribute

Finding



Idea or Concept

Occupation or Discipline

Organization

Group

Group Attribute

Intellectual Product

Language



Idea or Concept

Functional Concept

Qualitative Concept

Quantitative Concept

→ Spatial Concept

Body Location or Region

Body Space or Junction

→ Geographic Area

Molecular Sequence

Amino Acid Sequence

Carbohydrate Sequence

Nucleotide Sequence

Budapest



is an *Idea or Concept*

→ Idea or Concept
Functional Concept
Qualitative Concept
Quantitative Concept
Spatial Concept

Body Location or Region

Body Space or Junction

Geographic Area

Molecular Sequence

→ **Amino Acid Sequence**
Carbohydrate Sequence
Nucleotide Sequence

**Problem: Confusion of concepts
and entities in reality**

Blood Pressure Ontology

The hydraulic equation:

$$BP = CO * PVR$$

arterial blood pressure (BP) is directly proportional to the product of blood flow (cardiac output, CO) and peripheral vascular resistance (PVR).

UMLS-Semantic Types:

blood pressure is an *Organism Function*,
cardiac output is a *Laboratory or Test Result*
or *Diagnostic Procedure*

$BP = CO * PVR$ thus asserts that

blood pressure is proportional either to a
laboratory or test result or to a diagnostic
procedure

Problem: Confusion of reality with
our (ways of gaining) knowledge
about reality

What are the terms of ontologies

Concepts?

The Concept Orientation

Work on biomedical ontologies grew out of work on medical dictionaries and nomenclatures

Has focused almost exclusively on ‘concepts’ conceived (sometimes called ‘classes’, sometimes confused with terms/descriptions).

Concept-orientation also common in KR, has led to the entrenchment of an assumption according to which all that need be said about classes can be said without appeal to time or instances.

This, however, has fostered an impoverished regime of definitions in which the use of identical terms (like ‘part’) in different systems has been allowed to mask underlying incompatibilities.

is-a

Standard definition:

A is-a B =def every instance of *A* is an instance of *B*

= standard definition of computer science

adult is-a child

animal owned by the Emperor is-a animal

mammal is-a object weighing less than 200 kg

correct reading of *is-a*

1. *A* and *B* are natural kinds,
2. there are times at which instances of *A* exist,
3. at all such times these instances are **necessarily (of their very nature)** also instances of *B*

1. *eukaryotic cell is-a cell*
2. *mammal is-a animal*
3. *death is-a biological process*

Ontologies

Here *A* and *B* are *universals*

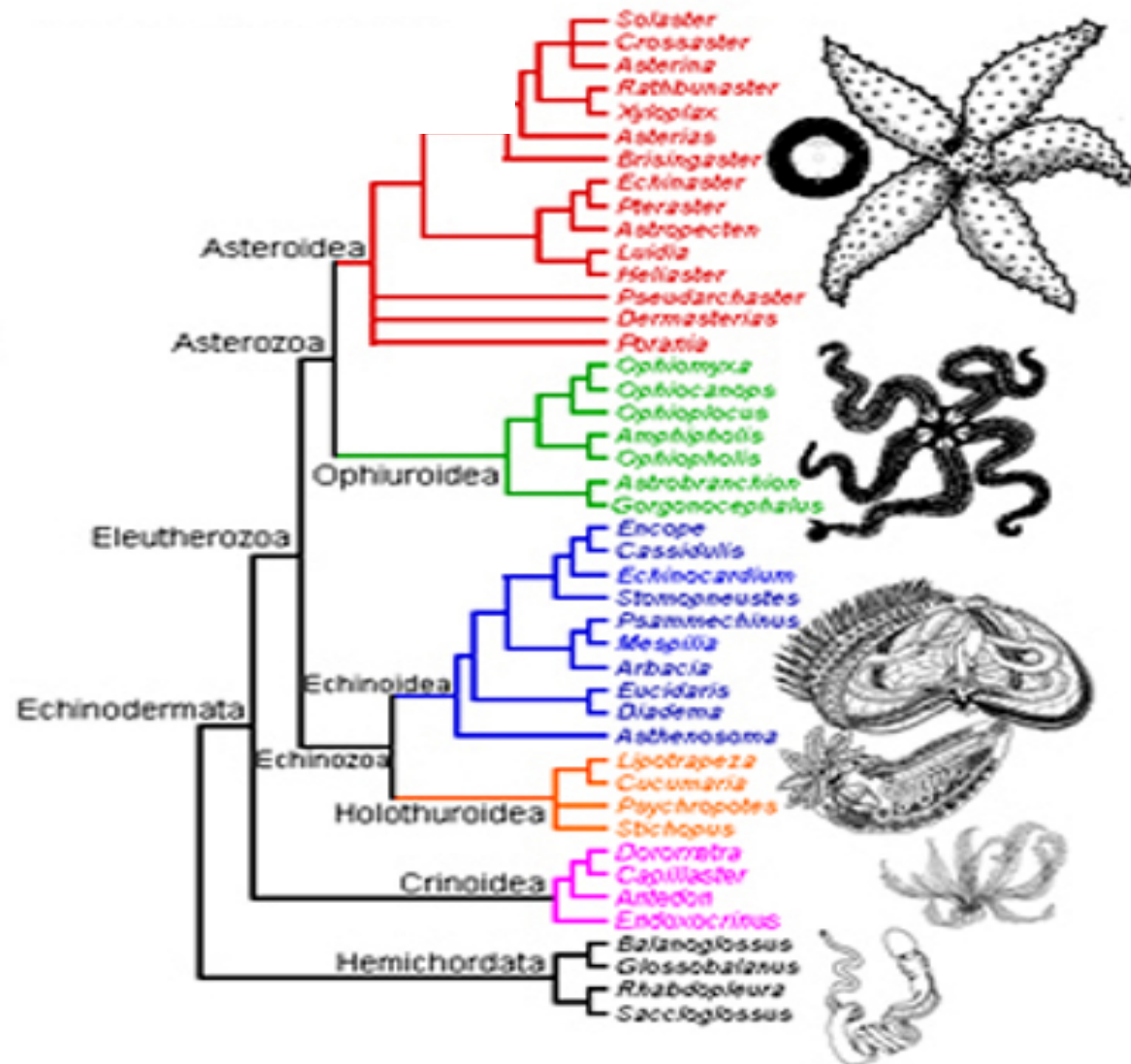
(= natural kinds, types ..., roughly analogous to biological species)

Universals have *instances* (you and me, your headache, my coughing)

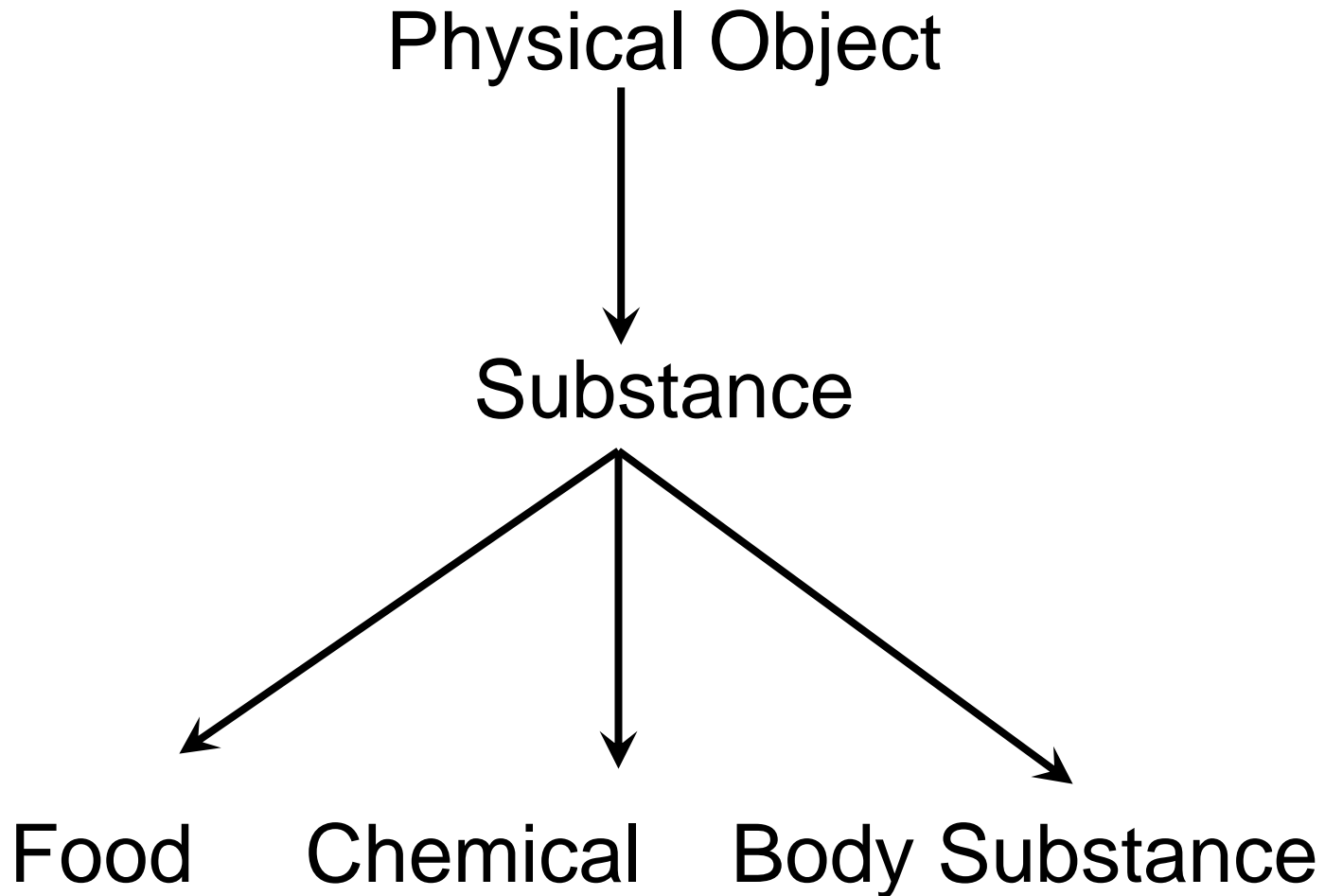
Instances are elite individuals

they are those which instantiate universals
(entering into biological laws)

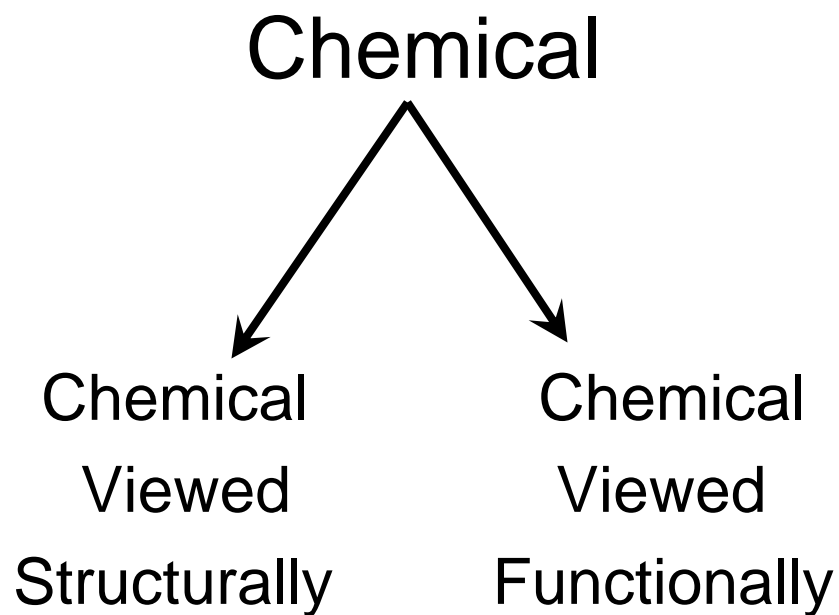
Linnaean Ontology



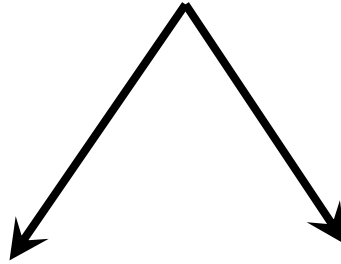
Confusion of Ontology and Epistemology



Confusion of Ontology and Epistemology

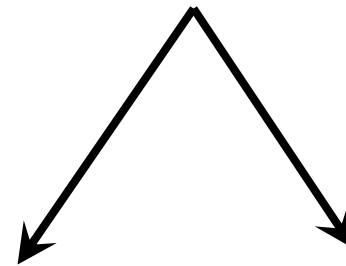
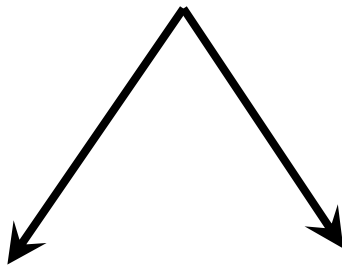


Chemical



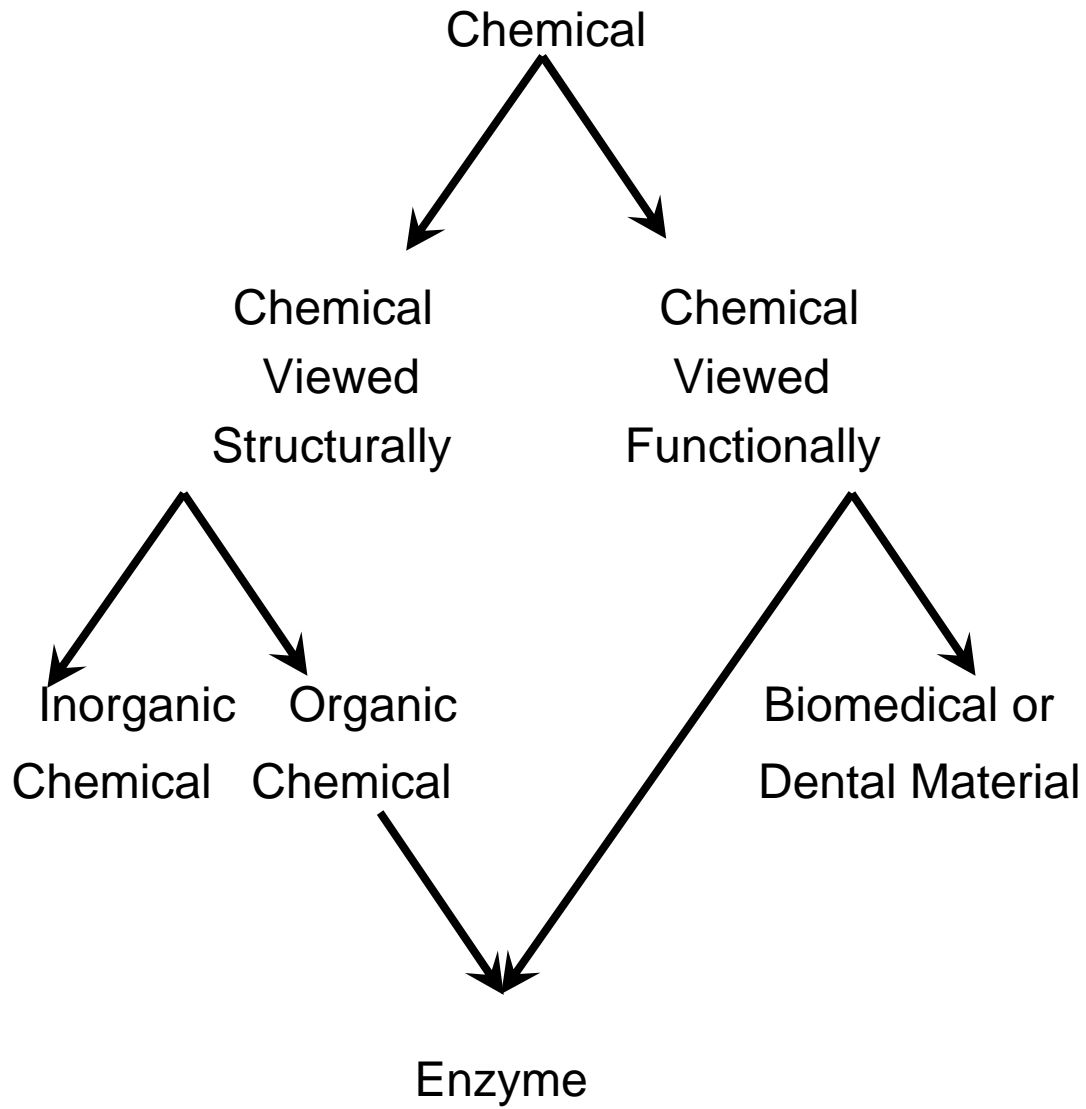
Chemical
Viewed
Structurally

Chemical
Viewed
Functionally

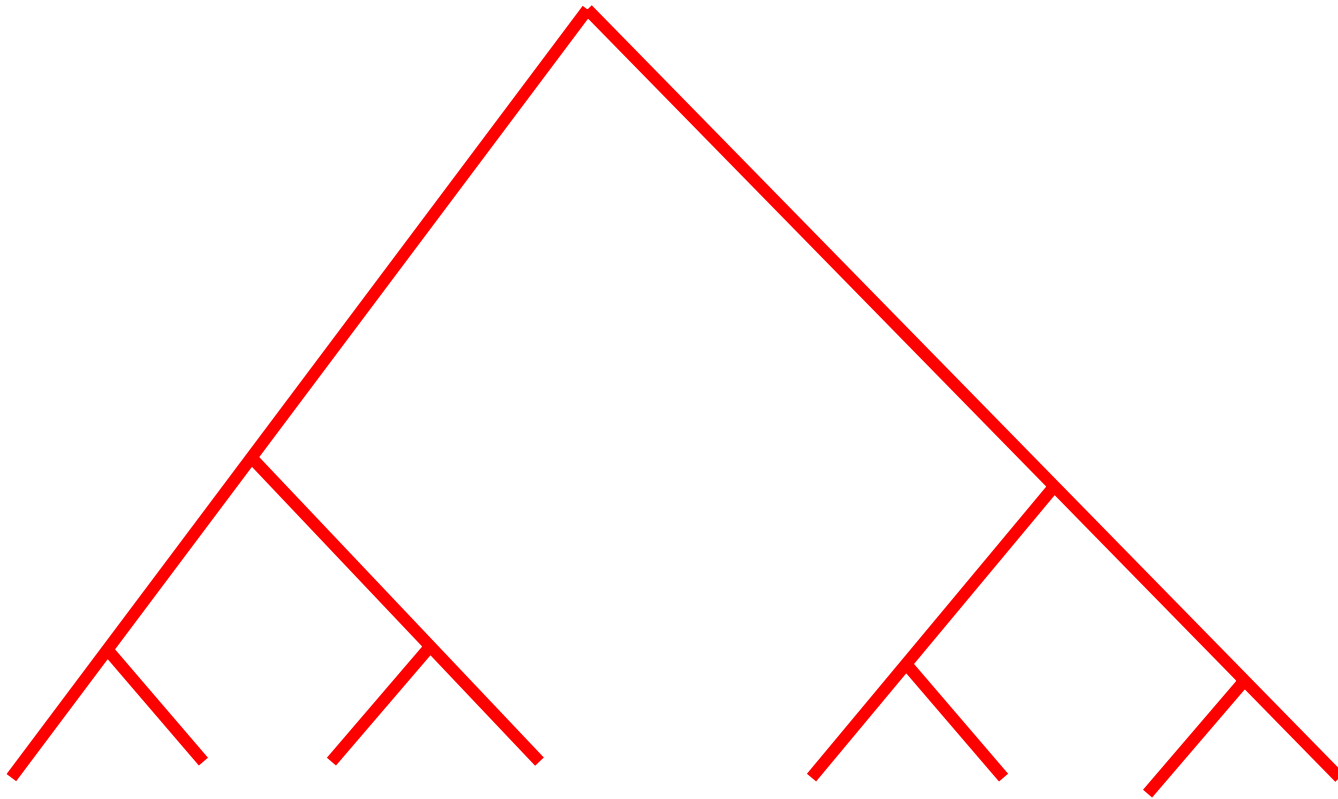


Inorganic
Chemical Organic
Chemical

Enzyme Biomedical or
Dental Material

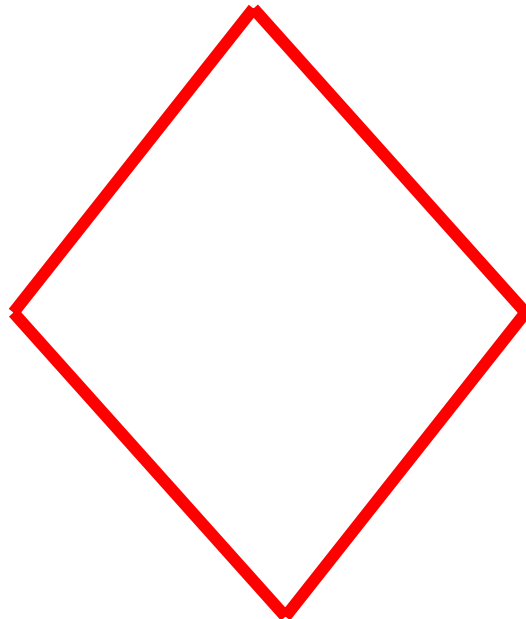


Is biological classification Linnaean?

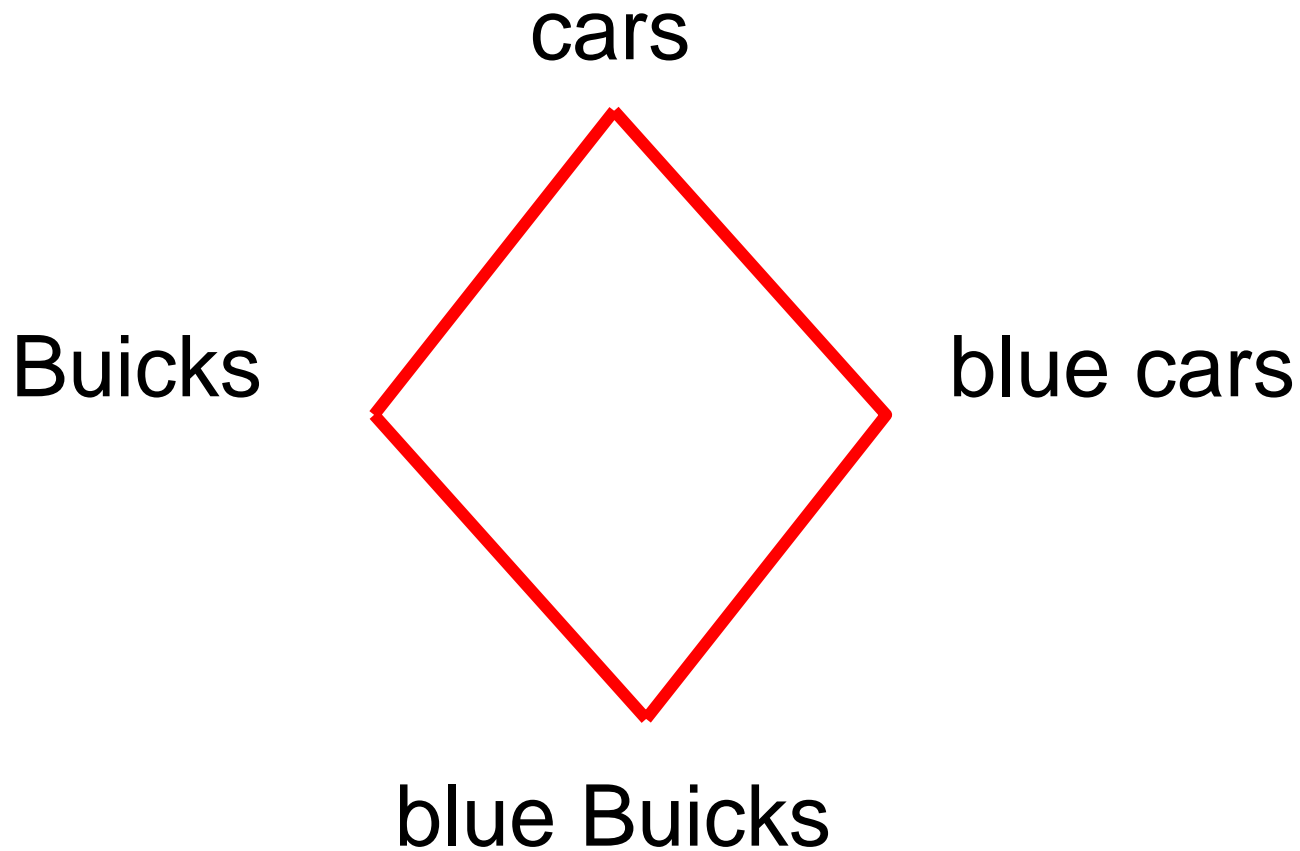


Principle of Single Inheritance

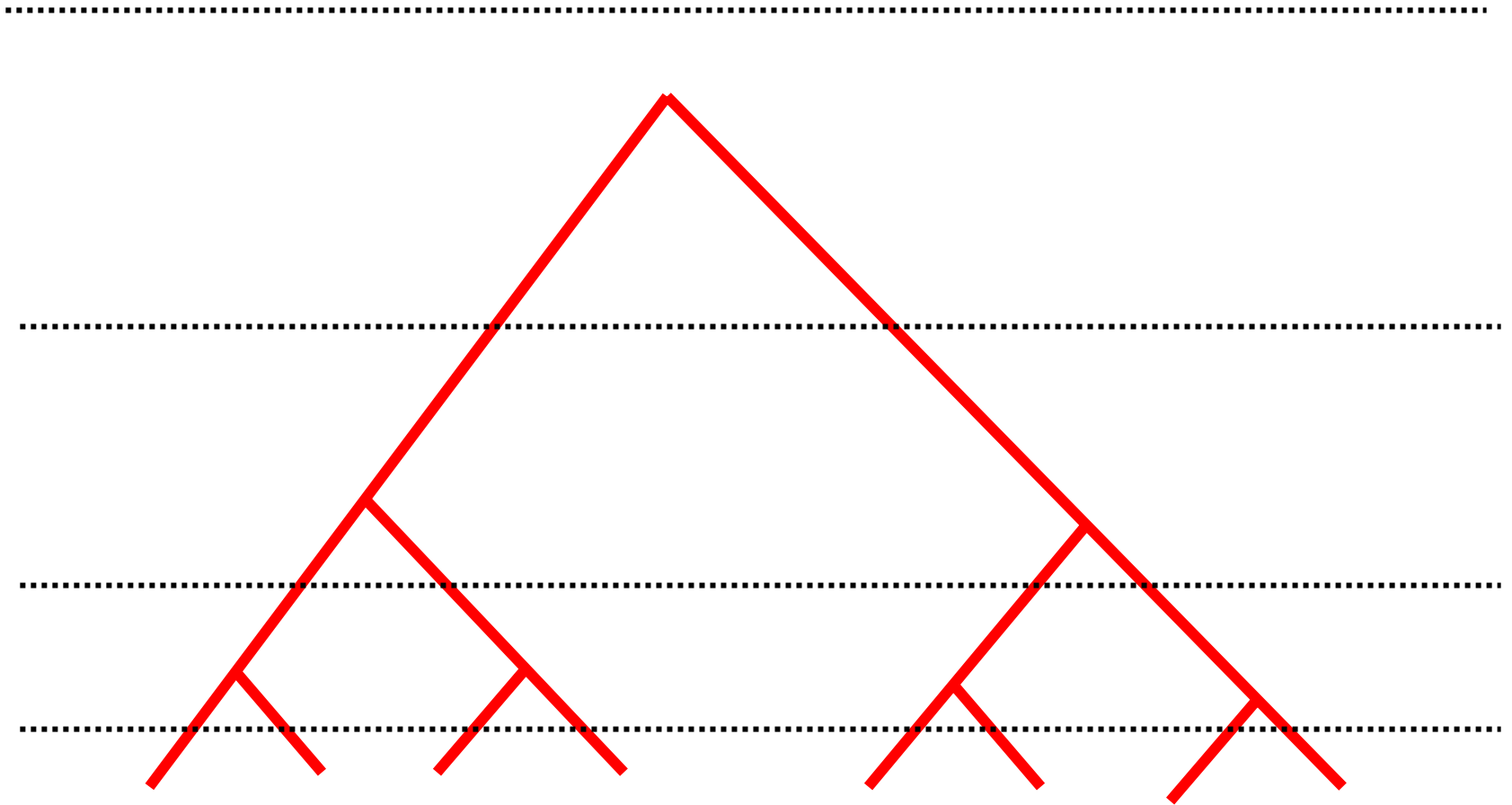
(rule of thumb) no class in a classificatory hierarchy should have more than one parent



The Problem of Multiple Inheritance



Principle of Taxonomic Levels



Principle of Taxonomic Levels

the terms in a classificatory hierarchy should be divided into predetermined levels (analogous to the levels of *kingdom*, *phylum*, *class*, *order*, etc., in traditional biology).

