Agenda • Day 1

- Introduction: What is an ontology and what is it useful for?
- Basic Formal Ontology: An upper-level ontology to support scientific research
- Open Biomedical Ontologies (OBO) and the Web Ontology Language (OWL)
- **The OBO Relation Ontology**

Realist Perspectivalism

There is a multiplicity of ontological perspectives on reality, all equally veridical i.e. transparent to reality

Two Cardinal Perspectives

1. Occurrents vs. Continuants

2. Granularity

(Micro vs. Meso vs. Macro)

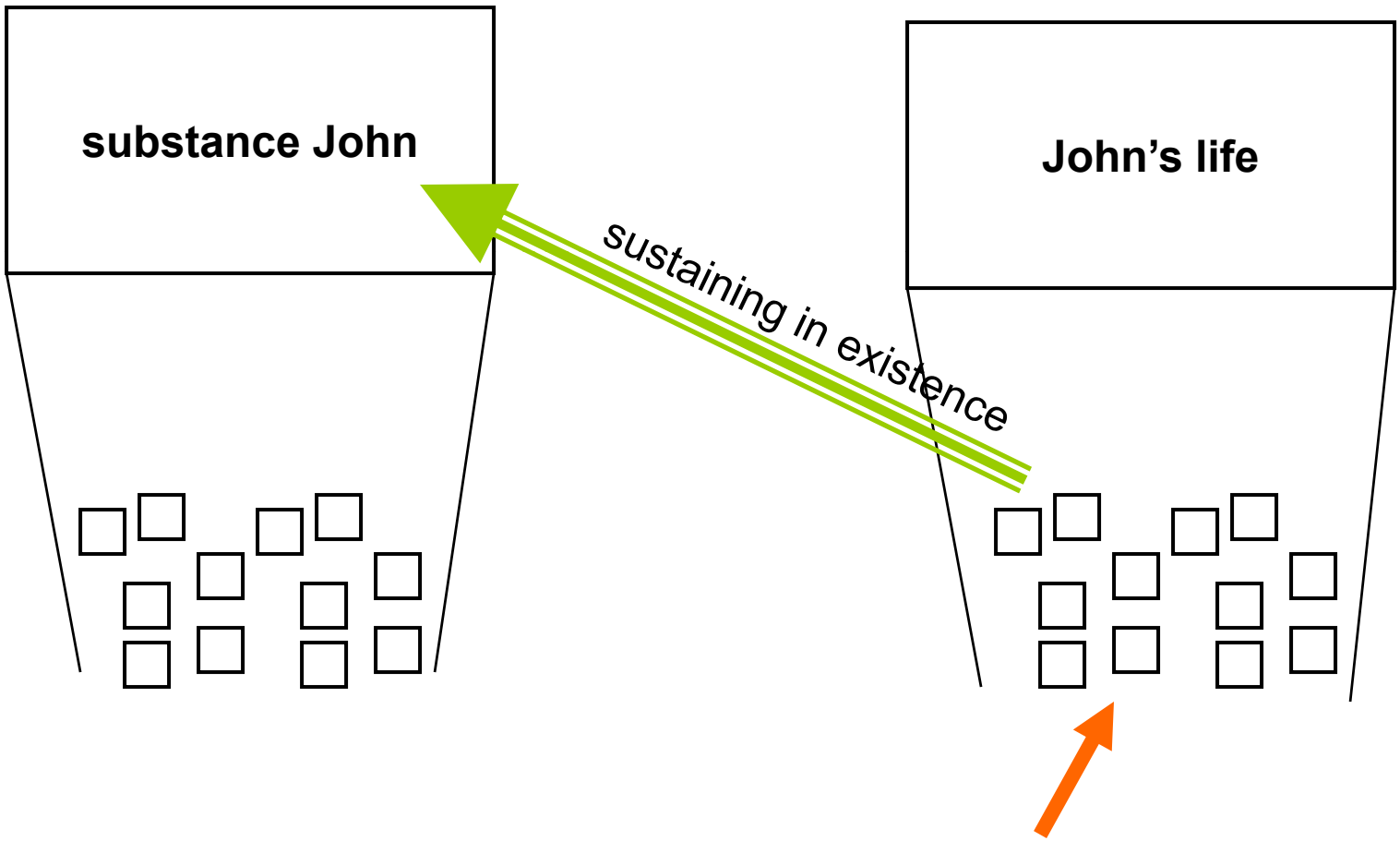
Instance-level relations

Mary’s part is an instance-level part of Mary

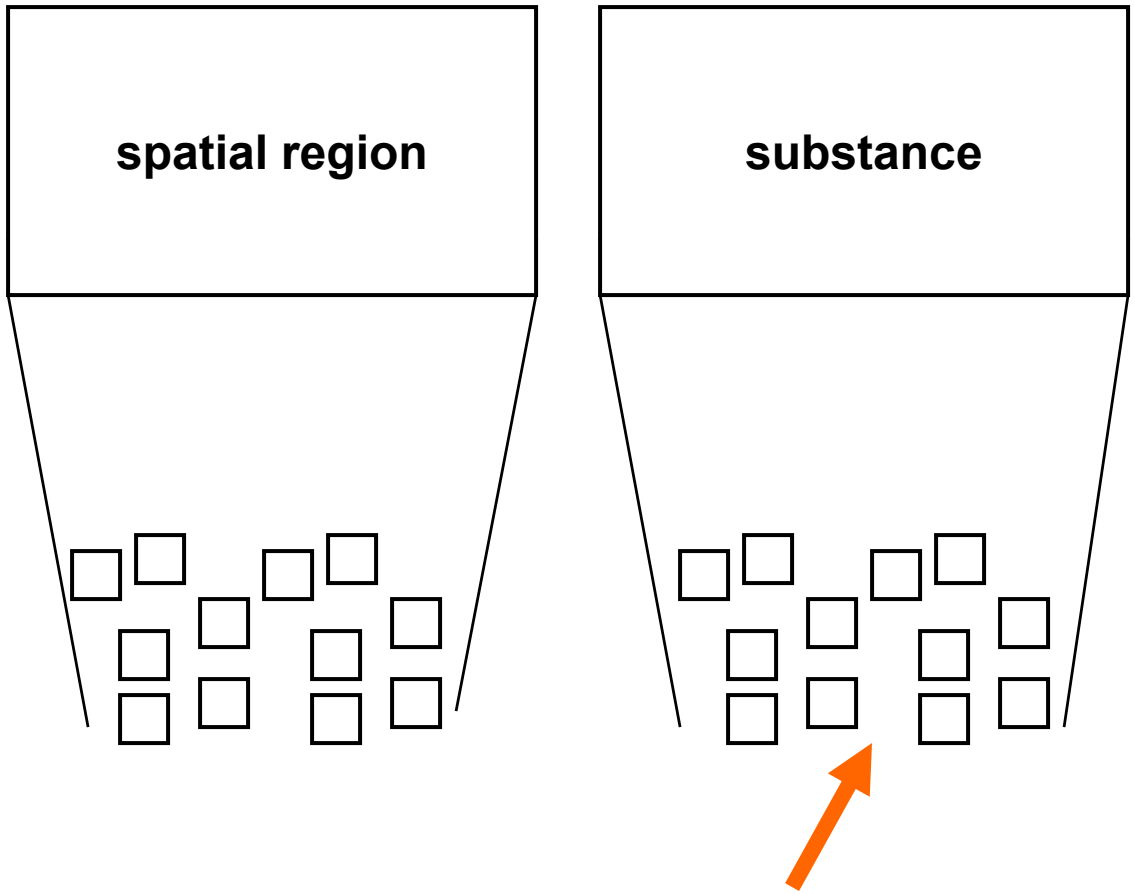
Instance-Level Part-Whole

Basic relation which holds exclusively between entities of the same top-level ontological category