‘depth’ in GO’s hierarchies not determinate because of multiple inheritance

Principle of Exhaustiveness

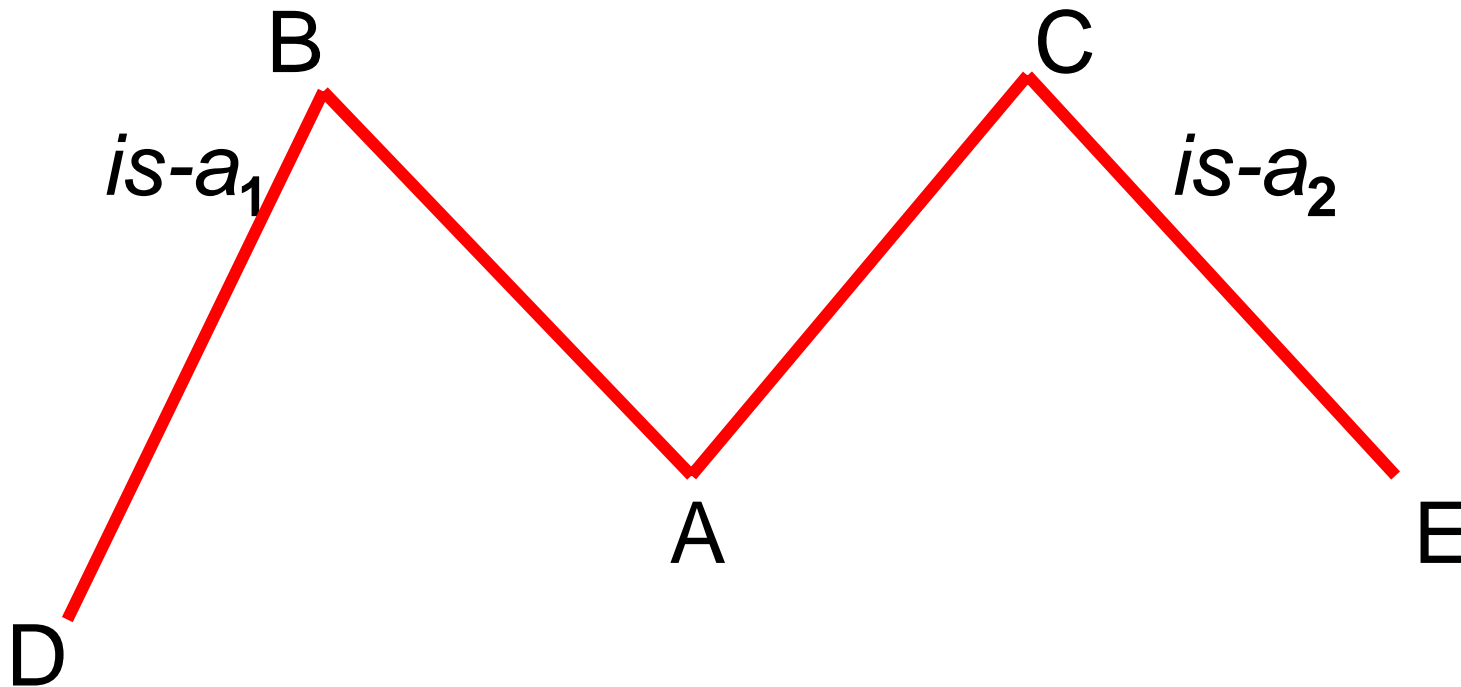
the classes on any given level should exhaust the domain of the classificatory hierarchy.

Single Inheritance + Exhaustiveness = JEPD

Exhaustiveness often difficult to satisfy in the realm of biological phenomena; but its acceptance as an ideal is presupposed as a goal by every scientist.

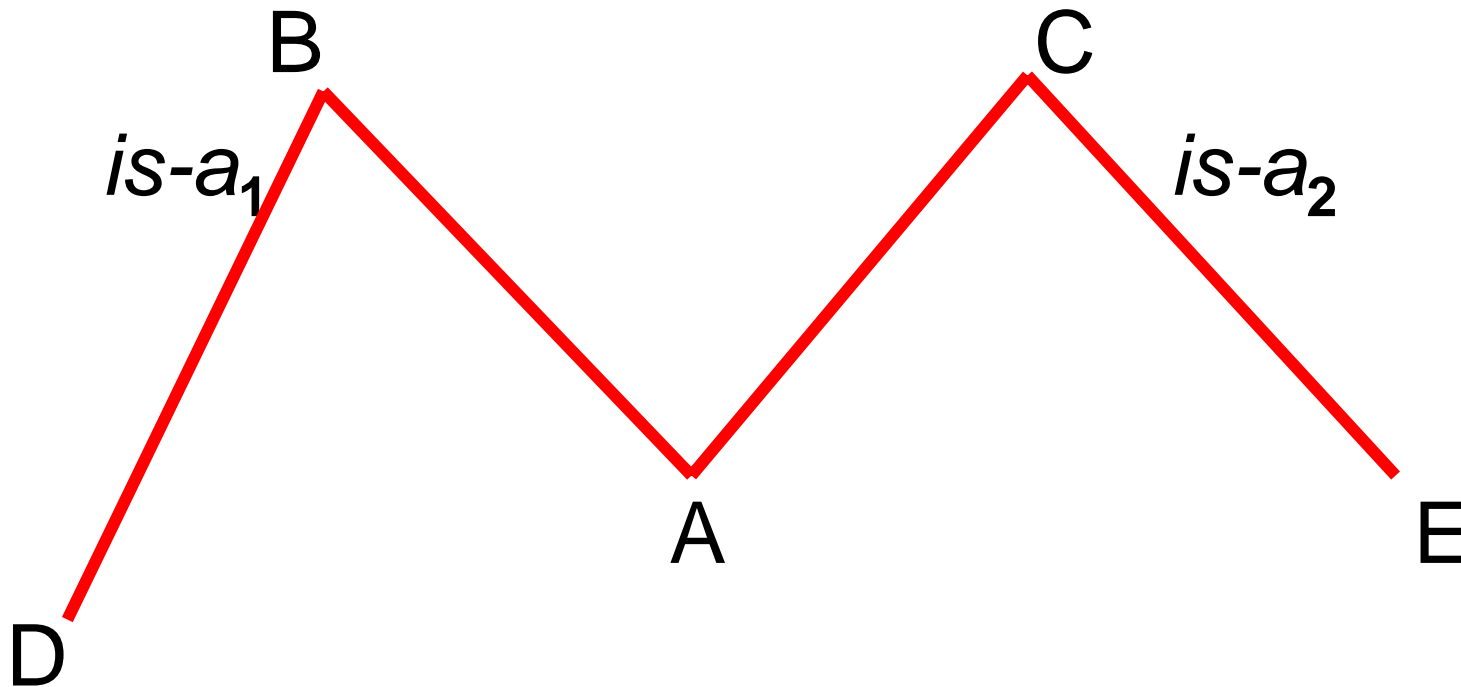
Single inheritance accepted in all traditional (species-genus) classifications

Problems with multiple inheritance



'sibling' is no longer determinate

Problems with multiple inheritance



'is_a' is no longer univocal

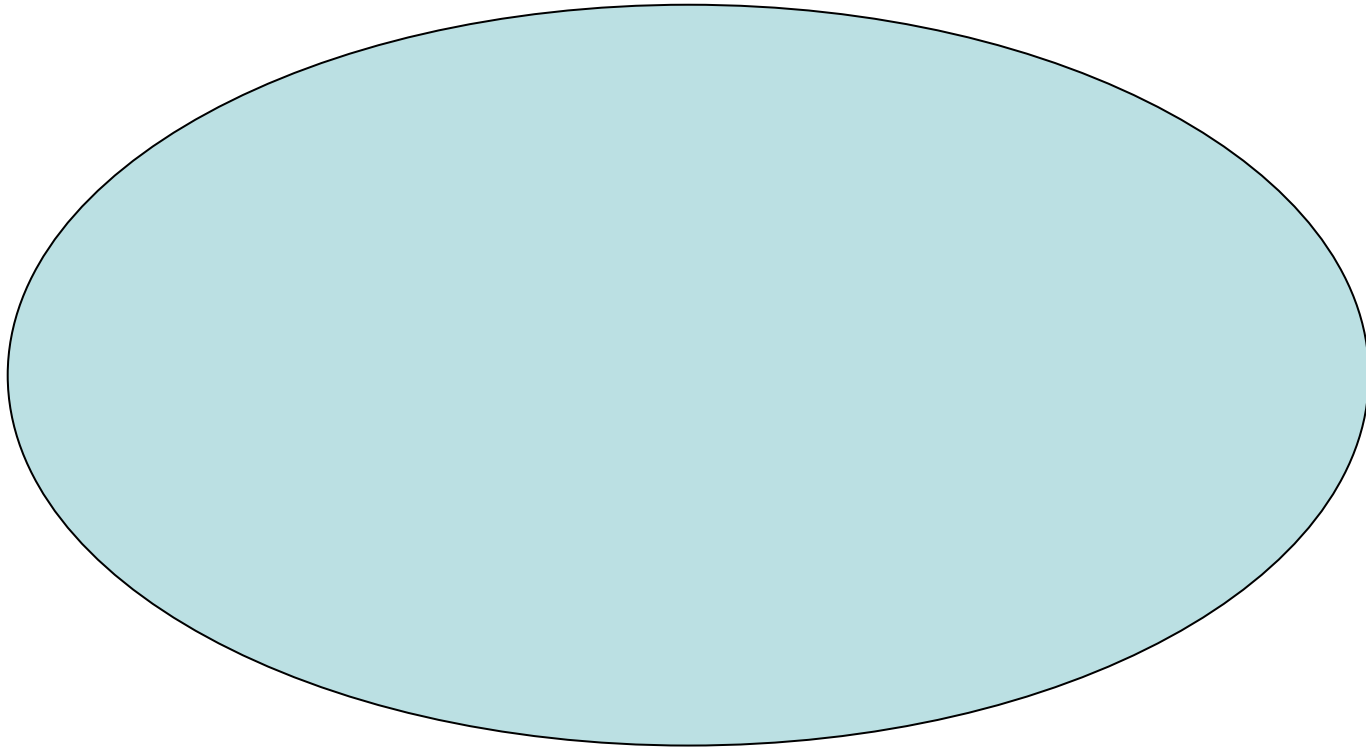
when '***is-a***' is pressed into service to mean a variety of different things

the resulting ambiguities make the rules for correct coding difficult to communicate to human curators

they also serve as obstacles to integration with neighboring ontologies

How are universals and instances
related together?

Entities



Entities

universals (classes, types, taxa, ...)



particulars (individuals, tokens, instances ...)

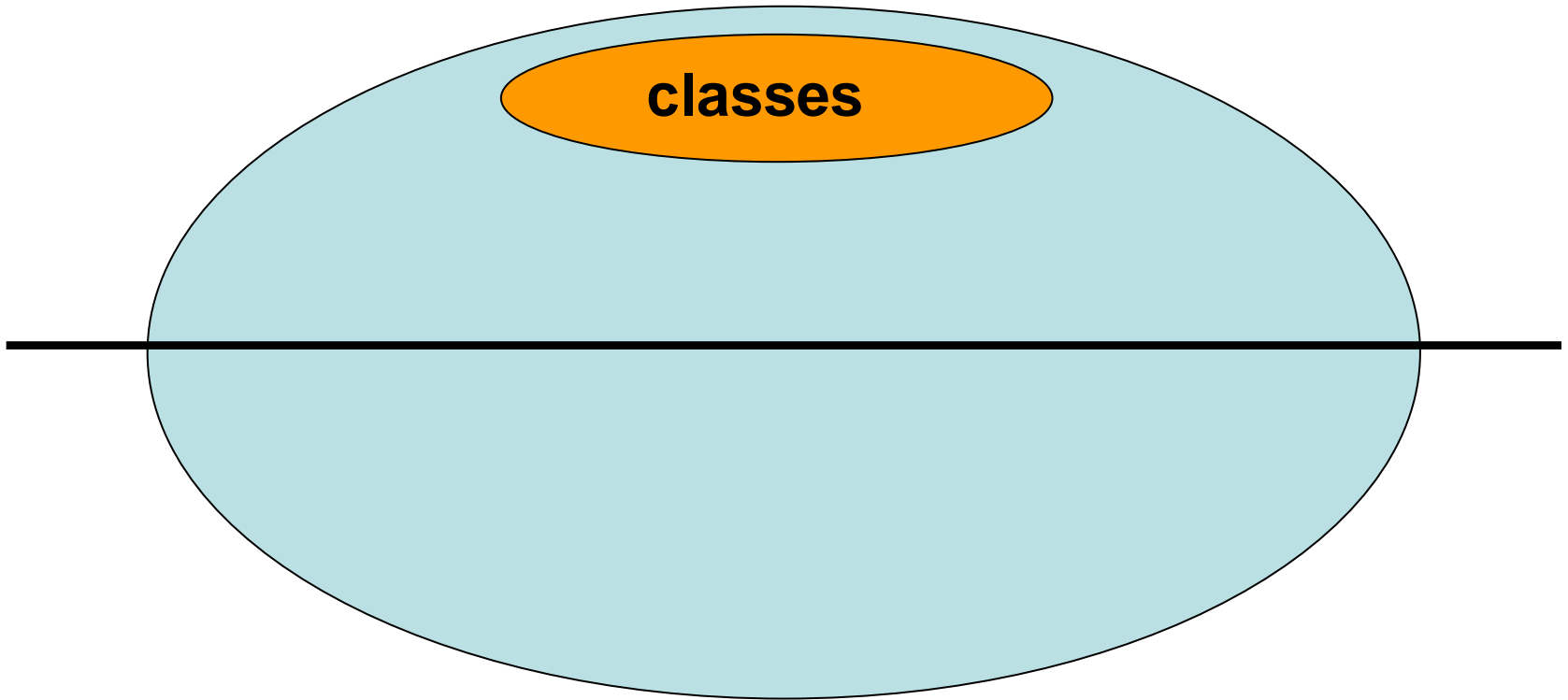
Axiom: Nothing is both a universal and a particular

Two Kinds of Elite Entities

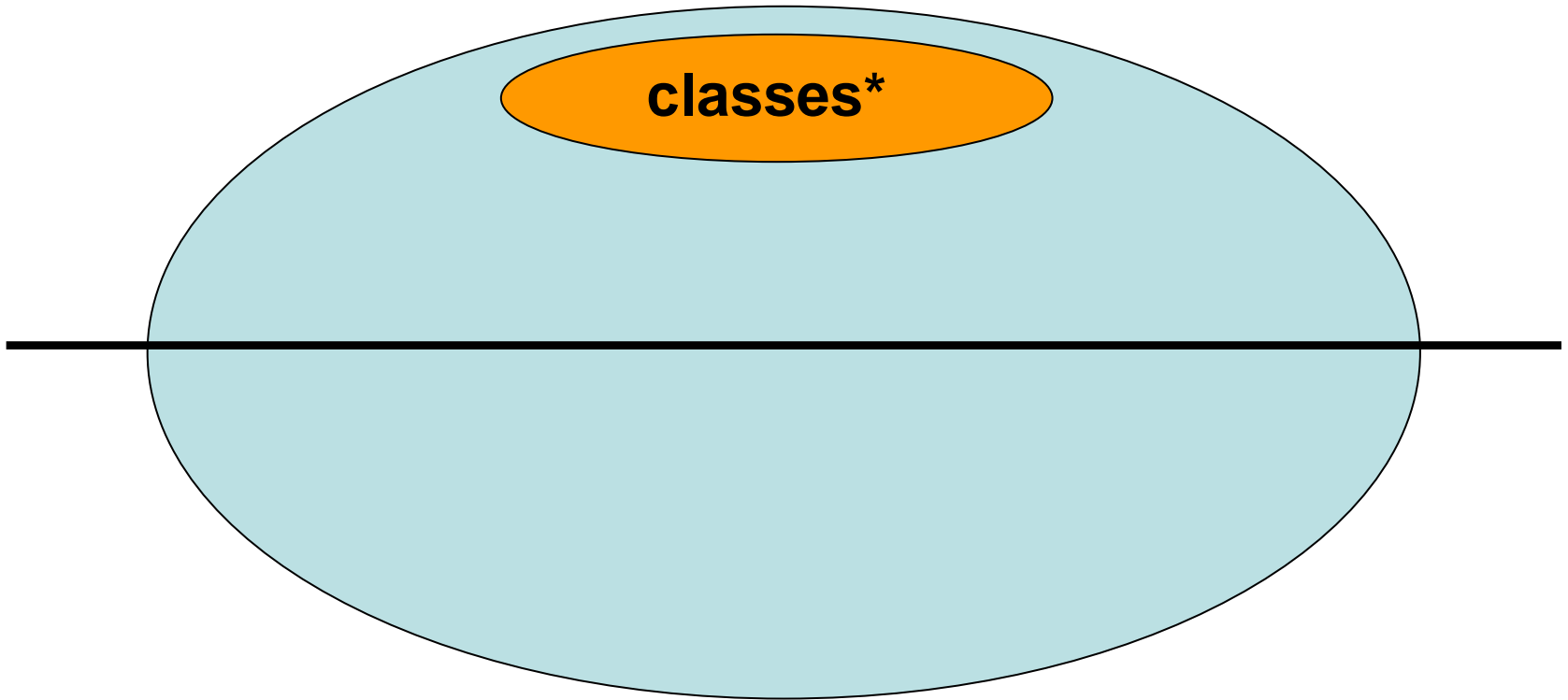
classes, within the realm of universals

instances within the realm of particulars

Entities



Entities



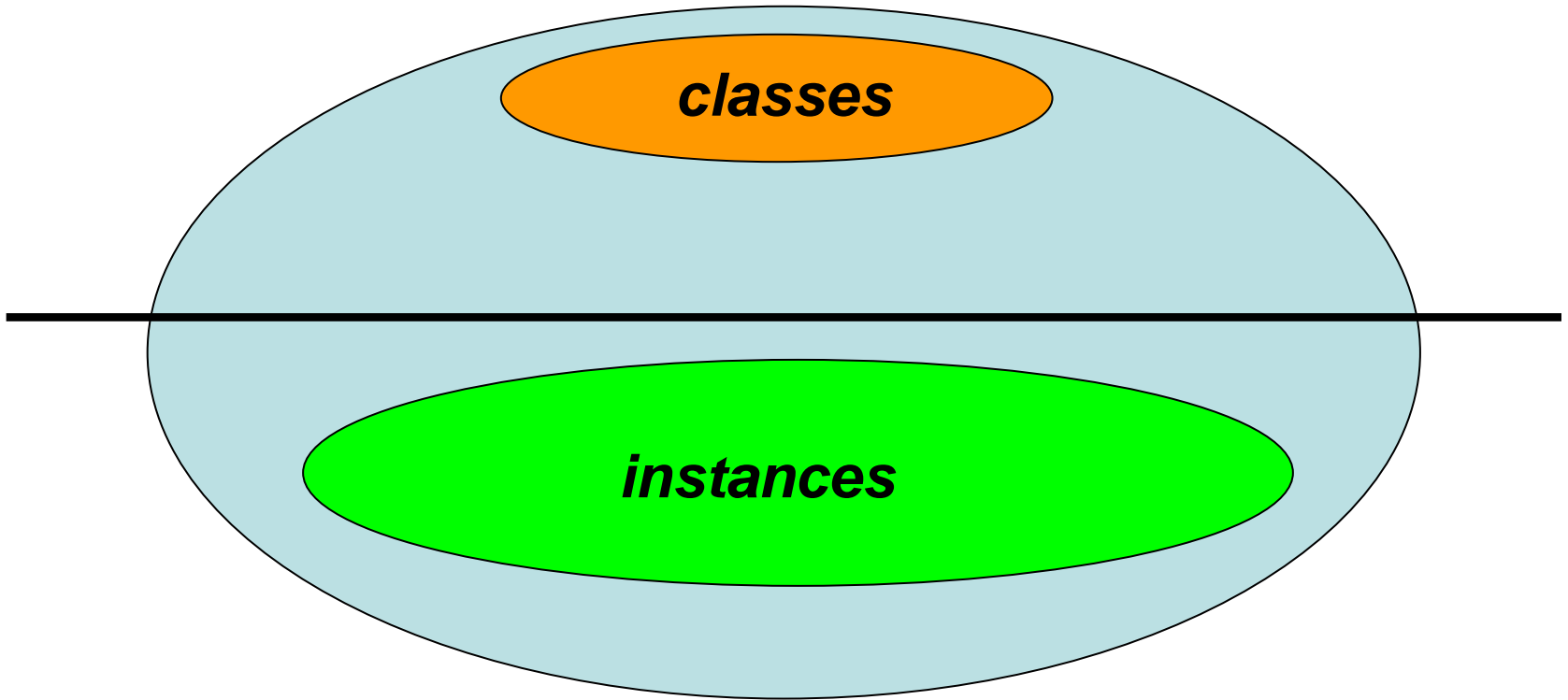
***natural, biological**

Entities

classes of *objects, substances*

**need modified axioms for classes of
functions, processes, pathways,
reactions, etc.**

Entities



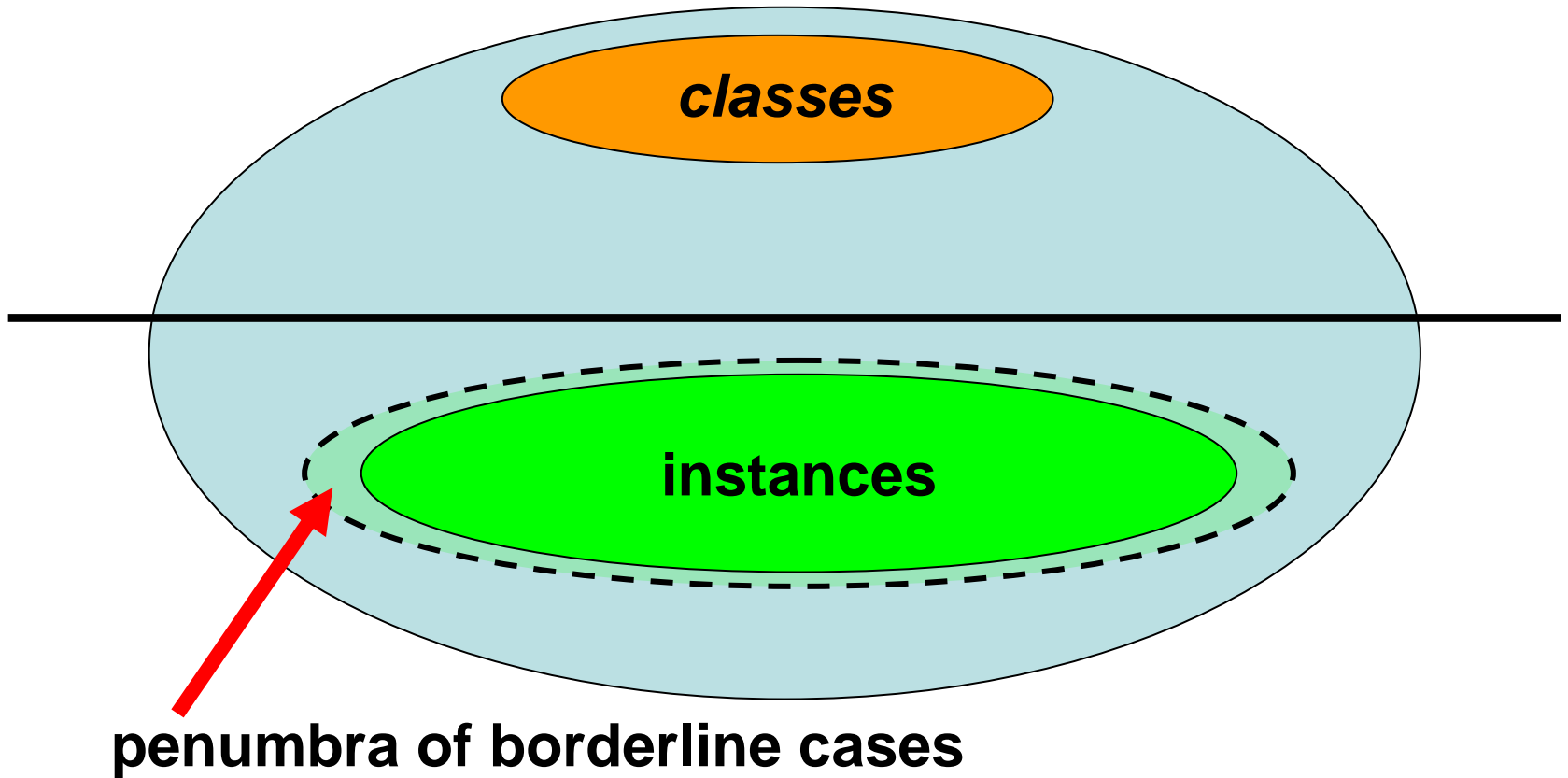
Classes are *natural* kinds

Instances are *natural* exemplars of *natural* kinds

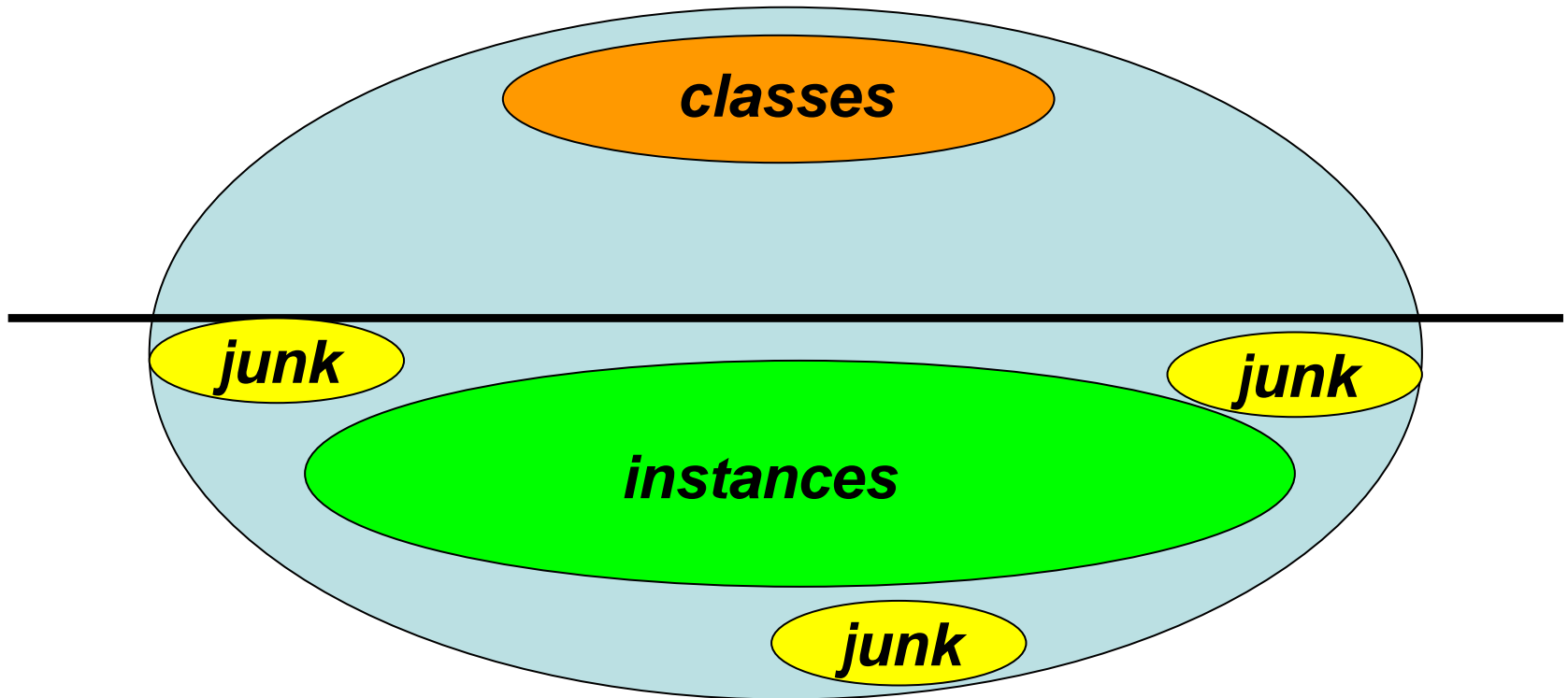
(problem of non-standard instances)

Not all individuals are instances of classes

Entities



Entities



example of junk: beachball-desk

Primitive relations: *inst* and *part*

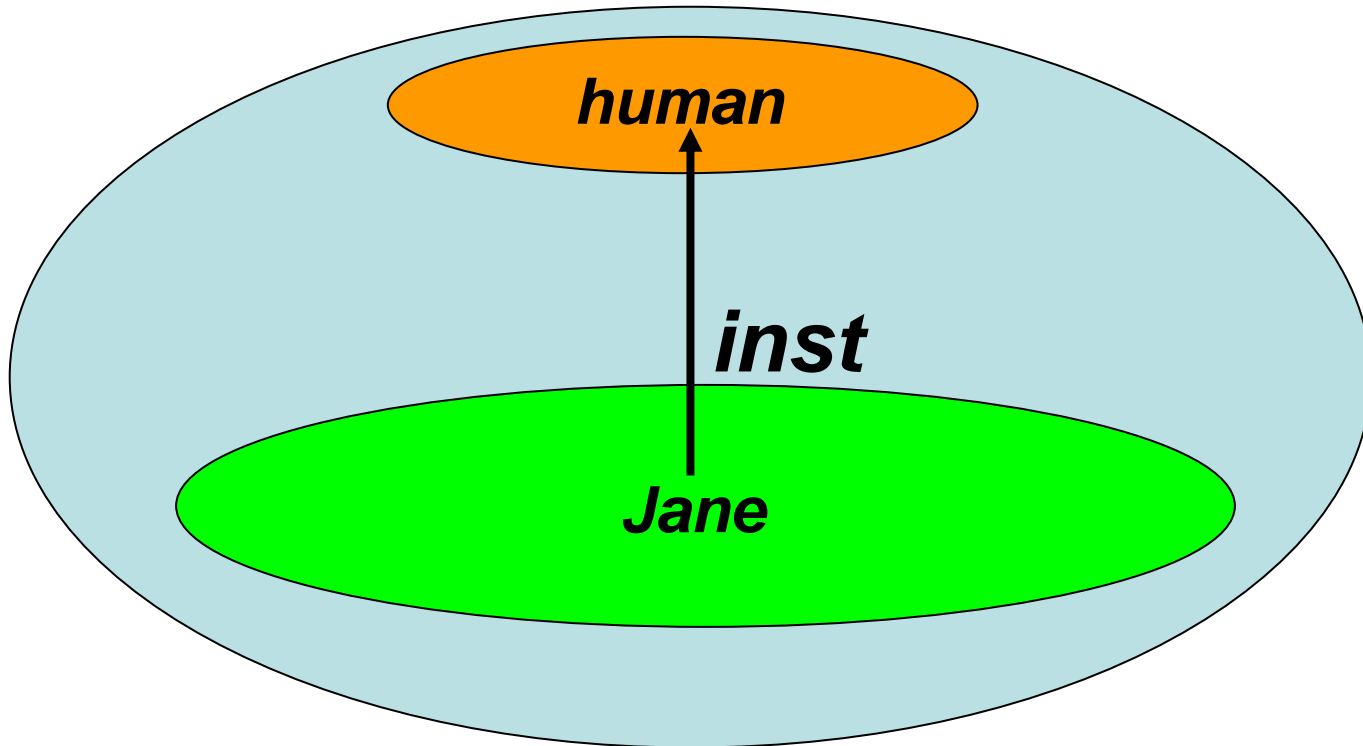
inst(Jane, human being)

part(Jane's heart, Jane's body)

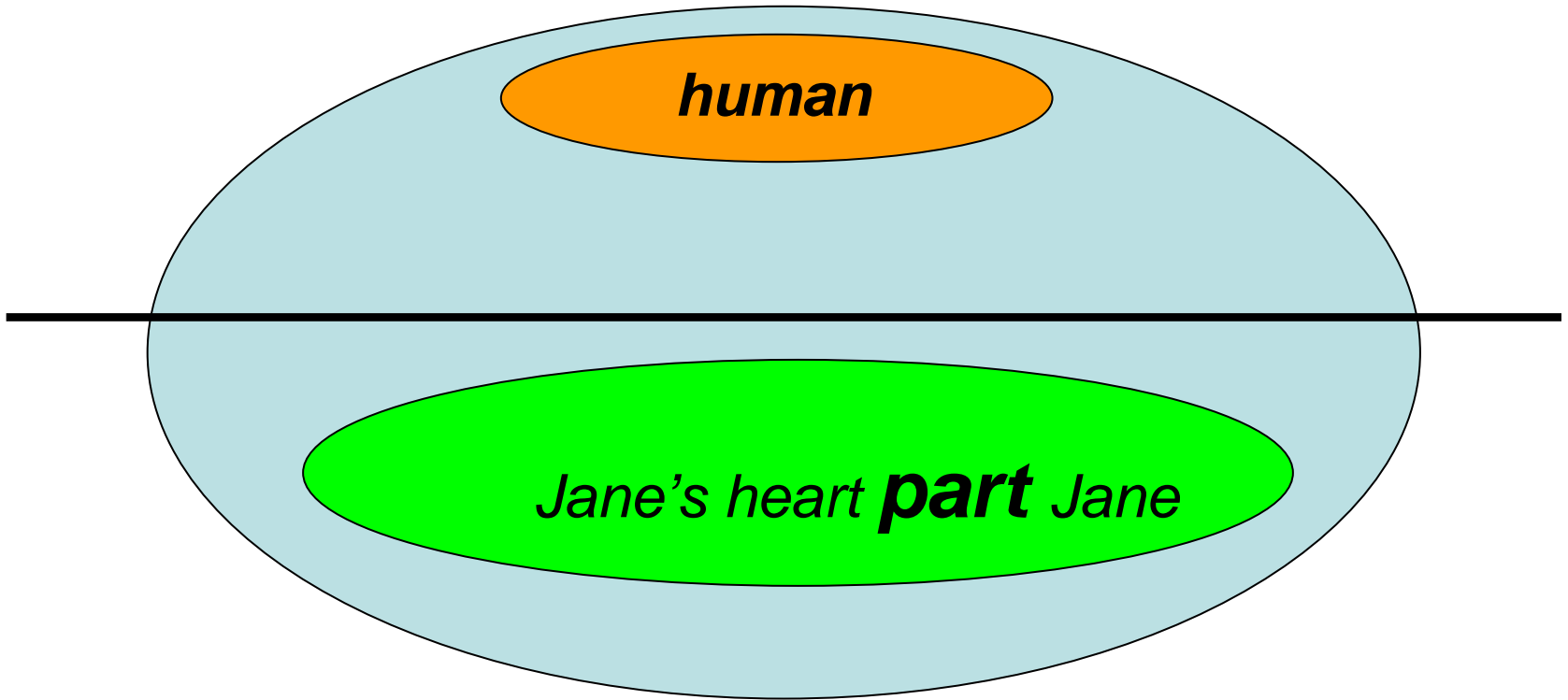
A class is anything that is instantiated

An instance as anything (any individual) that
instantiates some class

Entities



Entities



*part as a relation between
individuals*

subject to the **usual axioms of
mereology**

Two primitive relations: *inst* and *part*

inst(Jane, *human being*)

part(Jane's heart, Jane's body)

A universal is anything that is instantiated

An instance is anything (any individual) that instantiates some class

Two primitive relations: *inst* and *part*

Axioms governing *inst* :

- (1) it holds in every case between an instance and a class, in that order;
- (2) that nothing can be both an instance and a class.

Axioms governing *part* (= 'proper part')

- (1) it is *irreflexive*
- (2) it is *asymmetric*
- (3) it is *transitive*
- (4) it holds only between individuals
(usual mereological axioms)

Part_for and Has_Part

A part_for B =_{def}

given any x , if ***inst***(x , A) then there is some y
such that ***inst***(y , B) and ***part***(x , y)

B has_part A =_{def}

given any y , if ***inst***(y , B) then there is some x
such that ***inst***(x , A) and ***part***(x , y)

human testis part_for human being,

But not: *human being has_part human testis.*

human being has_part heart,

But not: *heart part_for human being.*

The usual part_of relation as a relation between universals

A part_of B =_{def} A part_for B & B has_part A

As exist only as parts of *Bs* and *Bs* are structurally organized in such a way that *As* must appear in them as parts.

Analogous problems for nearly all foundational relations of ontologies and semantic networks:

A causes B

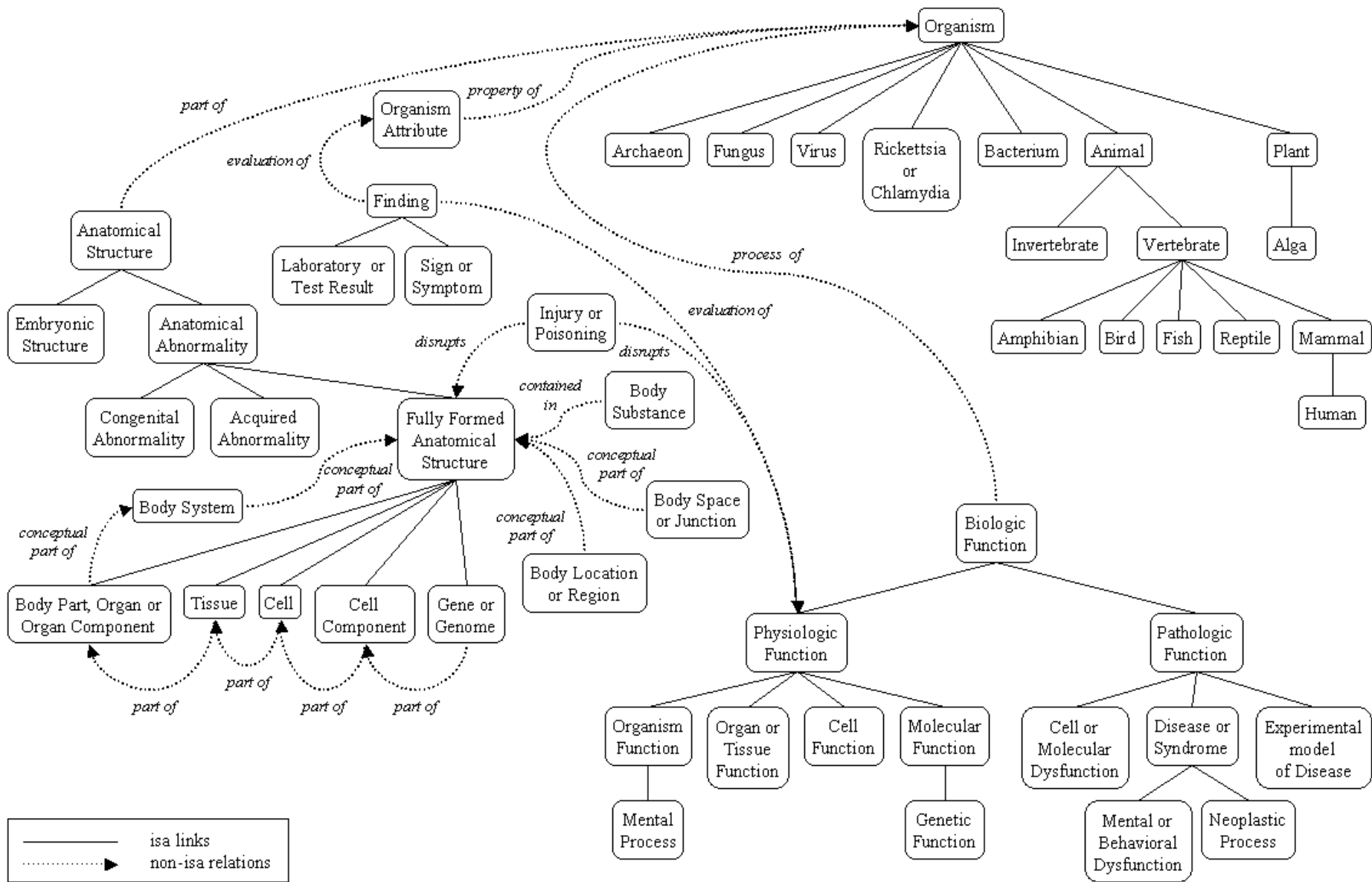
A is associated with B

A is located in B

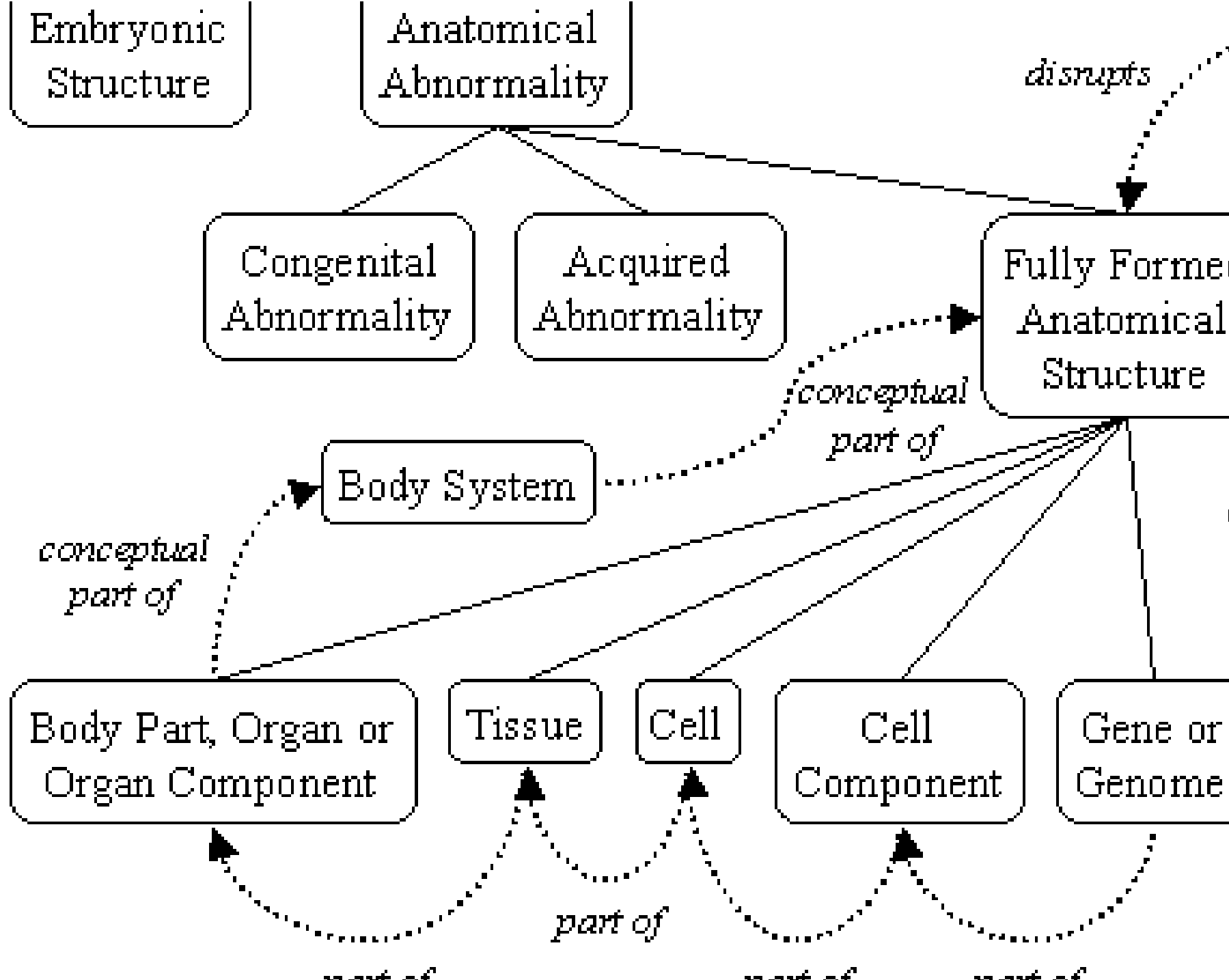
etc.

Reference to instances is necessary to clear up these problems

if they can be cleared up at all ...



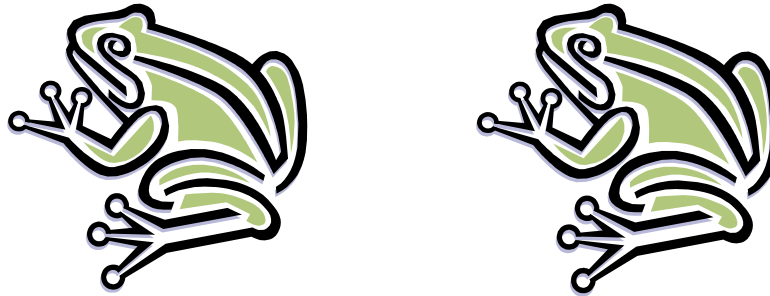
Fragment of the UML Semantic Network 95



Mental Process ***precedes*** Molecular Function
Mental Process ***precedes*** Genetic Function
Experimental Model of Disease ***precedes*** Cell or
Molecular Dysfunction
Acquired Abnormality ***affects*** Bird
Experimental Model of Disease ***affects*** Fungus
Physiologic Function ***affects*** Reptile
Antibiotic ***causes*** Experimental Model of Disease
Biomedical or Dental Material ***causes*** Mental or
Behavioral Dysfunction
Manufactured Object ***causes*** Disease or Syndrome
Vitamin ***causes*** Injury or Poisoning
Fungus ***location_of*** Vitamin
Organization ***location_of*** Diagnostic Procedure

What are universals?

invariants in reality



satisfying biological laws

(there are truths about universals in
biological textbooks)

Universals are Not Sums

Universals are distinguished by granularity: they divide up the corresponding domain into whole units or members, whose interior parts and structure are traced over. The *universal* human being is instantiated only by human beings as single, whole units.

A mereological sum is not granular in this sense (molecules are parts of the mereological sum of human beings)

Universals are Not Sets

Both universals and sets are marked by granularity – but universals are timeless

Both a universal and a set is laid across reality like a grid consisting (1) of a number of slots or pigeonholes each (2) occupied by some member.

But a set is *determined by its members*. This means that it is (1) associated with a specific number of slots, each of which (2) must be occupied by some specific member.

A universal survives the turnover in its instances: it is specified neither (1) what the number of associated slots should be nor (2) what individuals should occupy these slots. *Both may vary with time.*

A universal is not determined by its instances as a state is not determined by its citizens

A universal may vary with time as an organism may vary with time (by gaining and losing molecules)

Universals are Not Sets

A set is an abstract structure,
existing outside time and space.
The set of Romans timelessly has
Julius Caesar as a member.
Universals *exist in time*.



Two Questions

1. What does “Functional” mean in expressions like “Functional Genomics” ?
2. How can we use the answer to this question to help us understand notions fundamental to medicine such as “health” and “disease” ?

Towards an Tri-Categorical Ontology of Structures, Functions and Processes

Definition of Function in UMLS Semantic Network

Functional Concept =_{df} A concept which is of interest because it pertains to the carrying out of a process or activity.