Relations crossing the continuant/occurrent border are never part-relations

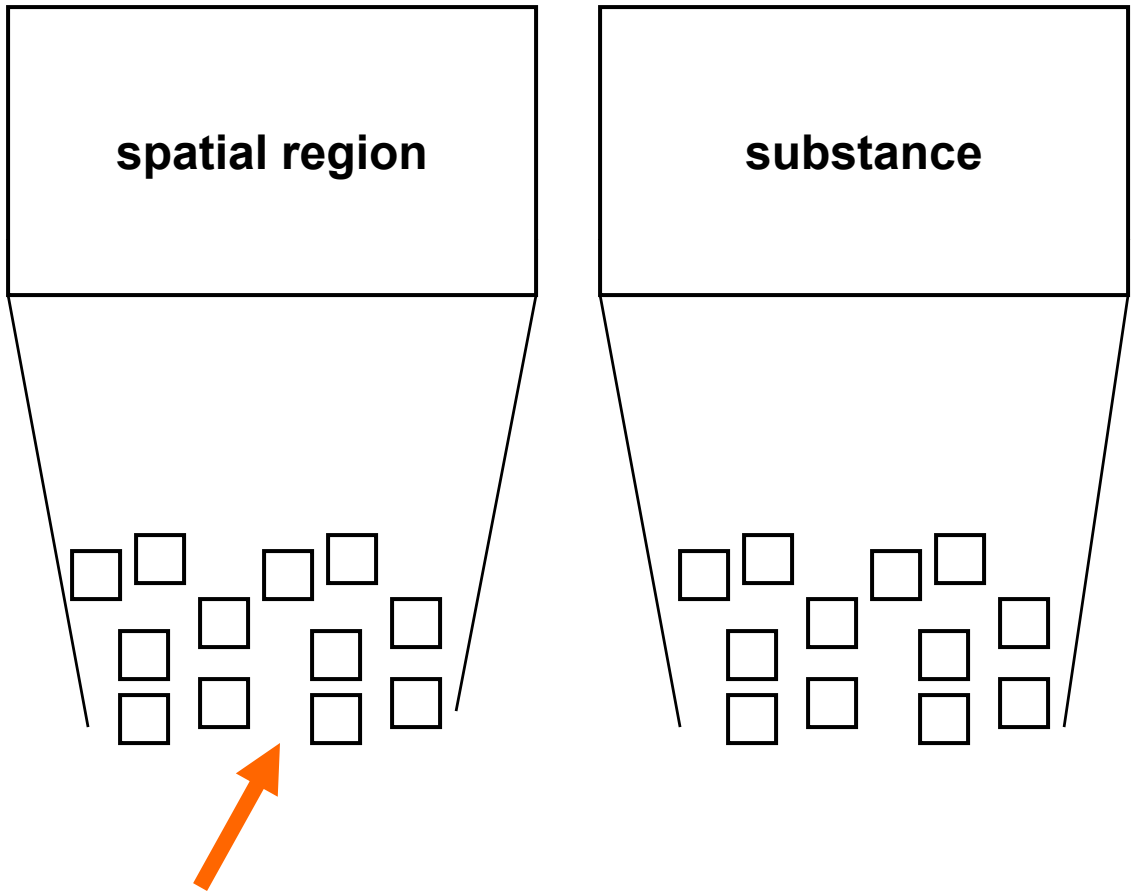


Granularity



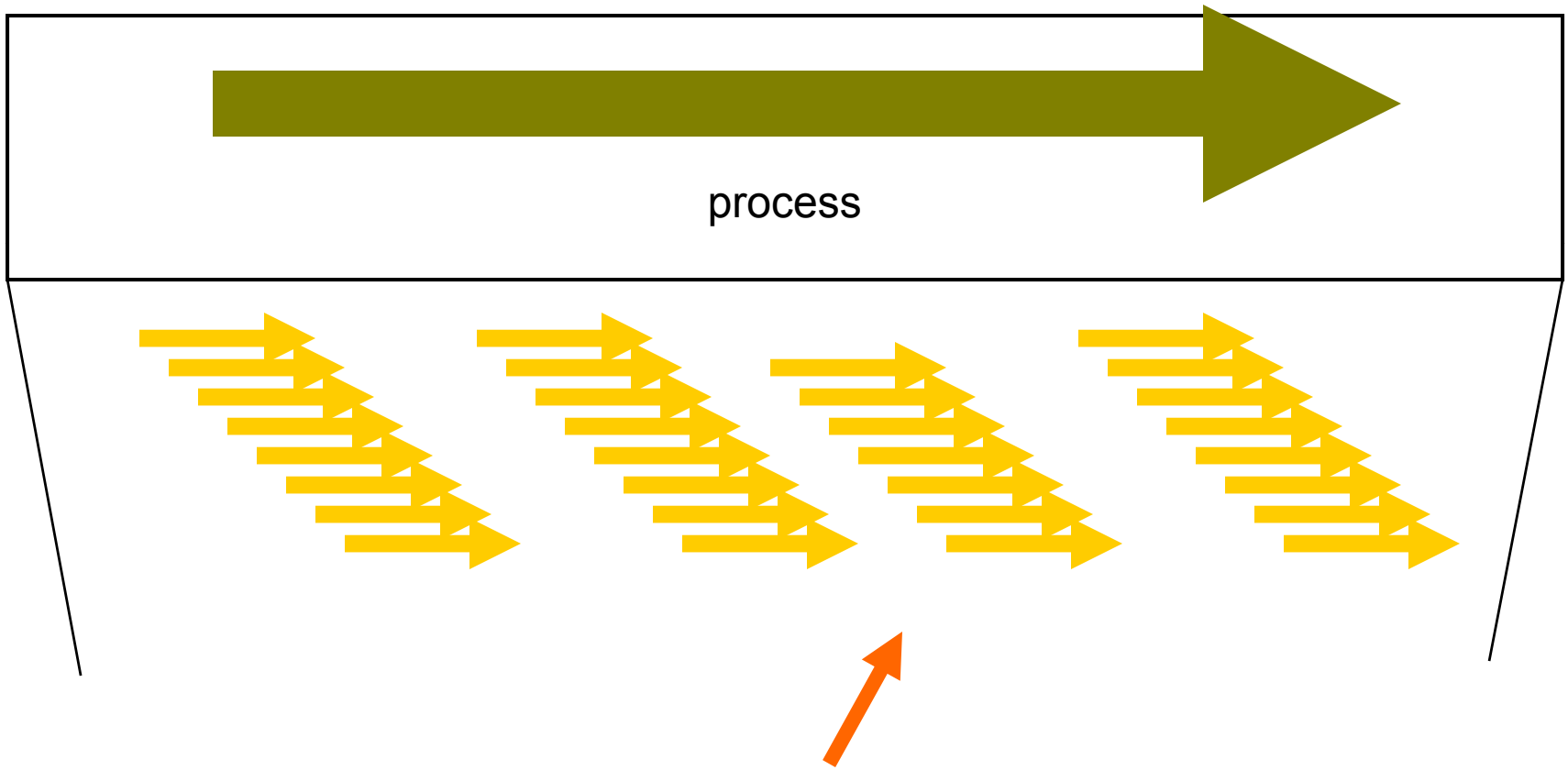
parts of substances are always substances

Granularity



parts of spatial regions are always spatial regions

Granularity



parts of processes are always processes

Intra-granular and cross-granular parthood

across continuants

Kevin's arm is part of Kevin

Kevin's molecule is part of Kevin

across occurrents

Kevin's leg-movement is part of Kevin's running

Kevin's cytometabolism is part of Kevin's running

How link continuants and occurrents together on the instance level?

via other formal relations, for example dependnce

DEPENDENCE

- one entity needs another entity to serve as its bearer

- quality depends on object

  John's suntan depends on John

- process depends on object

  John's sleeping depends on John

Objects participate in processes

PARTICIPATION

(a species of dependence)