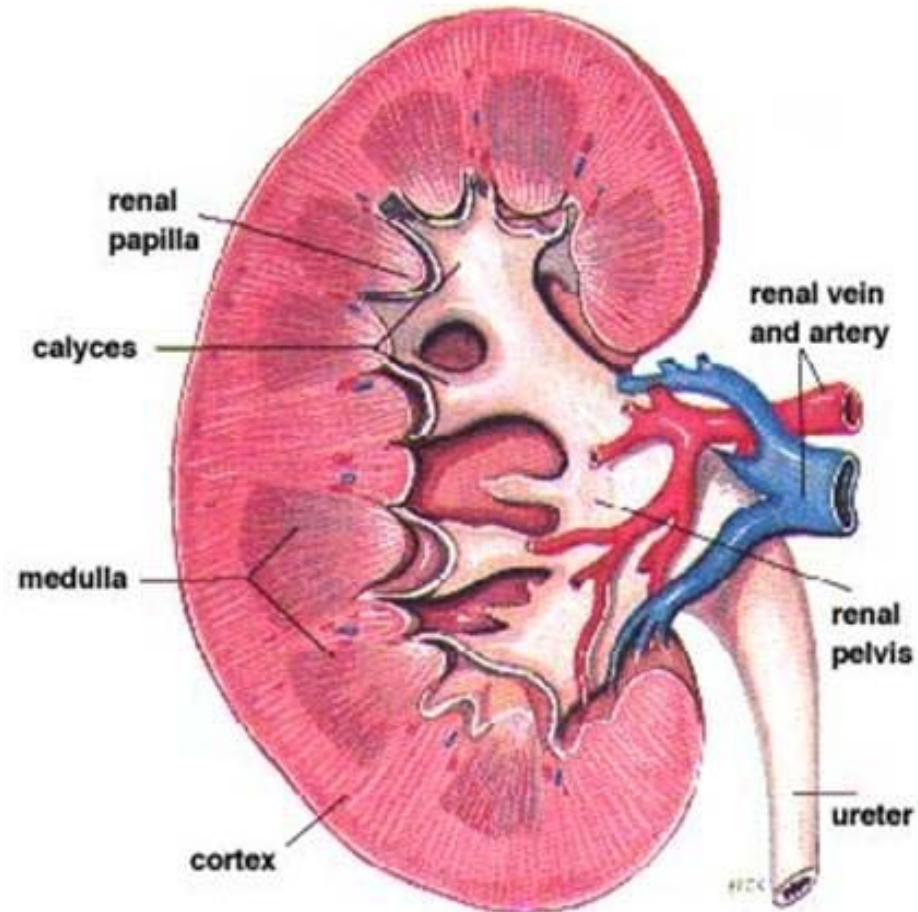
Function \neq Functional *Concept*

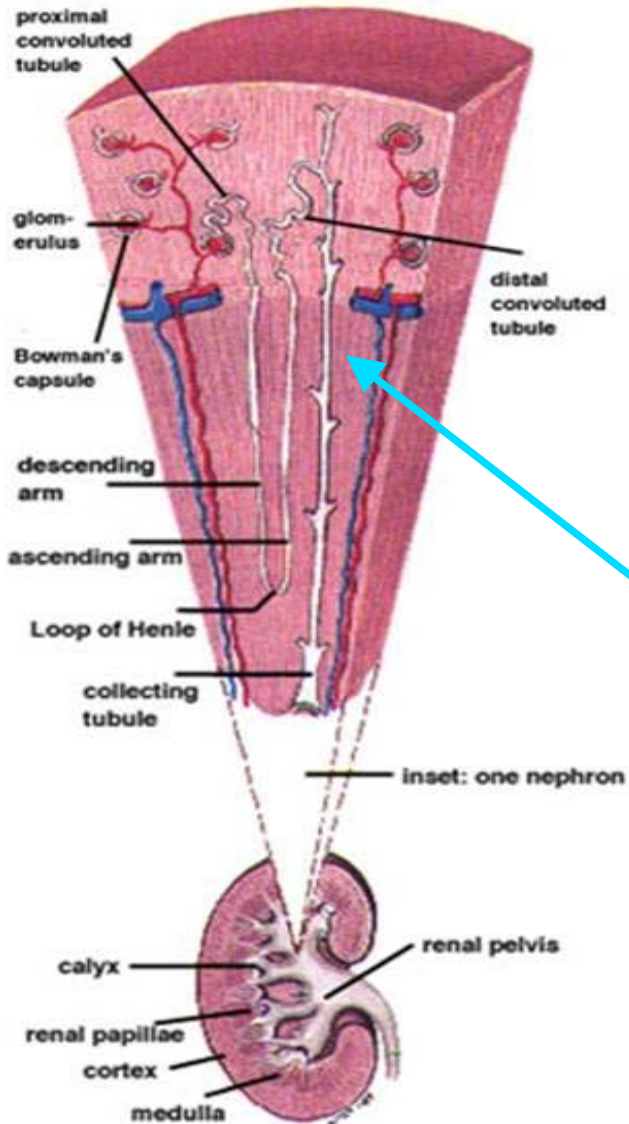
Function \neq *Realization* of a Function

The Kidney

From Andrew Lonie, University of Melbourne

Your entire blood volume flows through your kidneys every few minutes, leaving behind excess water, solutes and waste materials



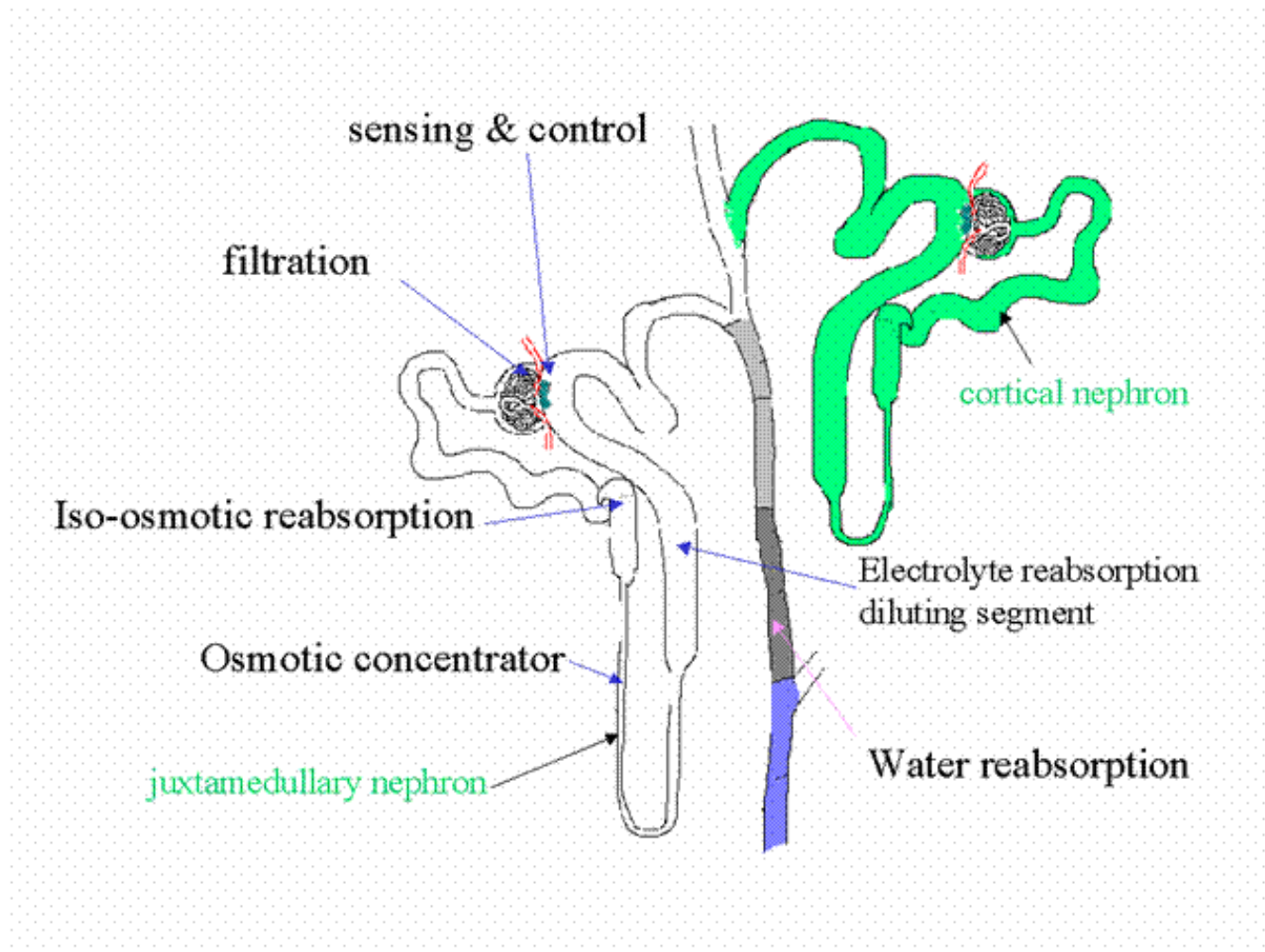


Essentially a massively parallel filter composed of 10^5 to 10^6 nephrons

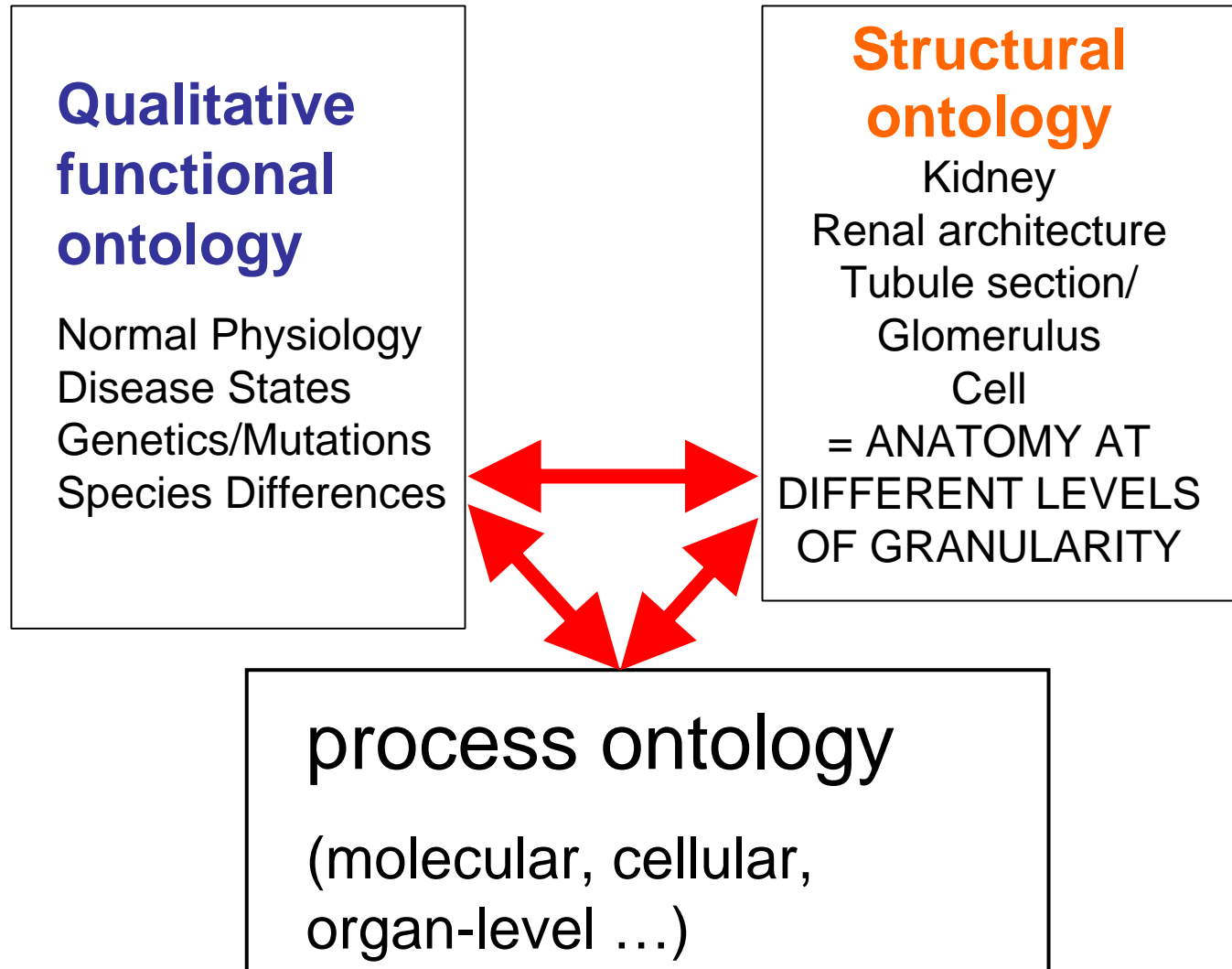
The *nephron* is the functional unit of the kidney

Each *nephron* is a very convoluted, long, thin tube lined with biochemical pumps

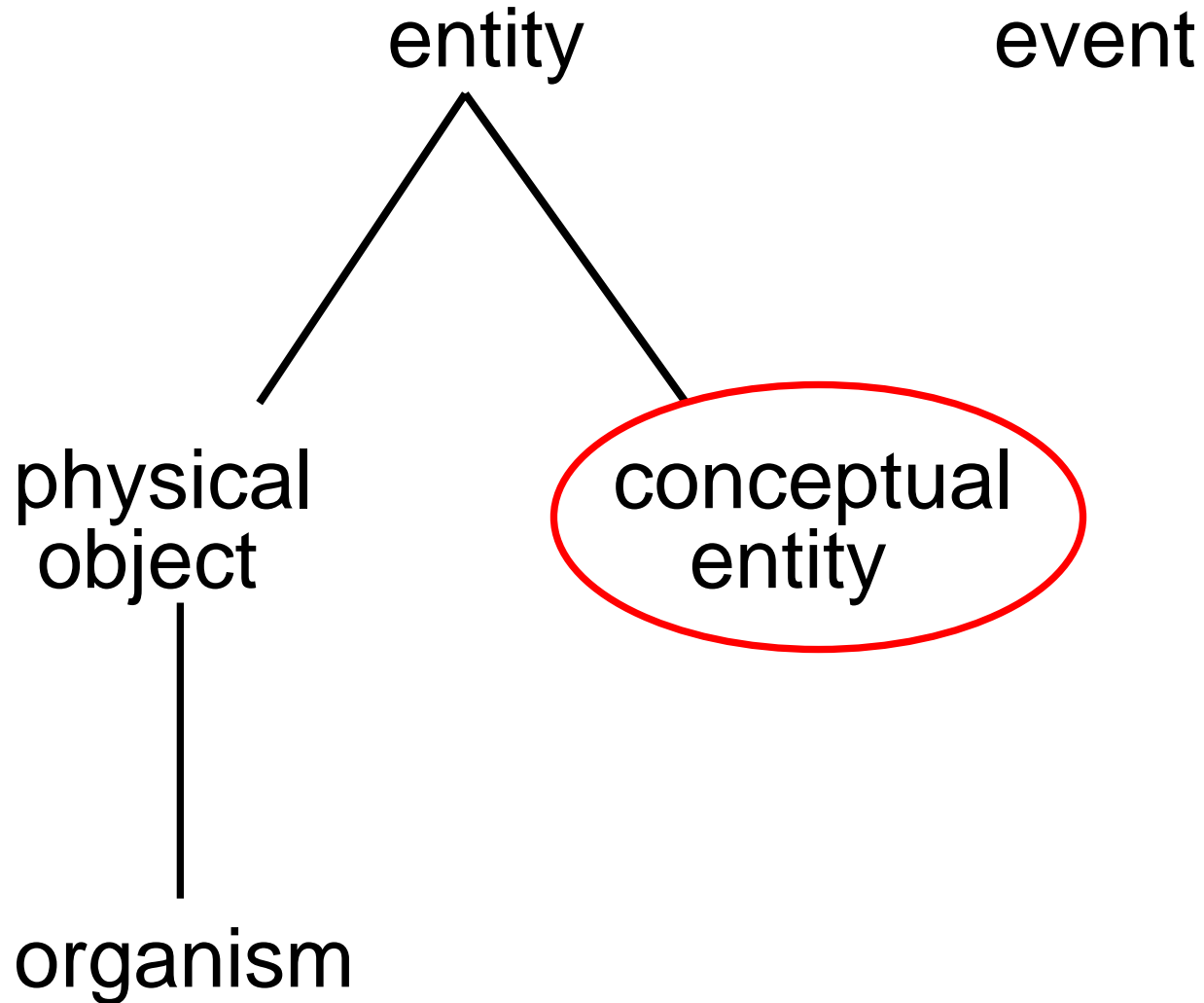
- 10 functional segments
- 15 different cell types



Structural and functional representation



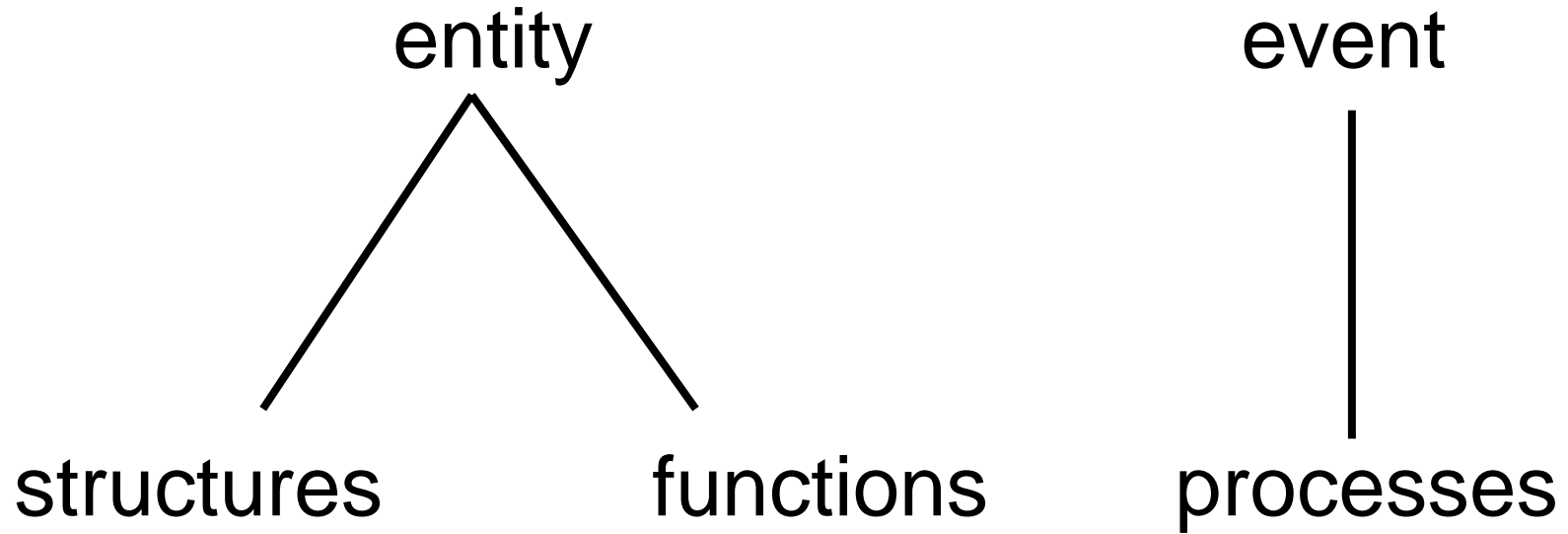
UMLS Semantic Network



Tri-Categorical Ontology present also in GO: The Gene Ontology

3 'ontologies' (large telephone directories)
of standardized designations for gene
functions and products

RUMLS Semantic Network



GO's three disjoint term hierarchies

the *cellular component* (***structure***) *ontology*,

e.g. flagellum, chromosome, cell

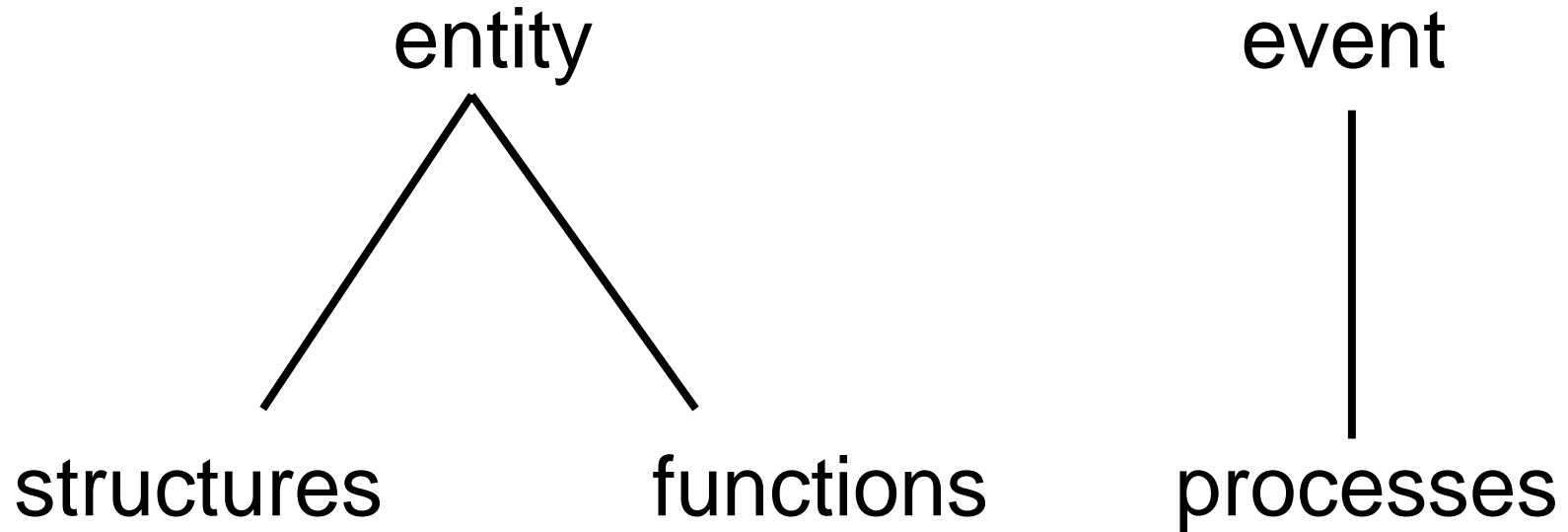
the *biological* ***process*** *ontology*,

e.g. glycolysis, death

the *molecular* ***function*** *ontology*,

e.g. ice nucleation, binding, protein stabilization

RUMLS Semantic Network



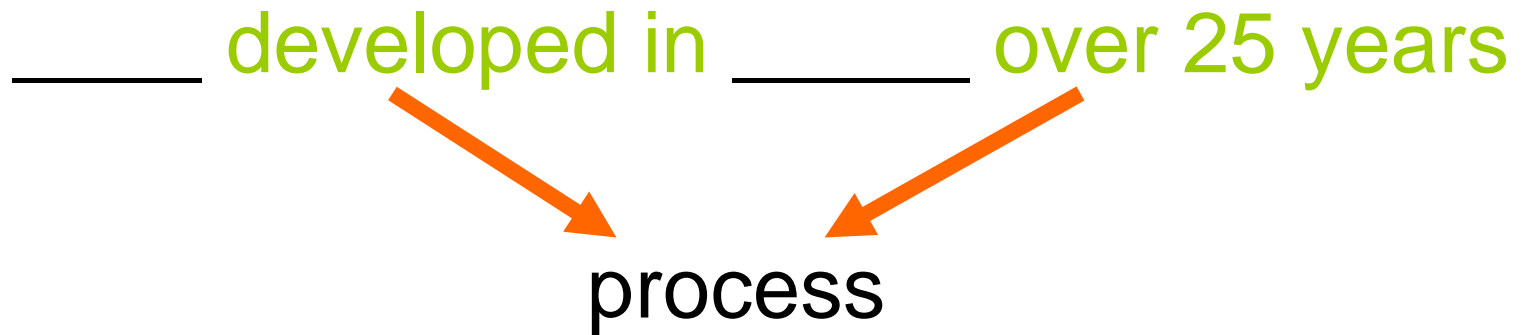
Functional Genomics

What does “Functional“ mean?

The Problem

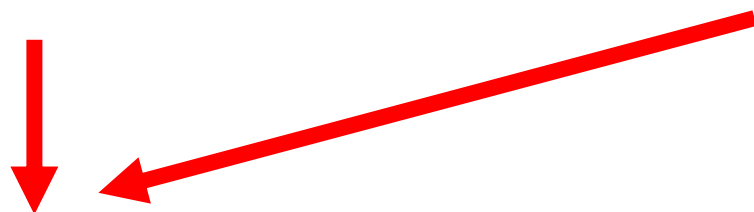
The tumor developed in John's lung over 25
years

The Problem



The Problem

The tumor developed in the lung over 25 years



substances

things

objects

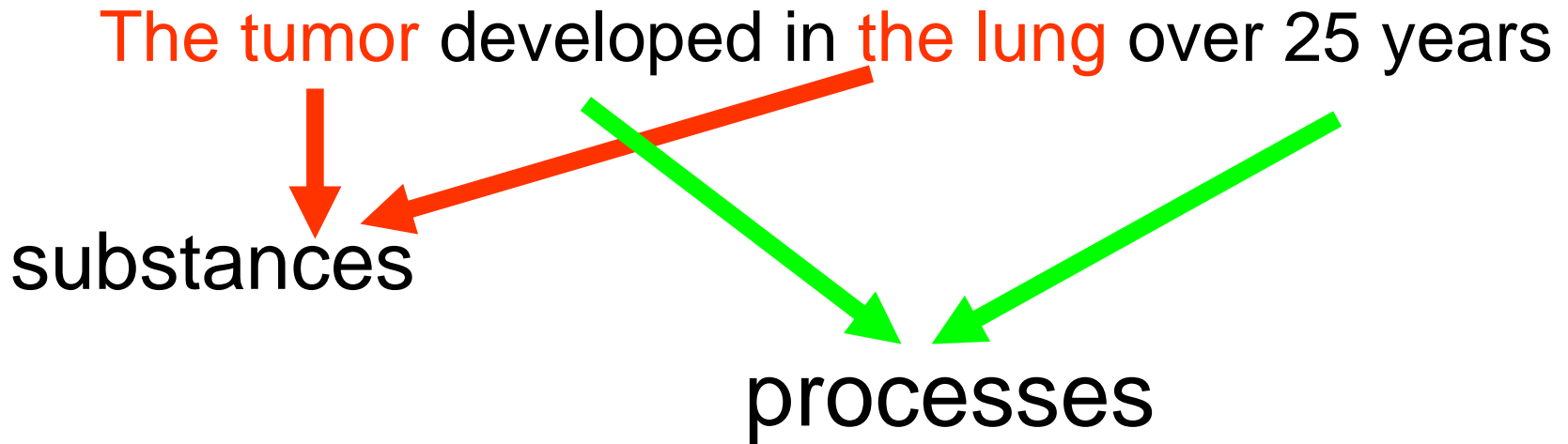
continuants

The Problem

The tumor developed in John's lung over 25 years

PARTHOOD NOT DETERMINATE

The Problem

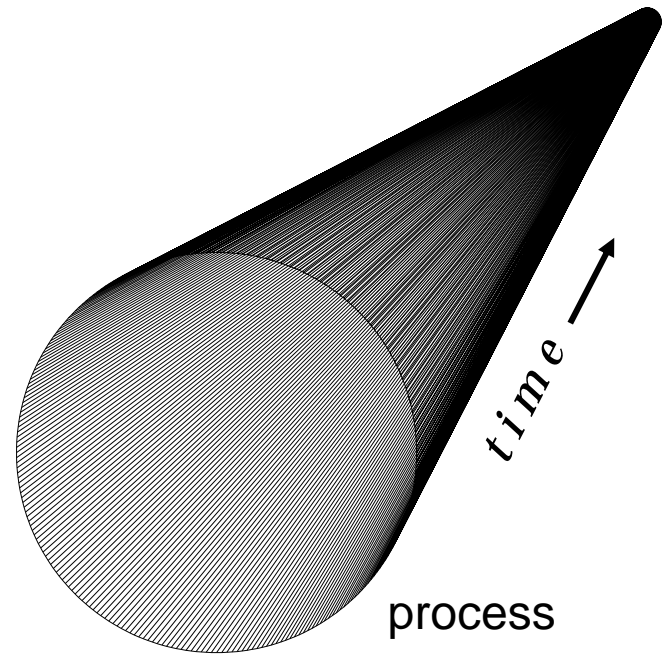


GLUING THESE TOGETHER YIELDS
ONTOLOGICAL MONSTERS

Substances and processes exist in time in different ways



substance



SNAP vs SPAN



Endurants vs perdurants

Continuant vs occurrents

In preparing an inventory of reality
we keep track of these two different kinds
of entities in two different ways

Fourdimensionalism

- only processes exist
- time is just another dimension, analogous to the three spatial dimensions
- substances are analyzed away as worms/fibers within the four-dimensional plenum

There are no substances

Bill Clinton does not exist

Rather: there exists within the four-dimensional plenum a continuous succession of processes which are similar in a Billclintonizing way

Fourdimensionalism (the SPAN perspective) is right in everything it says

But incomplete

Need for Two Orthogonal, Complementary Perspectives

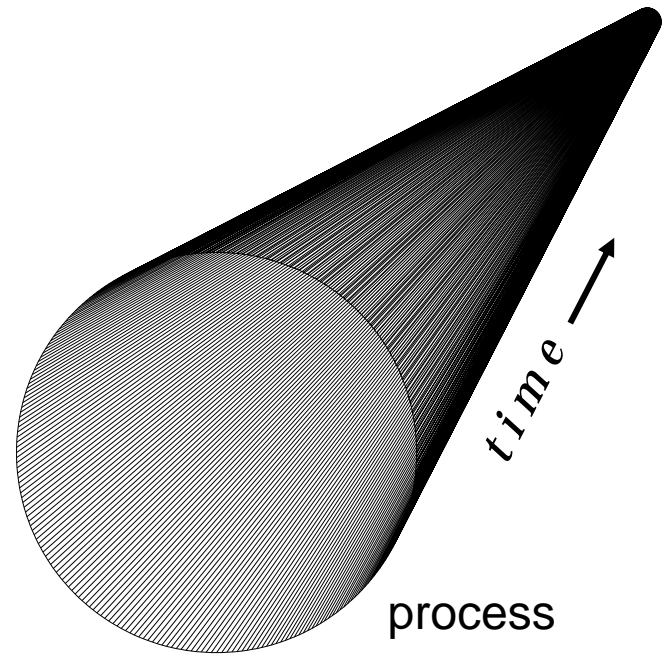
SNAP and SPAN

Snapshot ontology



substance

Video ontology



SNAP and SPAN

stocks and flows

commodities and services

product and process

anatomy and physiology

SNAP and SPAN

SNAP entities

- have continuous existence in time
- preserve their identity through change
- exist *in toto* if they exist at all

SPAN entities

- have temporal parts
- unfold themselves phase by phase
- exist only in their phases/stages

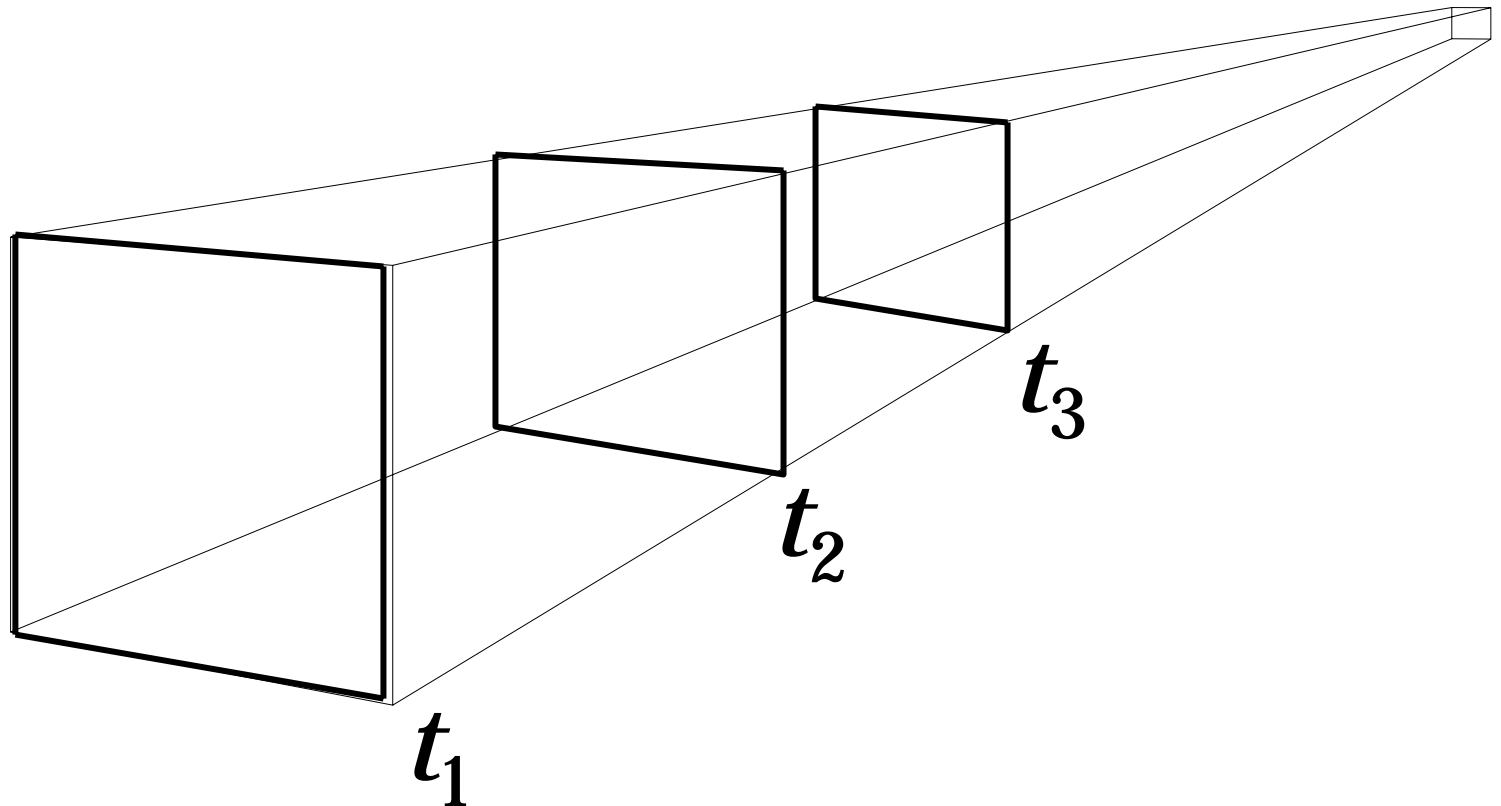
***You* are a substance**

Your *life* is a process

***You* are 3-dimensional**

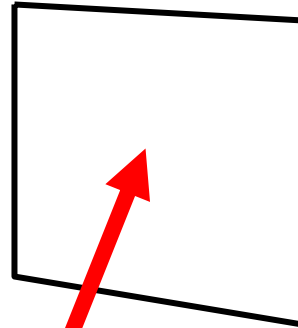
Your *life* is 4-dimensional

Many SNAP Ontologies



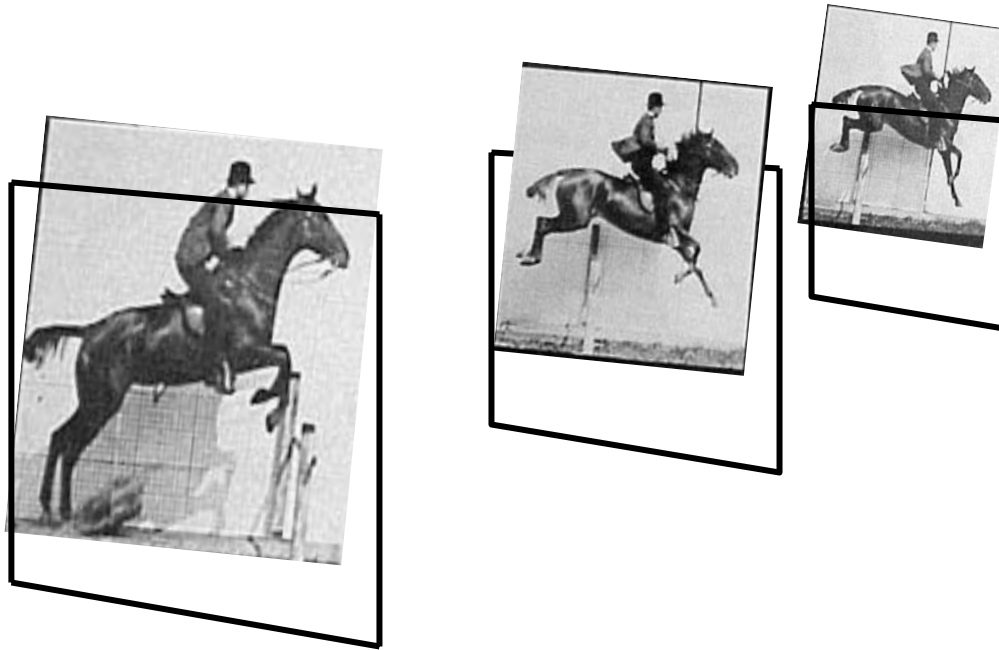
here time exists **outside** the ontology,
as an *index* or *time-stamp*

each SNAP_i section through reality



includes everything which *exists*
(present tense)

mereology works without restriction
(parthood is everywhere determinate) in
every SNAP_i ontology



Three kinds of SNAP entities

1. SNAP Independent Entities (you and me)
2. SNAP Dependent Entities
3. Spatial regions

SNAP dependent entities

States, powers, qualities, functions,
dispositions, plans, shapes, liabilities,
propensities...

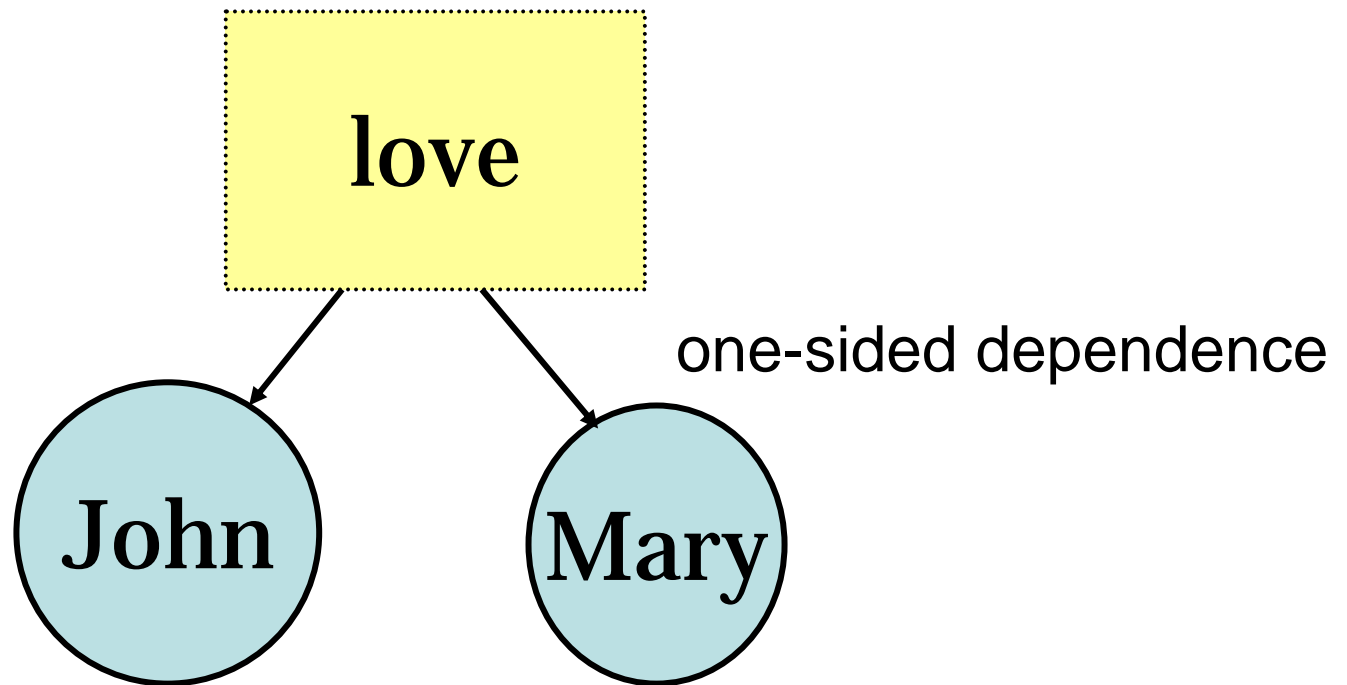
SNAP dependent entities:

one-place:

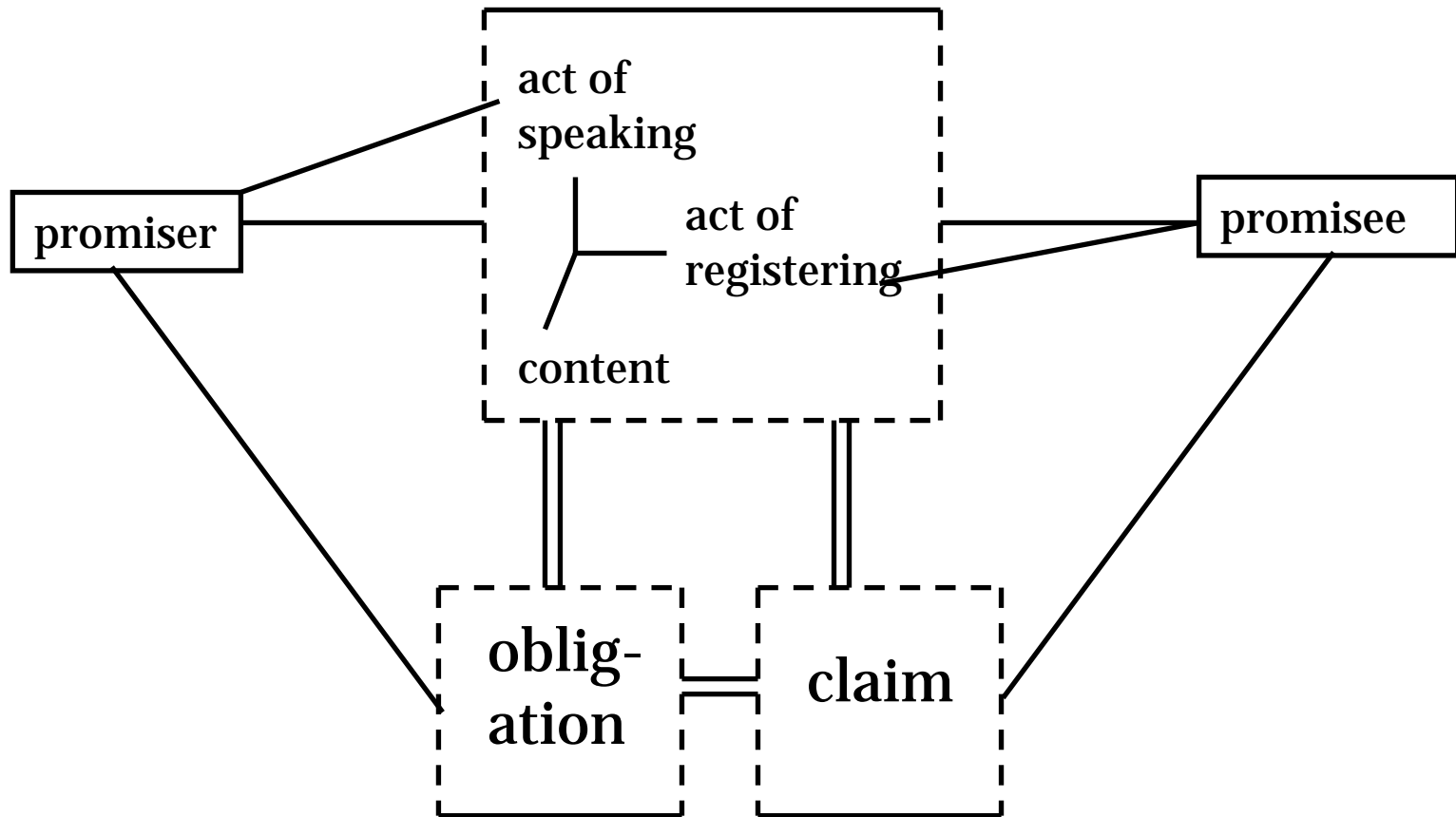
your temperature, color, height
my knowledge of French
the whiteness of this cheese
the warmth of this stone
the fragility of this glass

relational SNAP dependent entities

stand in relations of one-sided dependence to a plurality of substances simultaneously



A Window on Reality



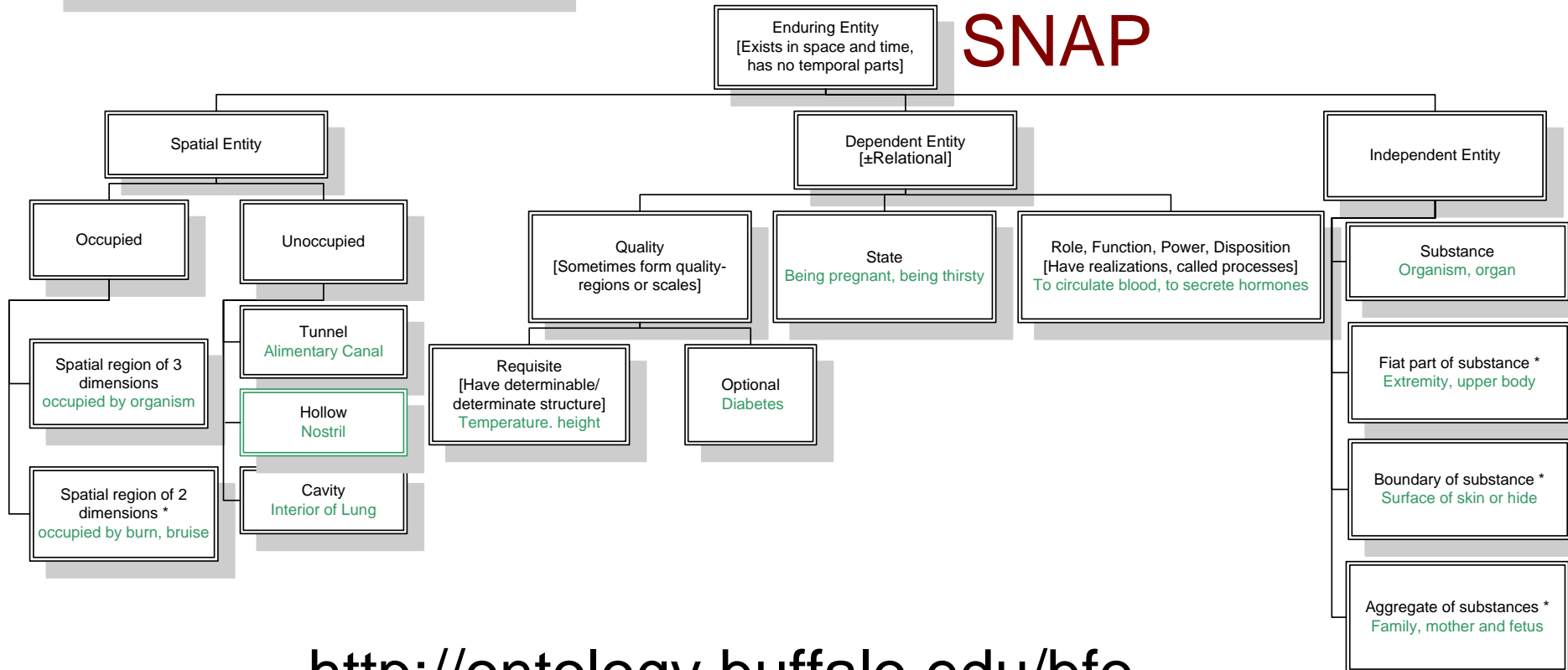
Spatial regions + sites (contexts, niches, environments)

Organism species *evolve into* environments

Domesticated spatial regions: rooms, nostrils, your alimentary tract

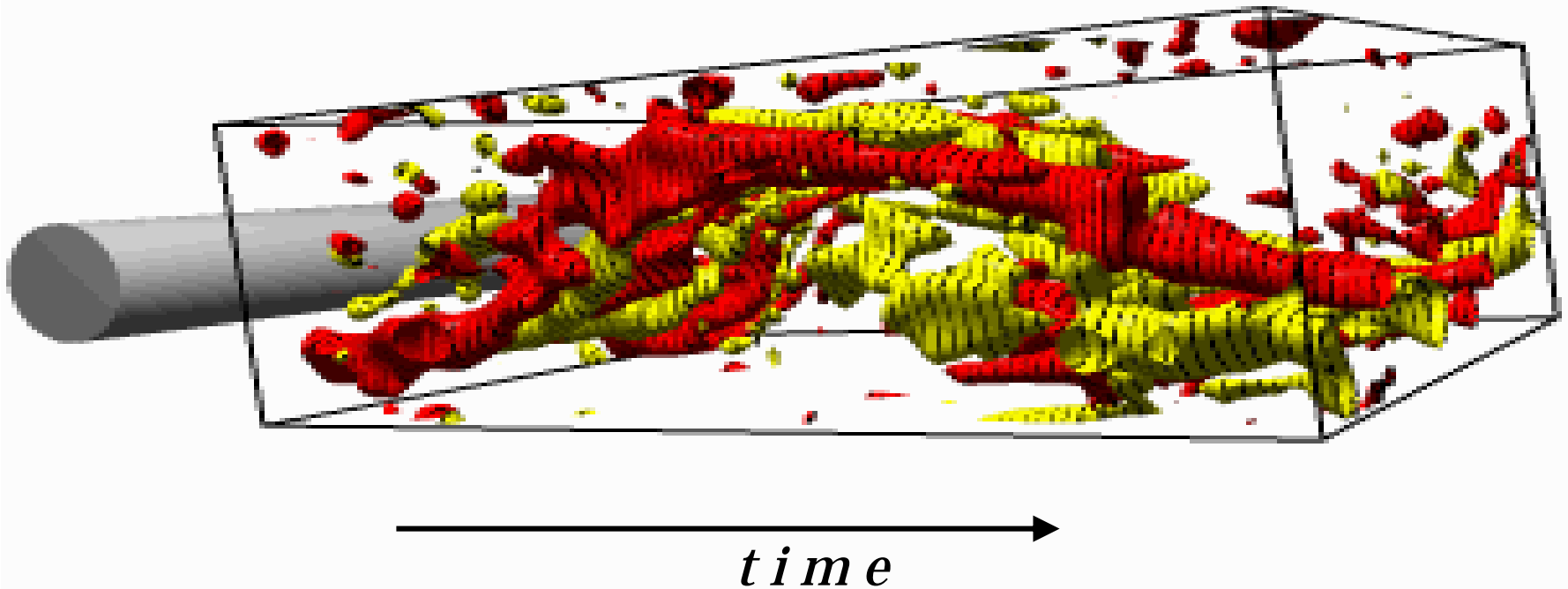
Fiat spatial regions: JFK designated airspace