Participation

A substance participates in a process

A runner participates in a race

A voter participates in an election

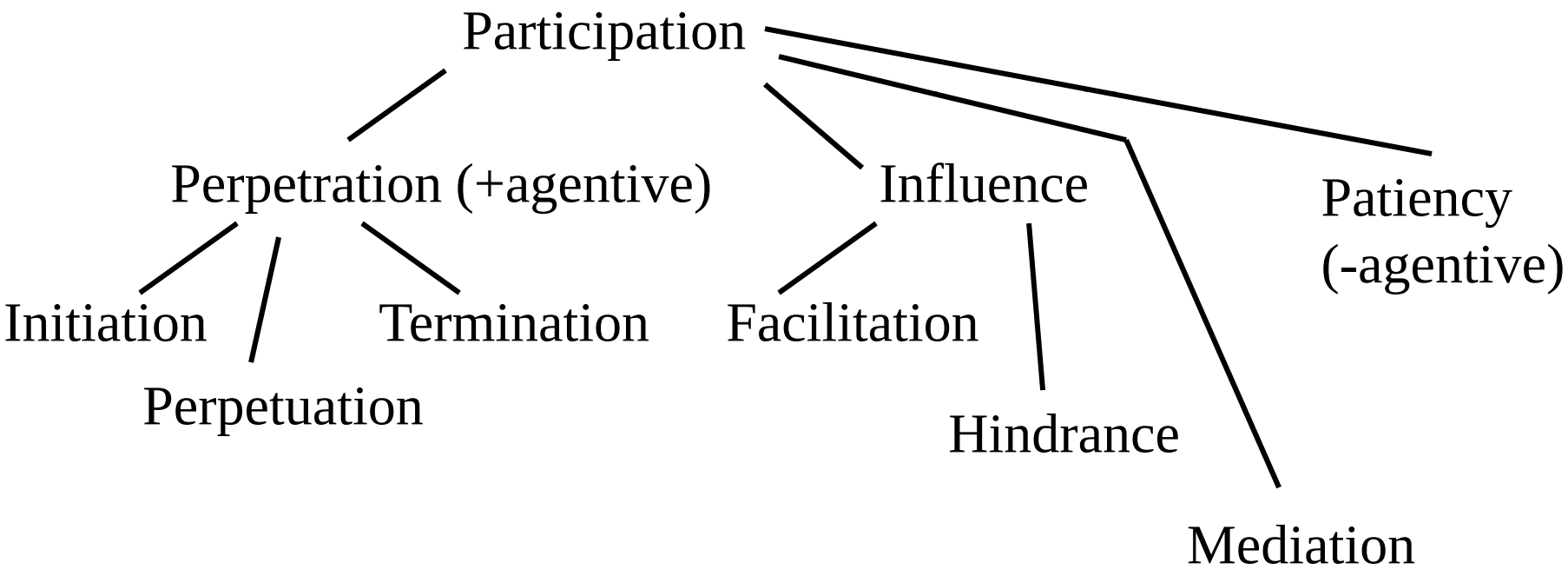
Axes of variation of participation

activity/passivity

direct/mediated

benefactor/malefactor
(conducive to existence) [MEDICINE]

Subtypes of participation



Initiation

A substance initiates a process:

The referee starts the race

The attorney initiates the process of appeal

Perpetuation

A substance sustains a process:

The singer sings the song

The charged filament perpetuates the emission of light

Termination

A substance terminates a process:

The operator terminates the projection of the film

The judge terminates the imprisonment of the pardoned convict

REALIZATION

A very general relation between a dependent continuant entity and a process

The *power* to legislate is realized through the passing of a law

The *role* of antibiotics in treating infections is via the killing of bacteria

Realization

the **execution** of a plan, algorithm

the **expression** of a function

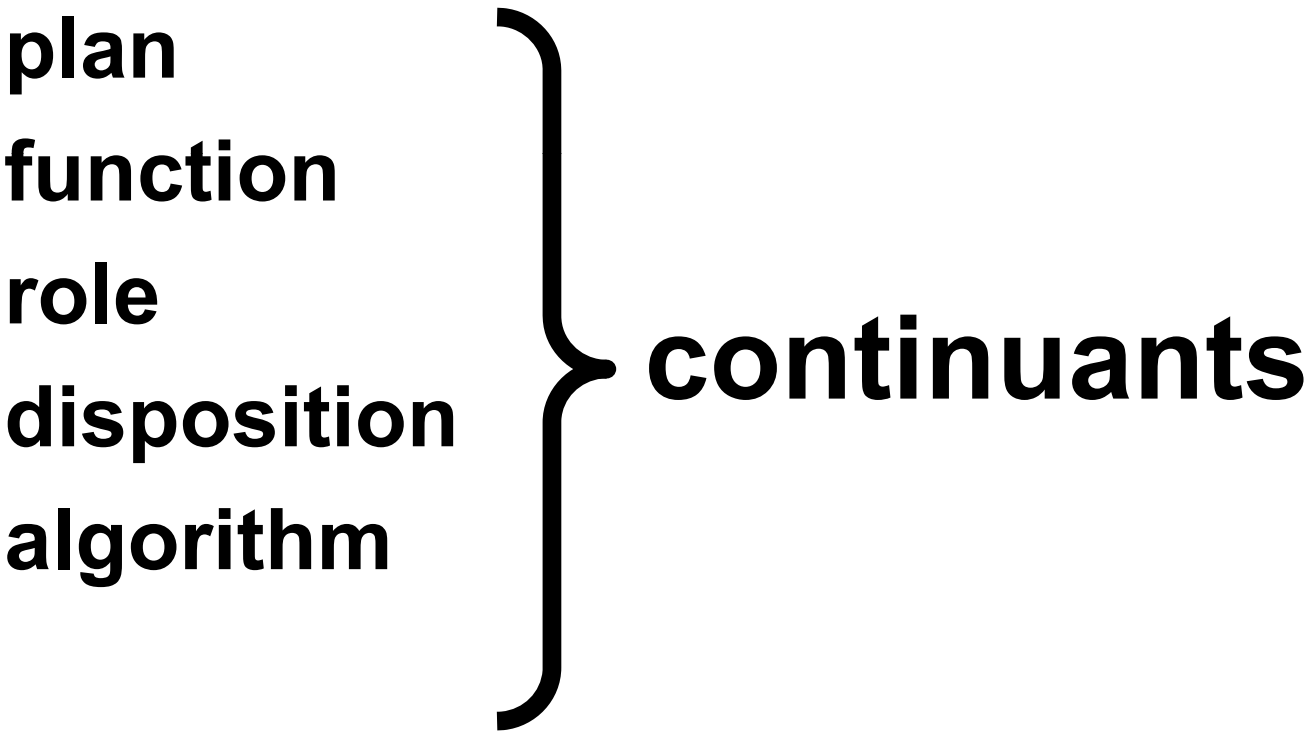