SNAP: Entities existing *in toto* at a time

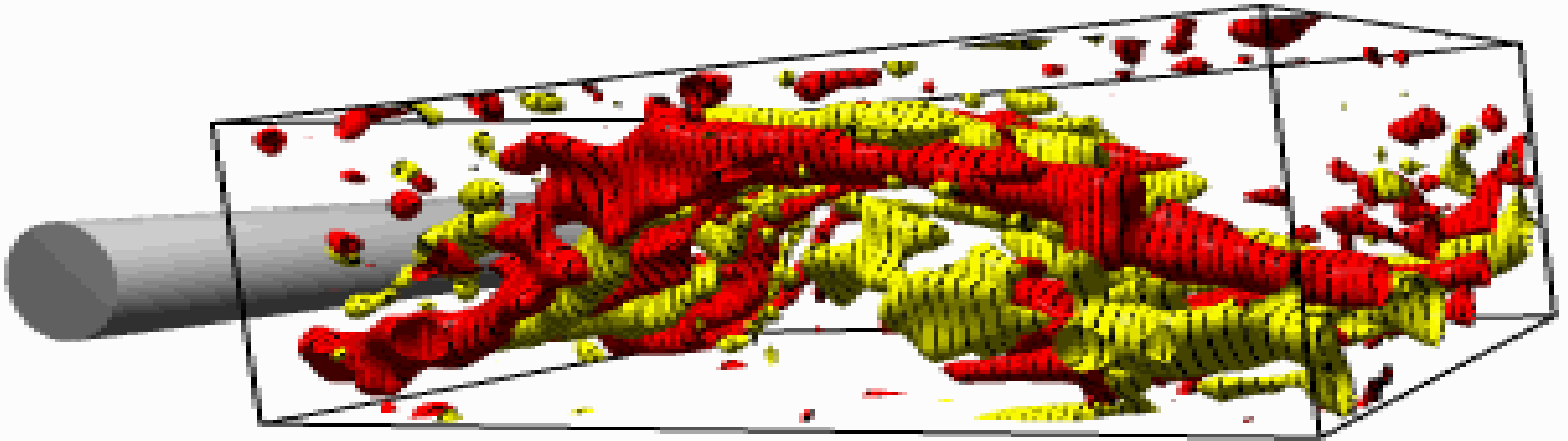


<http://ontology.buffalo.edu/bfo>

The SPAN Ontology



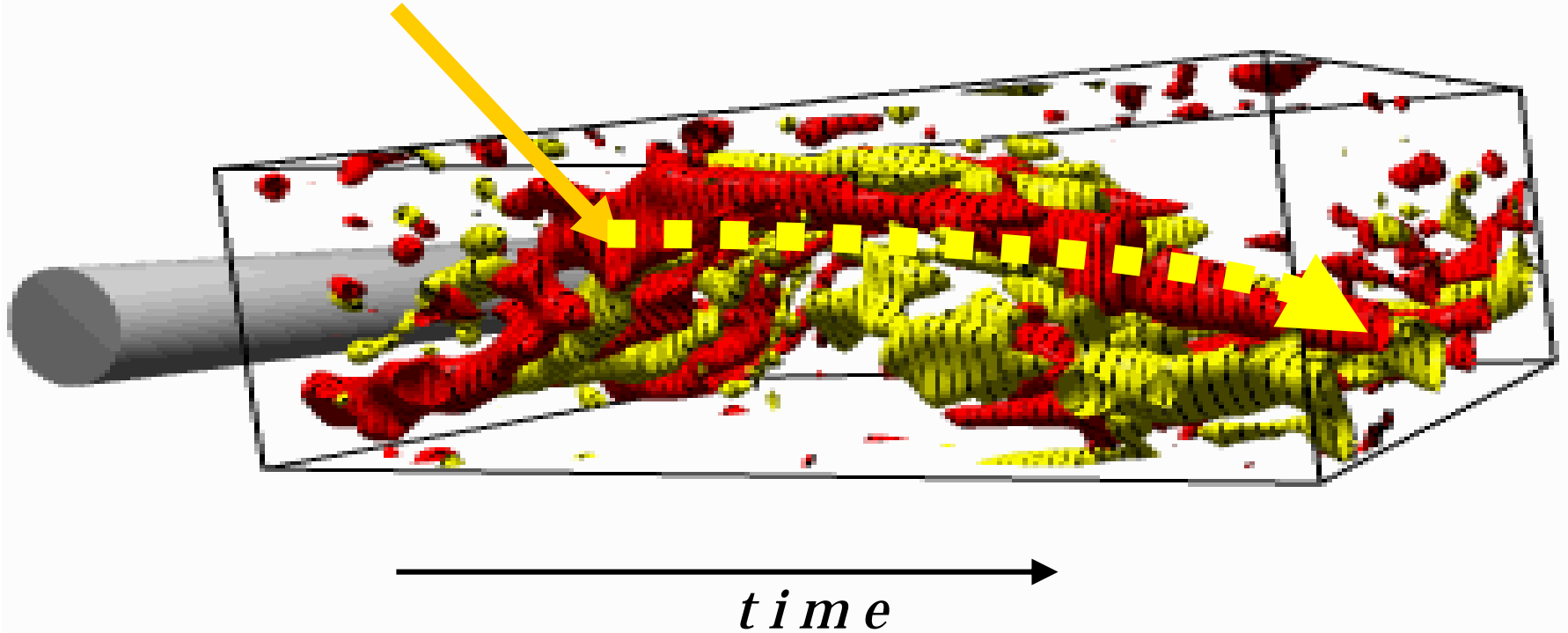
The SPAN ontology



here time exists as part of the domain of the ontology

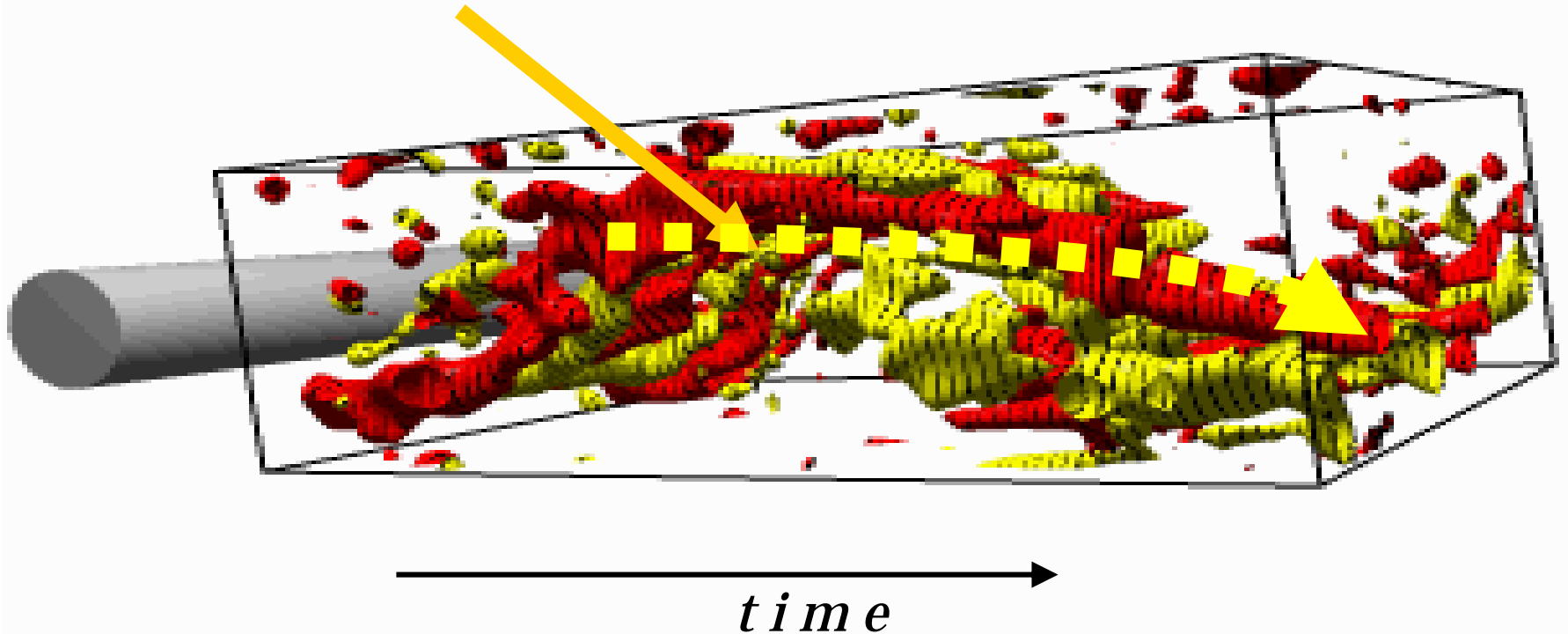
mereology works without restriction
everywhere here

clinical trial



mereology works without restriction
everywhere here

course of a disease



Processes, too, are dependent on substances

One-place vs. relational processes

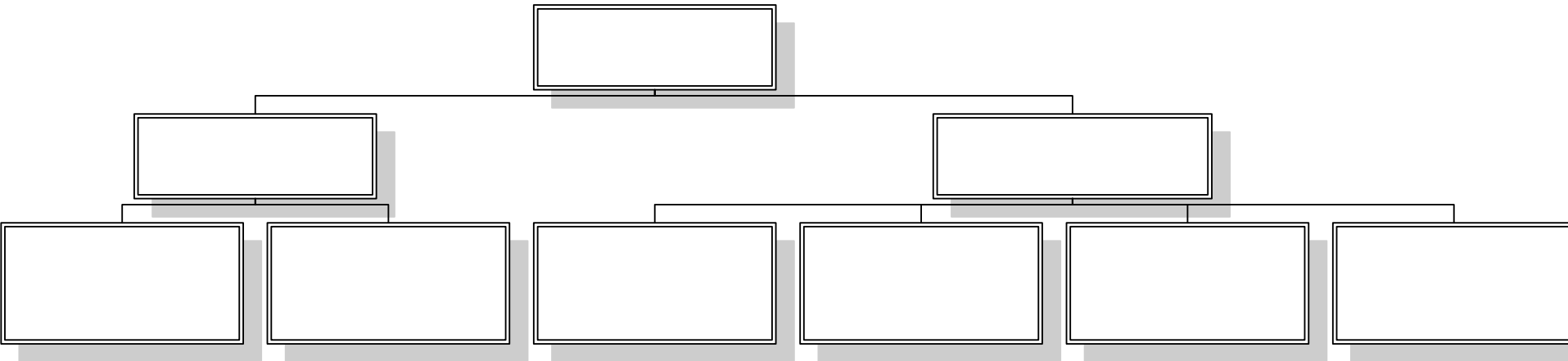
One-place processes:
your getting warmer
your getting hungrier

Relational processes

kissings, thumpings, conversations,
dancings, promisings, infectings, bindings

join their carriers together into *collectives*
of greater or lesser duration

SPAN: Entities extended in time



<http://ontology.buffalo.edu/bfo>

Two kinds of SPAN entities

1. Processes (including events: process-boundaries, settings)
2. Spatio-temporal regions

How do you know whether an entity is SNAP or SPAN?



problem cases

forest fire

hurricane Maria

traffic jam

ocean wave

disease

anthrax epidemic

forest fire:

a process

a pack of monkeys jumping from tree to tree
and eating up the trees as they go

the Olympic flame:

a process or a thing?

(anthrax spores are little monkeys)

A disease

The course/history of a disease

The Epidemic (SNAP)

The *Spread* of an Epidemic (SPAN)

Material examples:

performance of a symphony

projection of a film

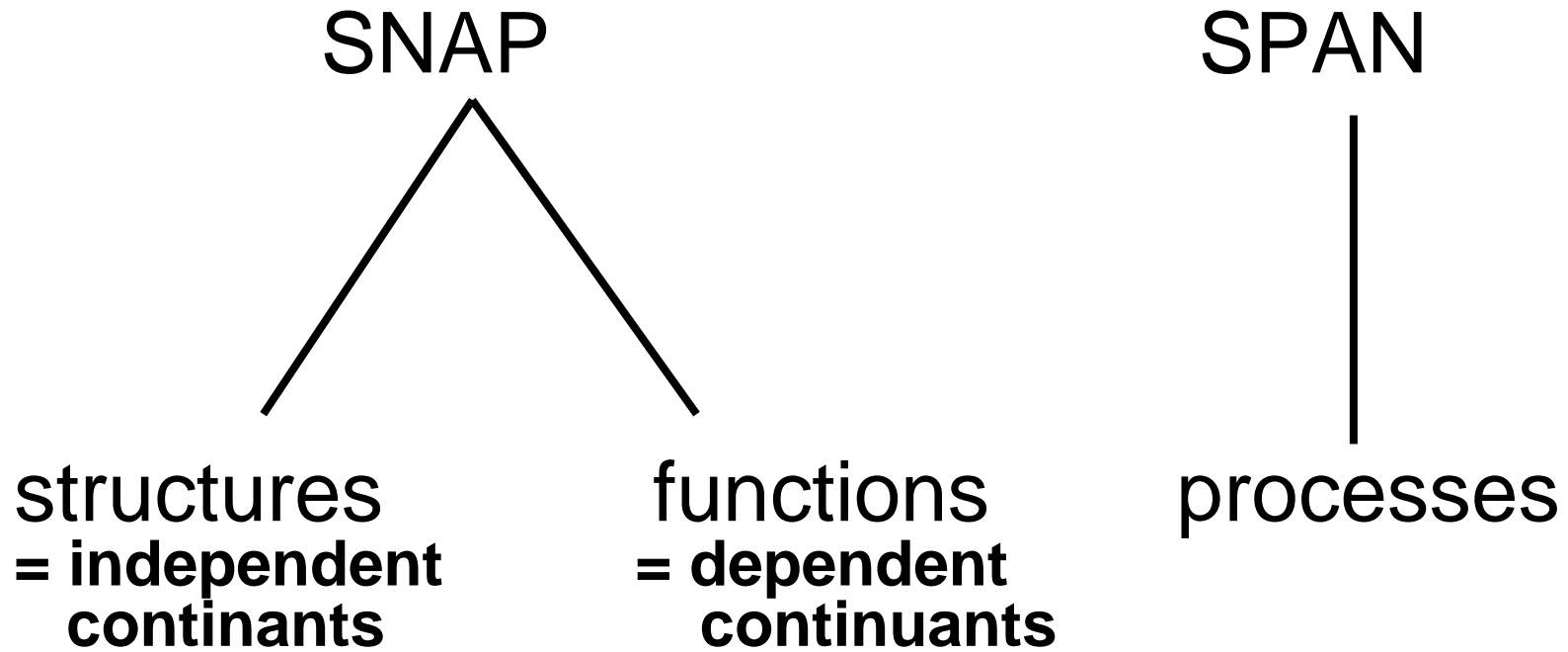
expression of an emotion

utterance of a sentence

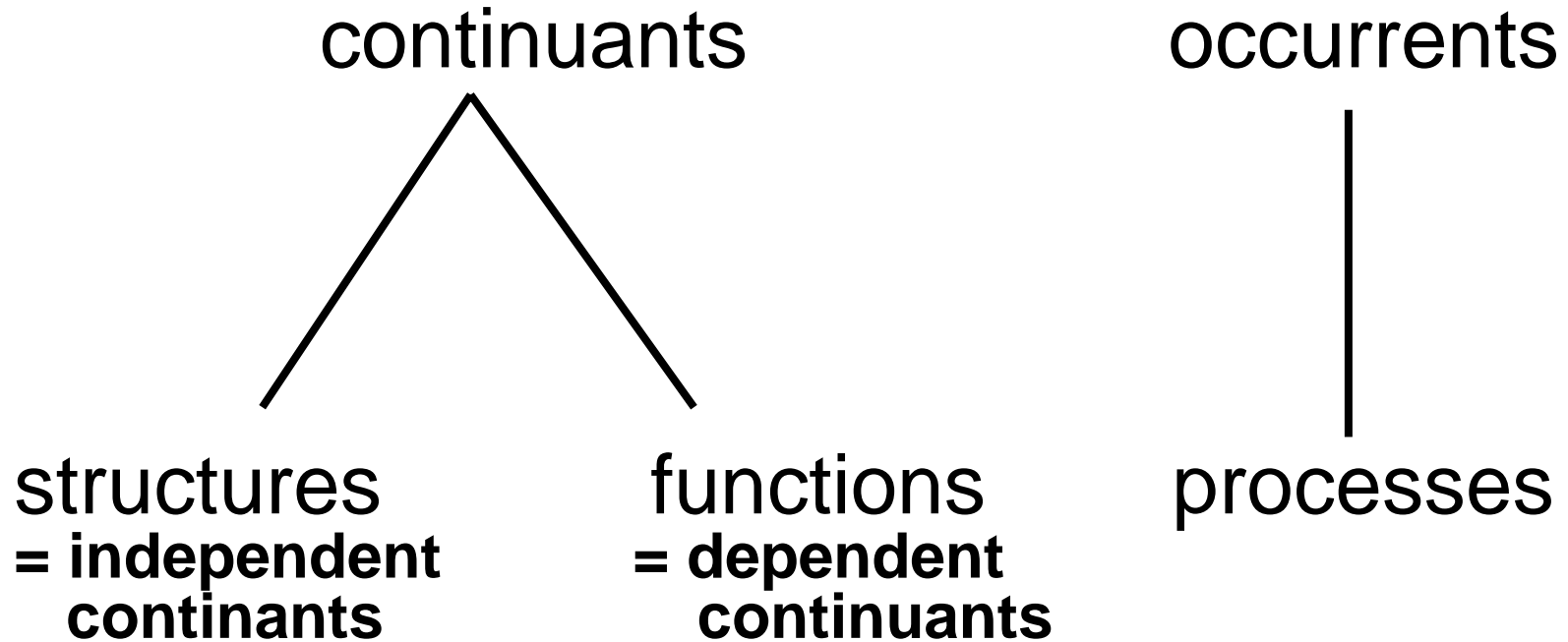
application of a therapy

increase of temperature

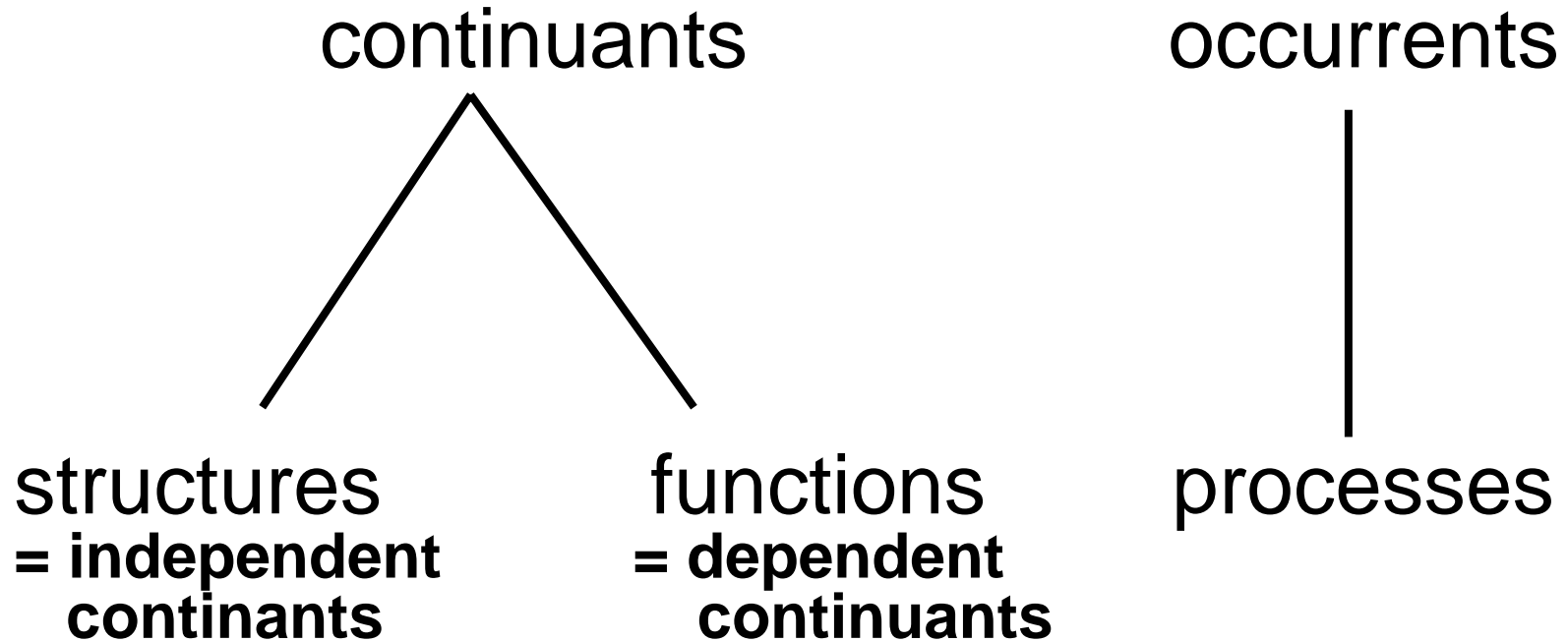
The Tri-Categorical Ontology



The Tri-Categorical Ontology



A Window on Reality



Entities in all three categories exist both as universals and as instances (as tokens and as types)

The function of *your* heart is: to pump blood
The function of *my* heart is: to pump blood

Functions are continuants

The function of your heart begins to exist with the beginning to exist of your heart, and continues to exist, self-identically, until (roughly) your heart ceases to be able to respond if stimulated by your sympathetic and parasympathetic nervous systems

Functions have bearers

The bearer of the function of your heart is:
your heart.

Functions are dependent continuants.

The bearers of functions are independent
continuants (hearts, screwdrivers ...)

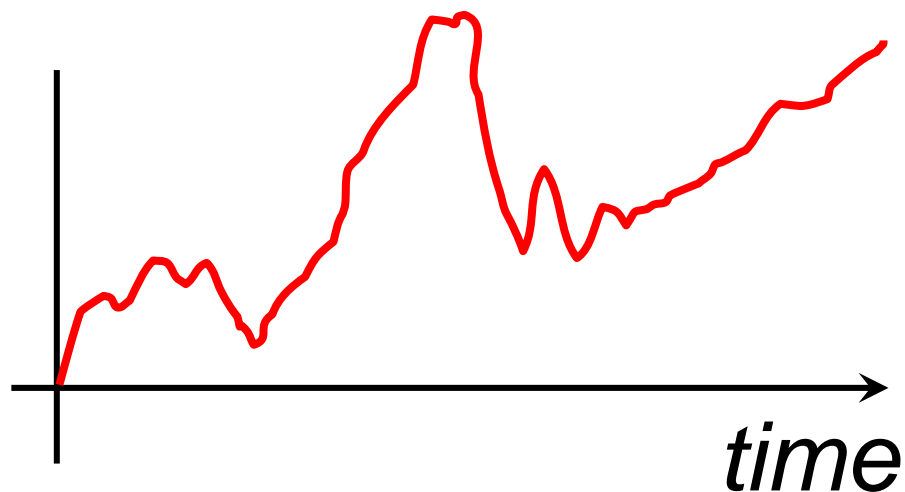
Functions are *realized*

in special sorts of processes called *functionings*

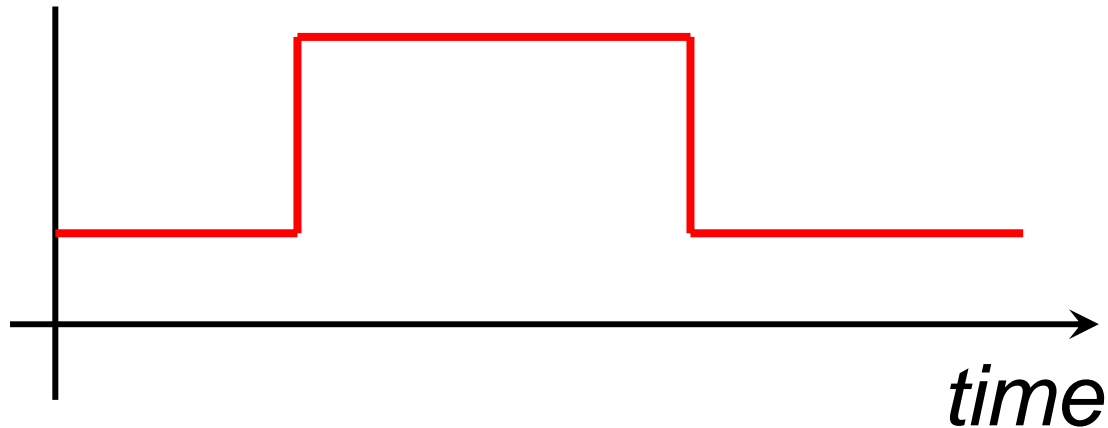
The processes taking place in or involving entities which are bearers of functions can be divided into two types: those which are realizations of their functions (also called *functionings*) and processes of other types (junk processes)

Functions can exist even when
they are not being realized

Processes (realizations) are
causal-energetic



Functions are historical (they exist
in time)
but they are also quasi-Platonic



Compare the relation between
temperature,

which is quasi-Platonic
and Brownian motion,
which is causal-energetic

Your temperature at t vs. the value of
your temperature at t

Your temperature is quasi-Platonic

Your temperature as a *determinable* is identical from one moment of your existence to the next

This determinable takes on different *values* at different times

Biological functions are always *constituent functions*

If X has a biological function then there is some Y of which X is a part and X's functioning is in the service of / for the benefit of Y

Functions are beneficial

If an organism has a constituent part X , and if X is the bearer of a function Z , then those processes which are the realizations of the function Z are (in normal circumstances) beneficial to the organism (\cong such as to sustain the organism in existence)

Functional Genomics

= study of what the genes contribute to the organism in the way of survival
(Bad genes do not *have* functions)

Every oncogene is a proto-oncogene

There is functioning, poor functioning,
malfunctioning

There is not having a function at all (and this can be either neutral in the stakes of beneficiality or also positively malignant)

Does this sense of 'function'
correspond to the way biologists talk?

Clinical vs. biological sense of 'function'

Biologists sometimes talk about biological structures 'gaining function' (= being switched on) even where their functioning is *not* beneficial

Are all functions associated with *mal*functionings?

Health – Disease – Illness

Diseased organ = organ
predisposed to malfunction
Its functioning is defective



Part Four: Definitions of Health

World Health Organization:

Health is the state of psychological and physical well-being of humans

Biostatistical Theory

Christopher Boorse

Health is conformity to normal species design (as statistically determined).

Abnormally healthy people are therefore in fact sick (?)

The Vital Goal Theory

Lennart Nordenfelt

Health is the bodily and mental state of a person which is such that he or she has an ability to realize vital goals, given standard or otherwise accepted circumstances.

Disease is a state or process of a person's body or mind that tends to cause ill health in the bearer.

The Ordinary Action Theory

K.W.M. Fulford

Health is being able to do what one ordinarily does in the absence of obstruction or opposition.

Illness is failing to do what one ordinarily does in the absence of obstruction or opposition.

The Abnormality Theory

Lawrie Reznek

Disease is a state of a person which issues in abnormal behavior;

something is an abnormal bodily or mental process if it does standard members of the human species some harm in standard circumstances;

something does a person harm if it makes the person less able to live a good or worthwhile life.

Problems with standard definitions

1. Circularity
2. Make health a social construction
3. Make health a Cambridge property
4. Confuse state and process, disposition and realization, potentiality and actuality
5. Do not apply to organisms other than humans

Circularity

Health is ... well-being

Health is ... being able to live a good or worthwhile life

Disease is a state ... that tends to cause ill health in the bearer

Health a social construction

Health is ...the ability to realize vital goals,
given standard or otherwise accepted
circumstances

Illness = what the insurance company will
pay to treat

Health a Cambridge Property

Health is conformity to normal species design (as statistically determined).

If everyone in society becomes sicker and you remain the same, then *you* are the person who becomes unhealthy

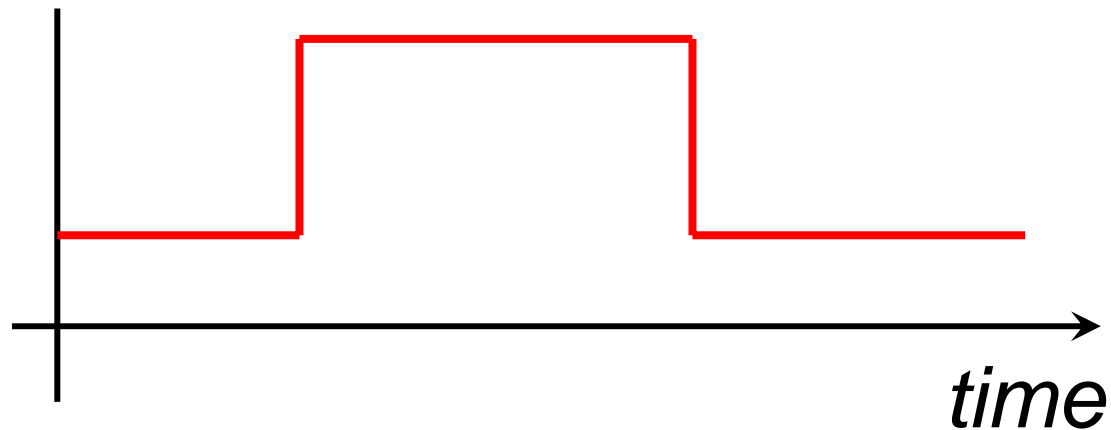
Ontology of Disease

Diseases are, like functions, dependent continuants

They are states or conditions which endure for a certain time and have a **course** or **history**, which is an occurrent

Disease tokens, like roles and functions, do not change through their existence over time

Diseases are both historical and quasi-Platonic



Functions

This is a screwdriver

This is a good screwdriver

This is a broken screwdriver

This is a heart

This is a healthy heart

This is an unhealthy heart

Functions are associated with certain characteristic *process shapes*

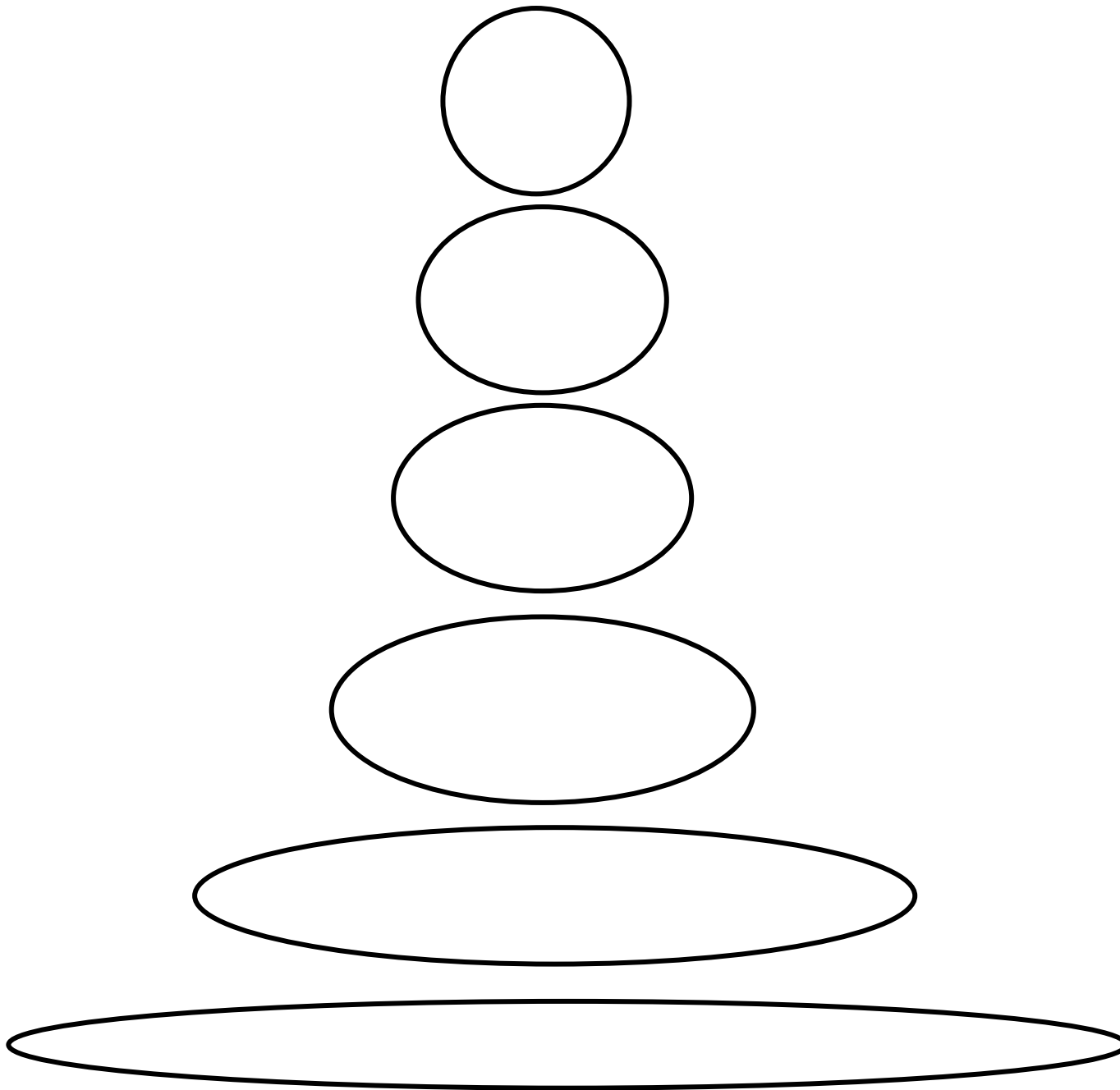
Screwdriver: rotates and simultaneously moves forward simultaneously transferring torque from hand and arm to screw

Heart: performs a contracting movement inwards and an expanding movement outwards simultaneously transferring hydraulic pressure to the blood stored within its chambers

For each function

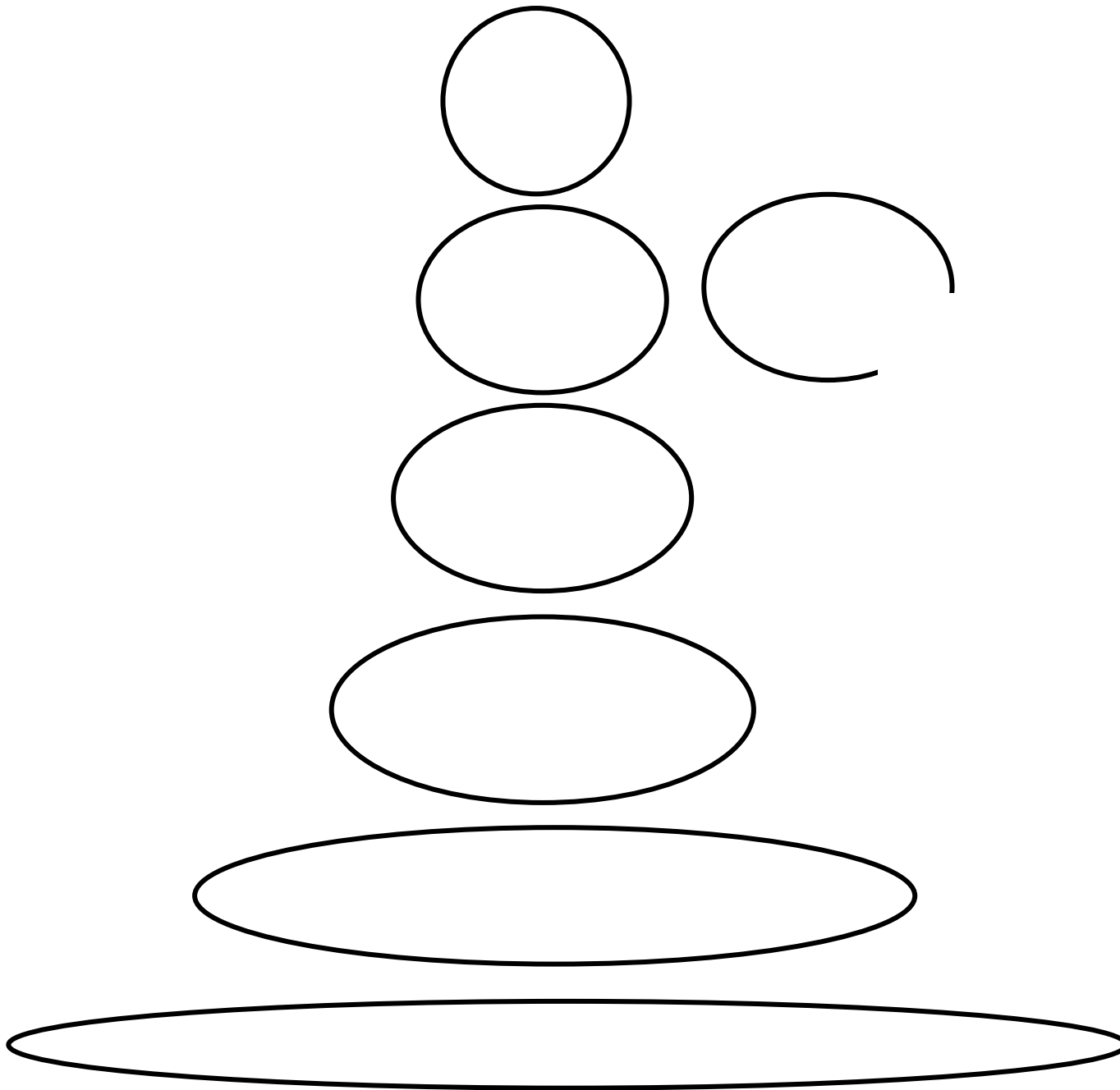
there is an associated *family* of (four-dimensional) process shapes, organized around a core of prototypical process shapes representing good functioning

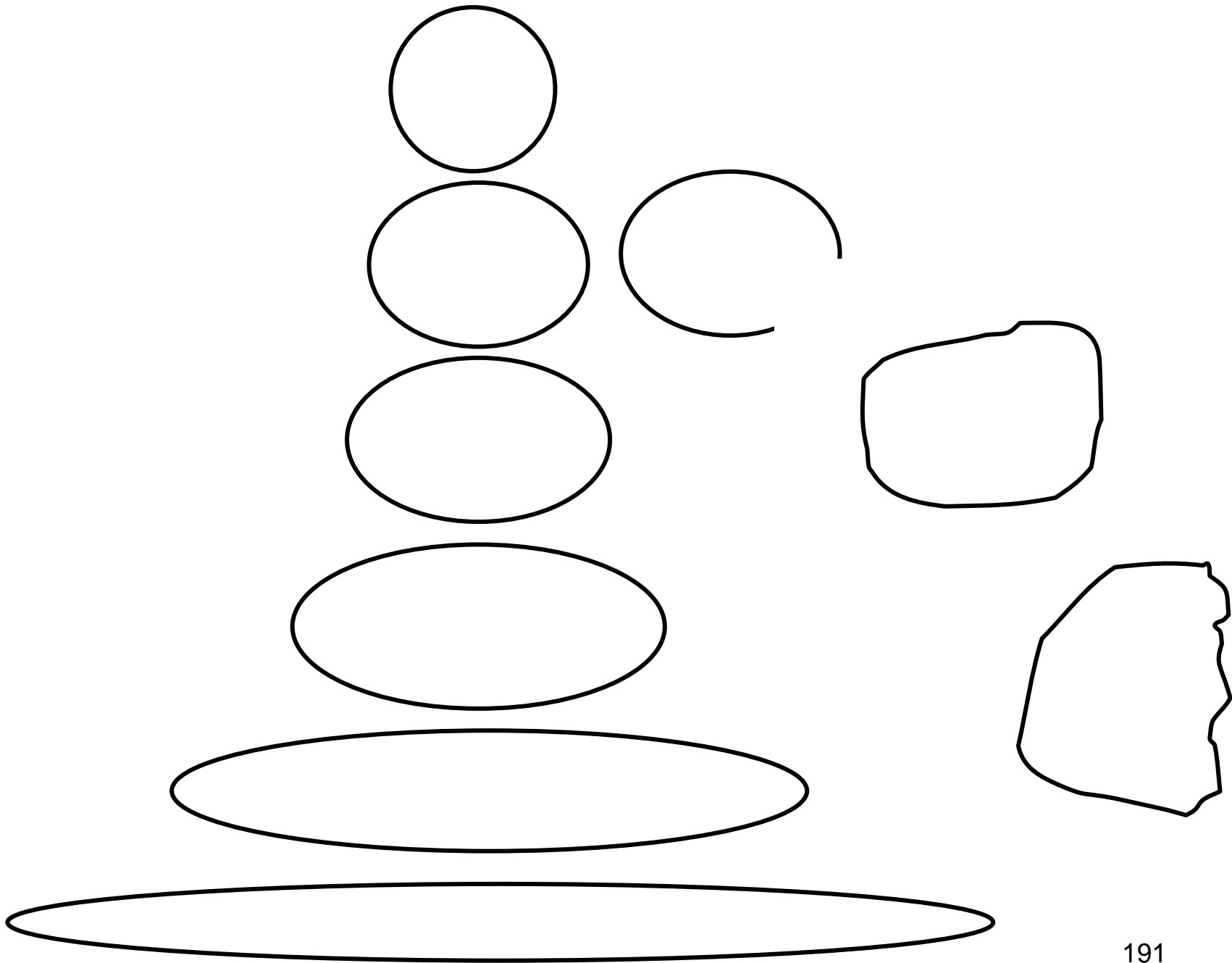
The prototypes play a role analogous to the standard meter rule in the organization of those one-dimensional shapes we call lengths



Outside the core

are process shapes which are not instances
of functioning at all

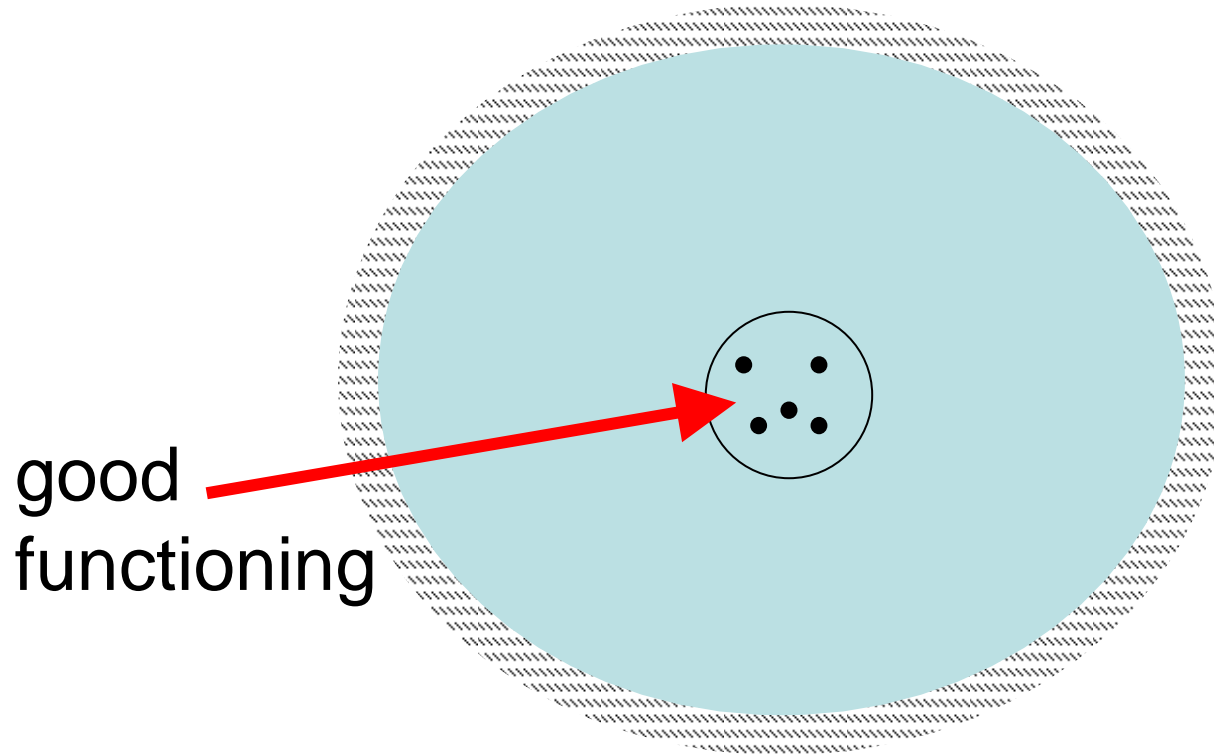




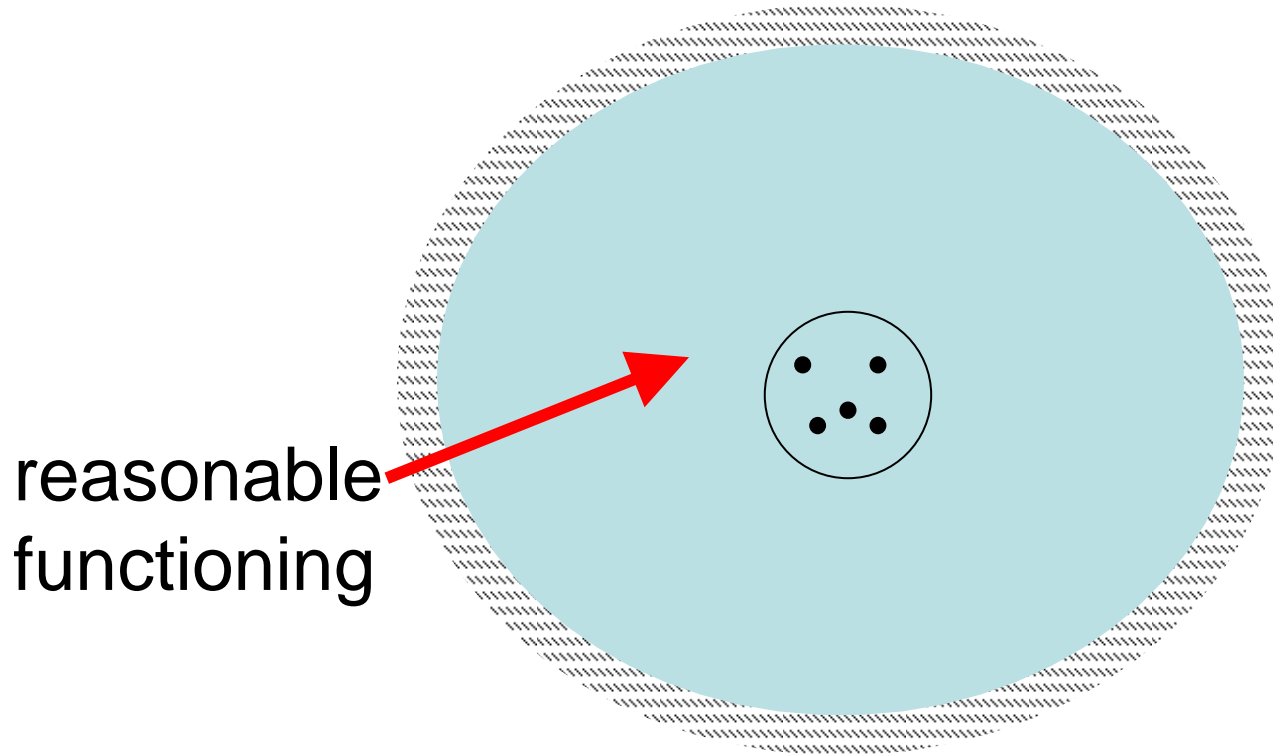
Normal functioning

= functioning (realizing a four-dimensional shape) at or close to the prototype

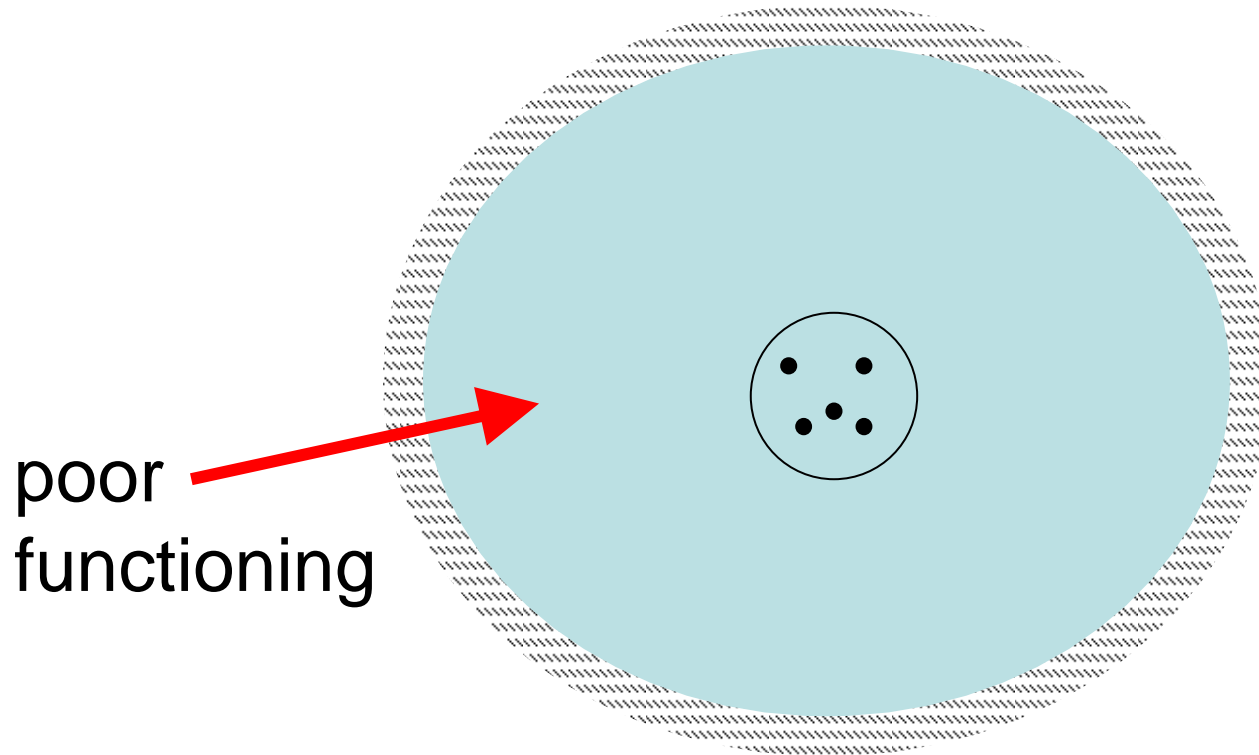
Prototypes



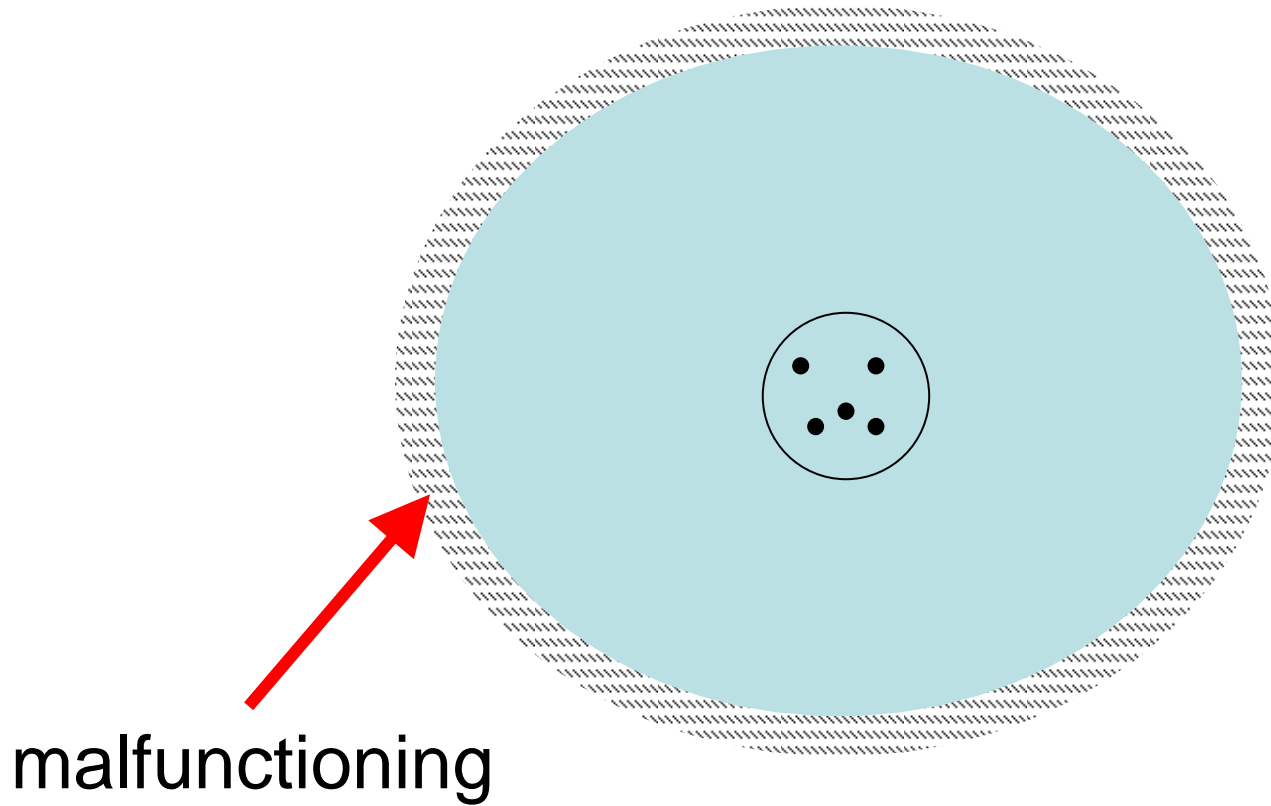
Prototypes



Poor functioning

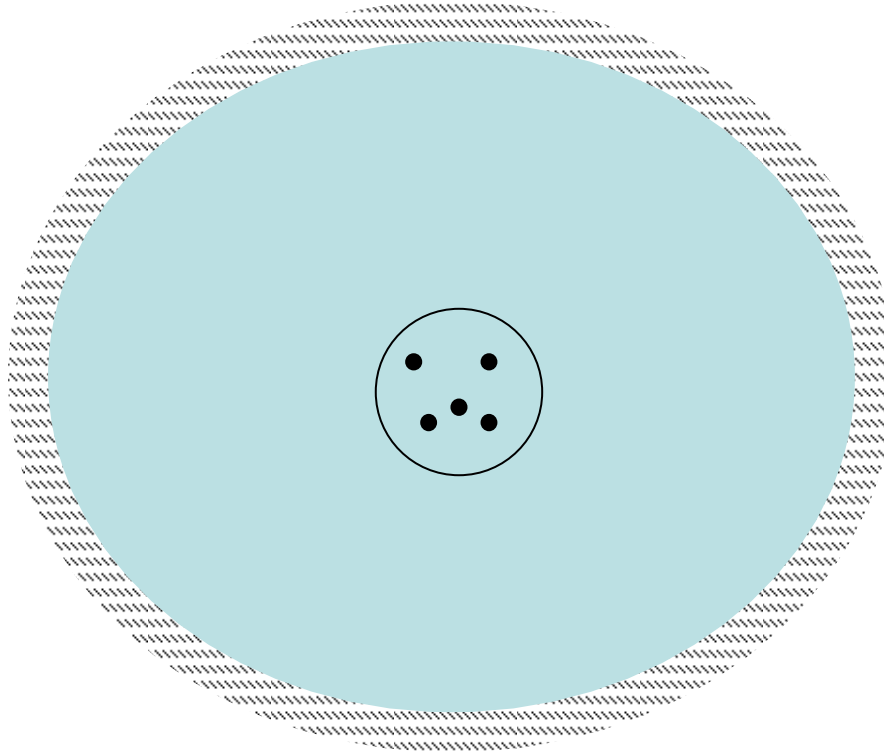


Malfunctioning



Death?

not
functioning
at all



Not functioning at all

leads to death *modulo* internal factors:

- plasticity

- redundancy (2 kidneys)

- criticality of the system involved

external factors:

- prosthesis (dialysis machines, oxygen tent)

- special environments

- assistance from other organisms

Relevance of Millikan

Prototypical functioning = exercising what Millikan calls 'proper function'

(defined historically)

X is the proper function of Y means: 1) Y performs X and 2) Y exists because its predecessors' performing the function X is responsible for my existing

It is not the function of the nose to hold up spectacles *because this was not selected for*

Millikan = backward looking,
focused on whole species

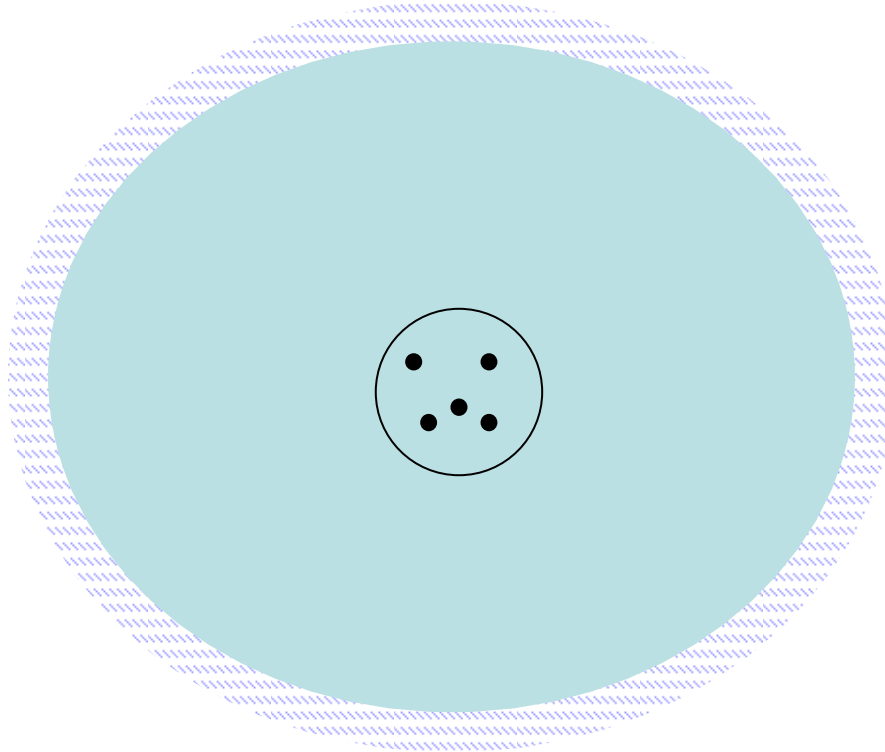
This account = forward looking, focused on
single organism

X has a function = (1) X's functioning is
beneficial to the organism of which X is a
part

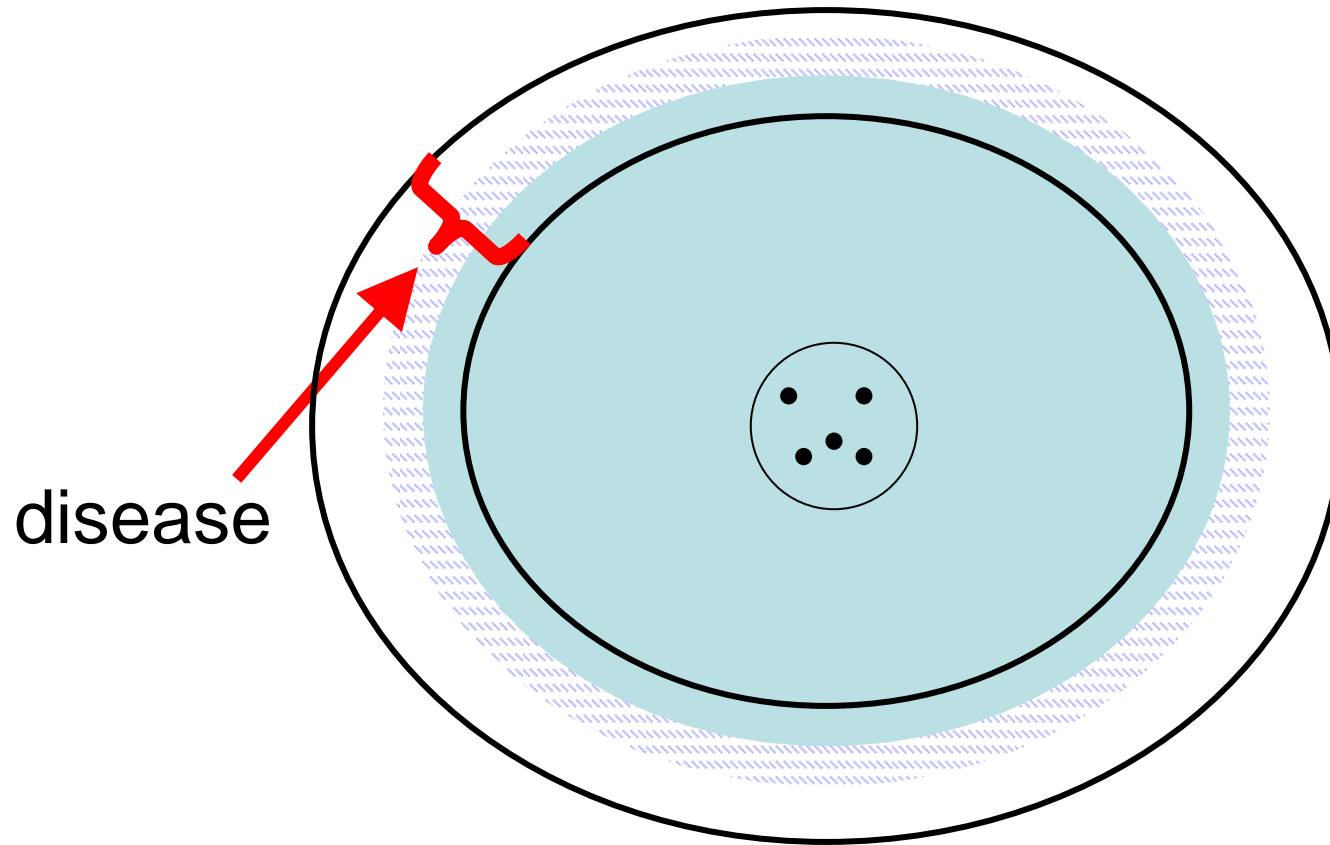
Boorse's Internal Impairment Theory

Disease is an internal state which is an impairment or limitation of normal functional ability.

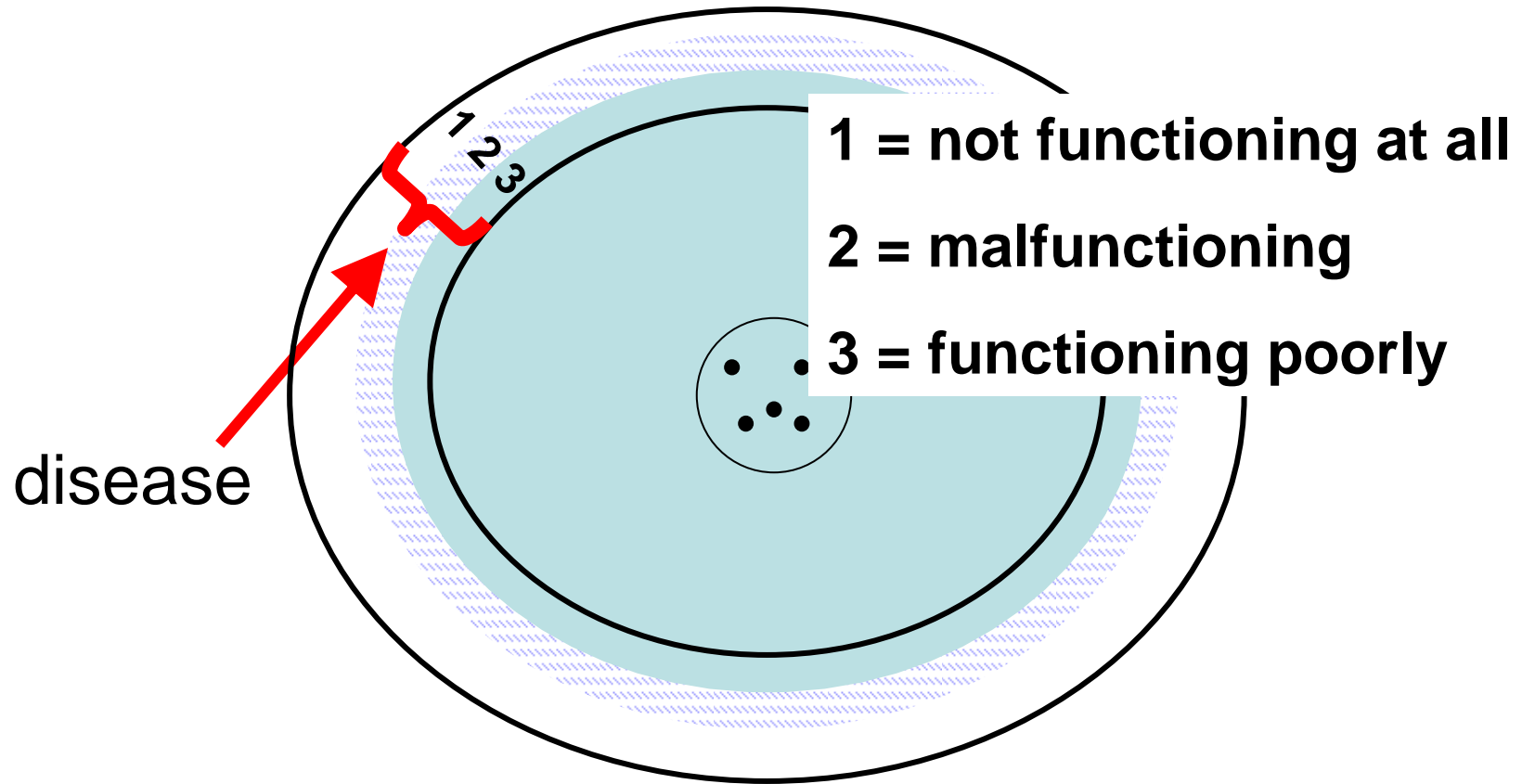
Disease



Disease = remoteness from prototypical functioning



Disease = remoteness from prototypical functioning



Not functioning at all

= death *modulo*:

criticality of the system involved

Biological entities have biological functions only as parts of organisms

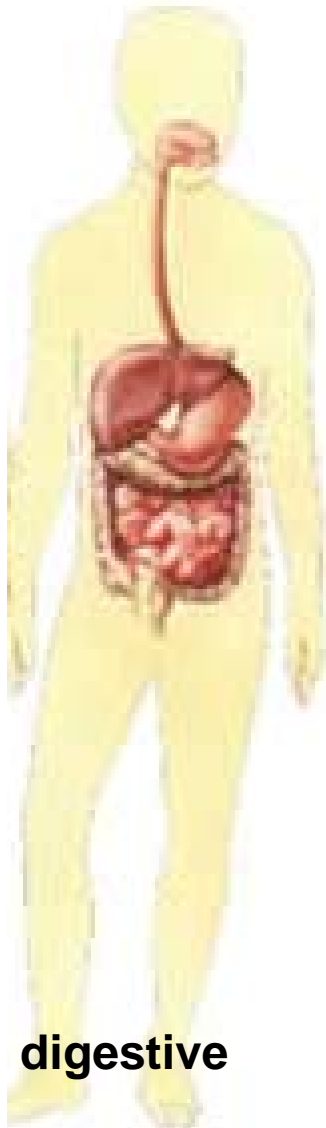
An organic entity functions in the service of the organism of which it is a part

There are immediate parts of the organism – the bodily systems – which function directly in the service of the organism.

And there are mediate (= smaller) parts of the organism – cells, tissues, organs ... -- which function in the service of larger parts

Immediate parts of the organism
are more critical

Bodily Systems



digestive



respiratory



skeletal



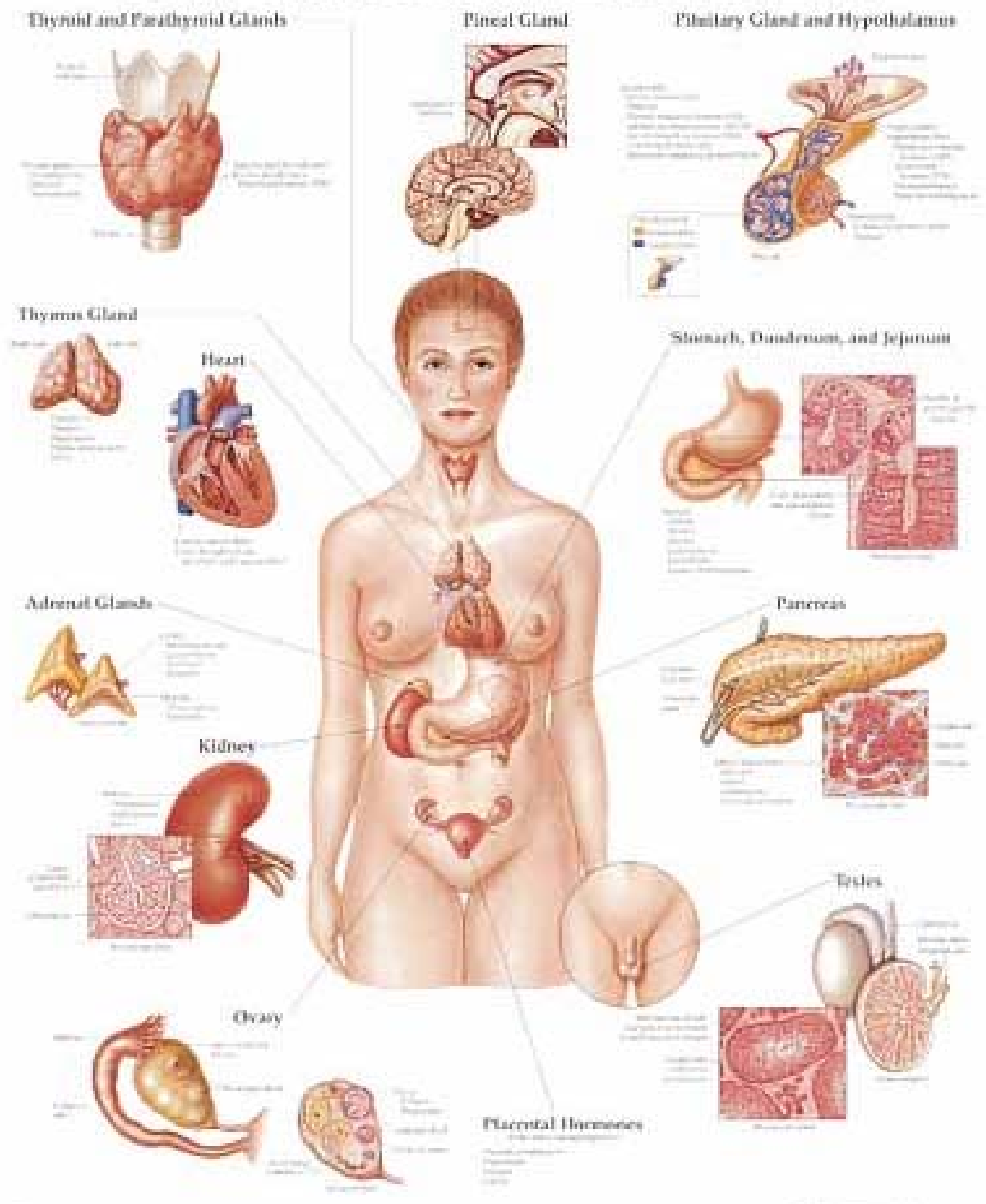
musculatory



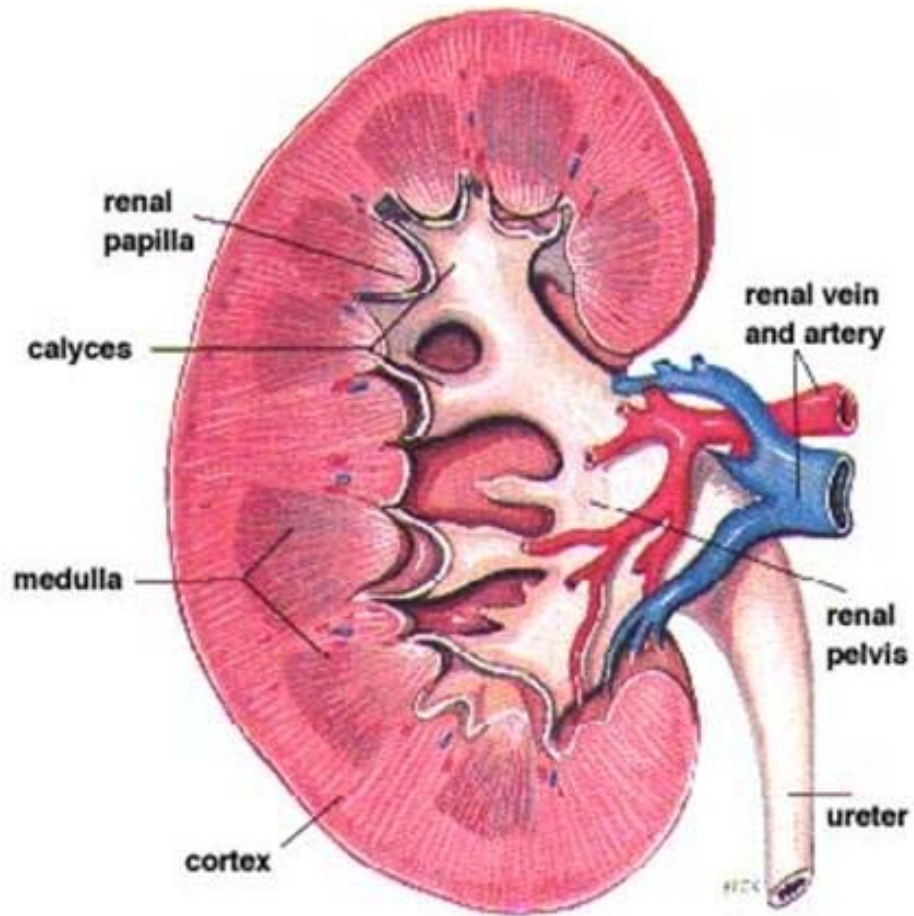
circulatory

immune

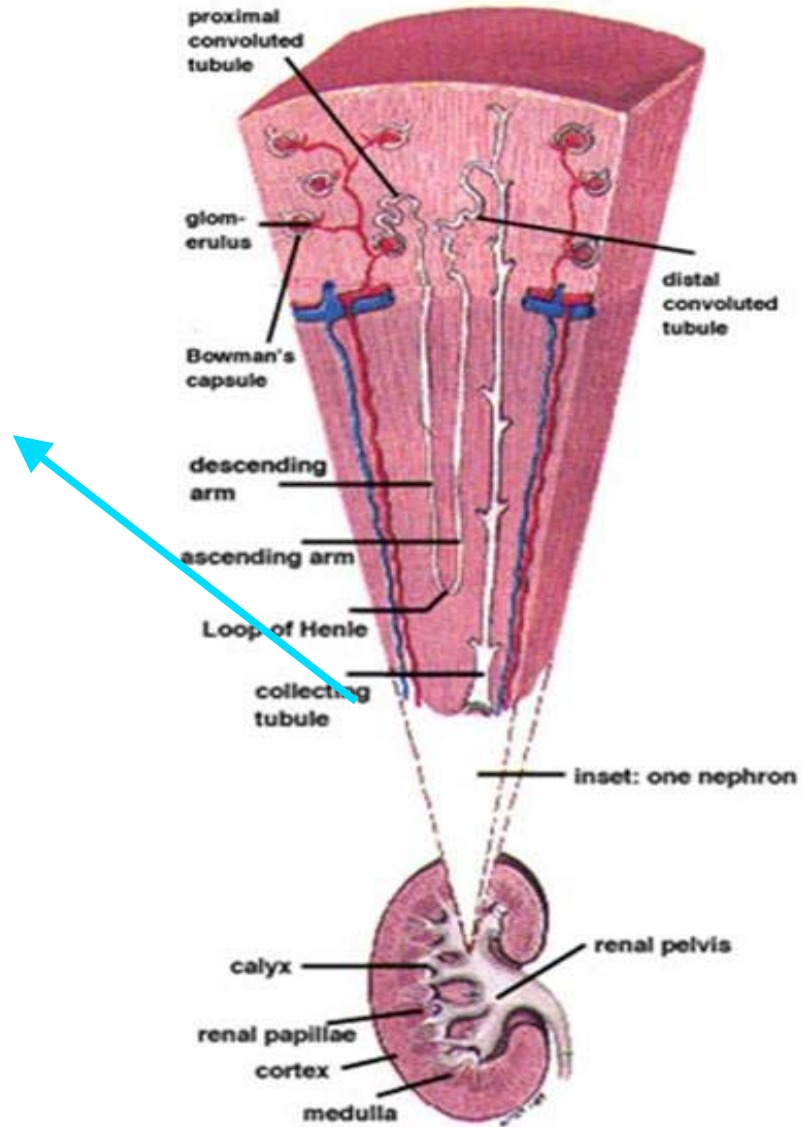
ENDOCRINE SYSTEM



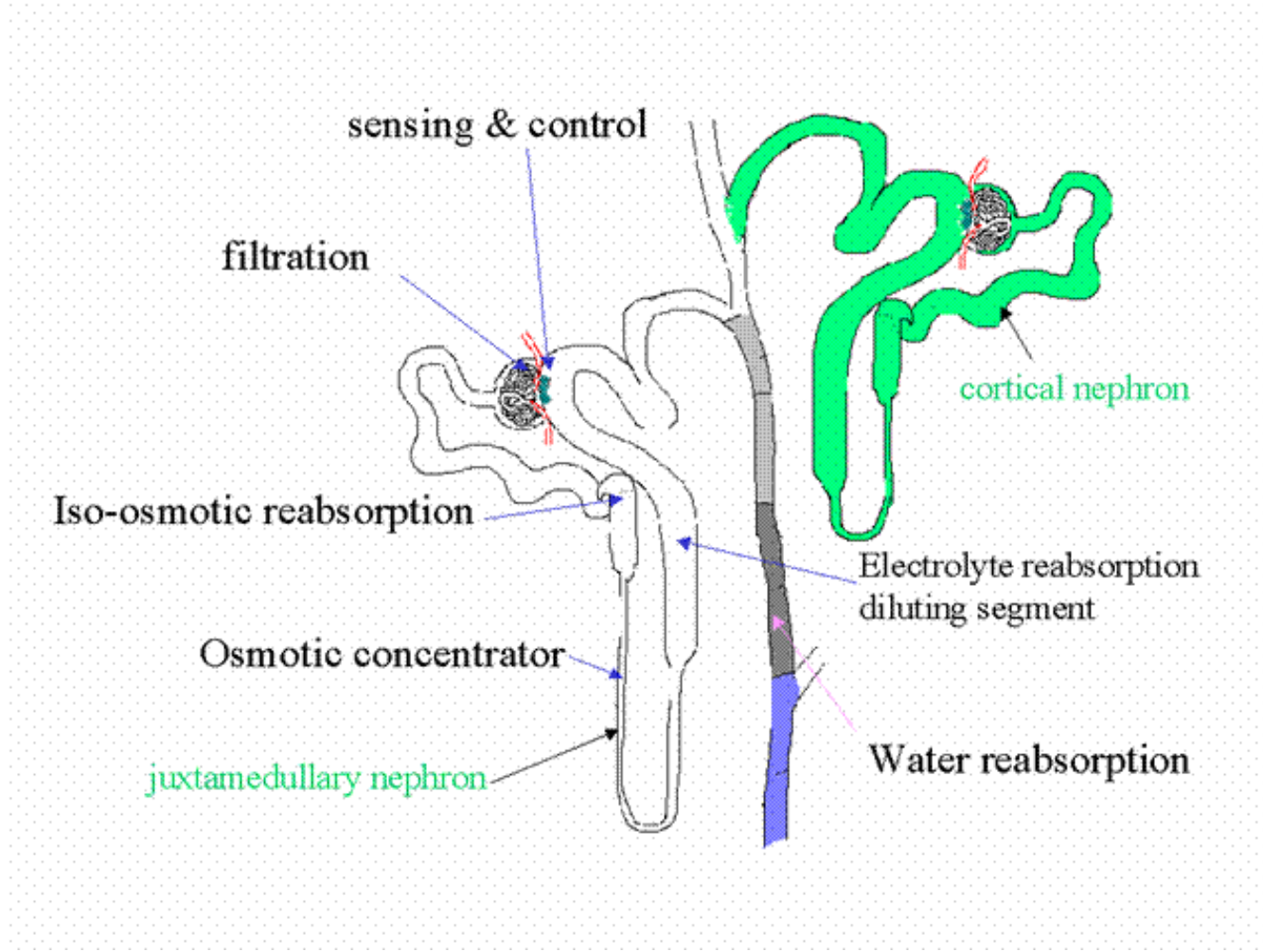
KIDNEY



NEPHRON



FUNCTIONAL SEGMENTS



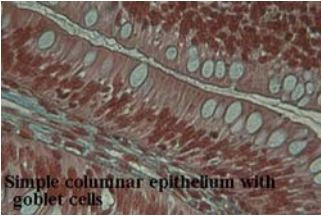
Organism



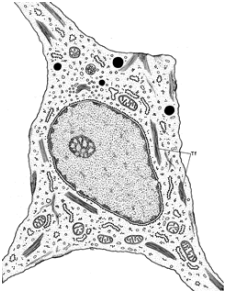
Organ



Tissue



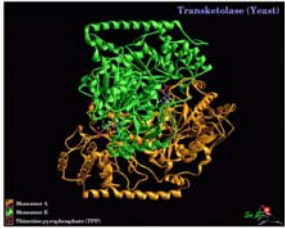
Cell



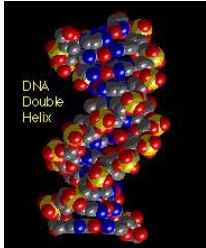
Organelle



Protein



DNA



Coda on 'Normal'

Normal functioning of the pancreas

Normal functioning of the sexual organs

On the several senses of 'normal' in biology

Problem: The Sexual Organs do not have Biological Functions

A constituent part of an organism has a function = its functioning is beneficial to the survival of the host organism

– this does not hold for the reproductive system and its parts

Hence the sexual organs do not
have functions

Alternatively they have functions in relation
to some larger whole (the family, the
dynasty ...)

Compare the role of worker bees in bee
colonies ...



The End