the **exercise** of a role

the **realization** of a disposition

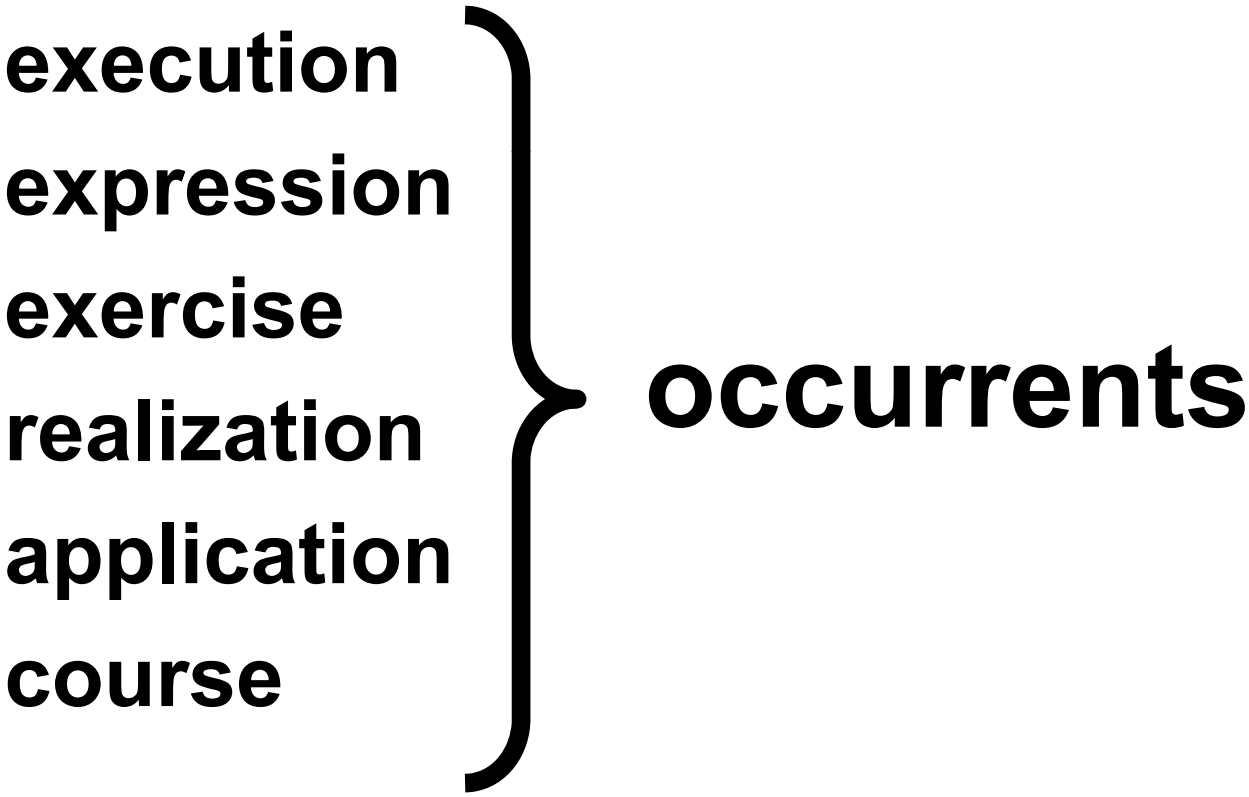
Material examples

performance of a symphony
projection of a film
expression of an emotion
utterance of a sentence
application of a therapy
course of a disease
increase of temperature

Realizable dependent entities



Their realizations



Continuant → Occurrent

Participation

Independent Continuant → Process

Realization

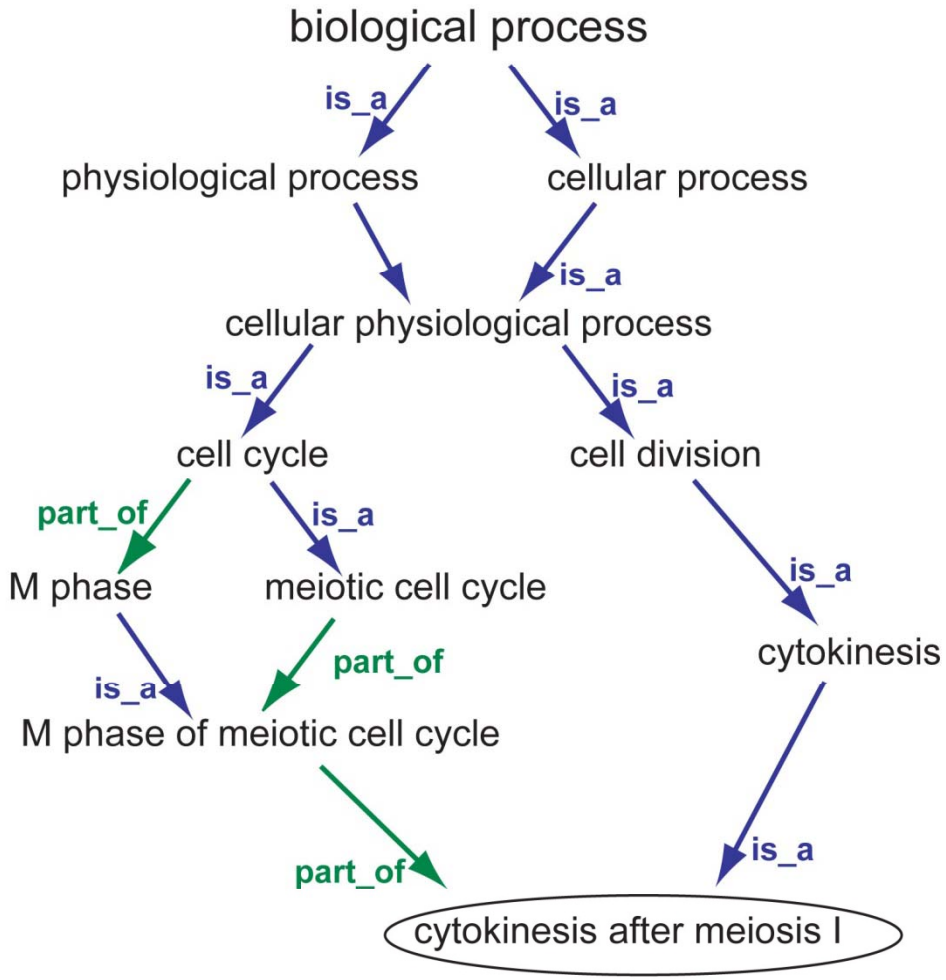
Dependent Continuant → Process

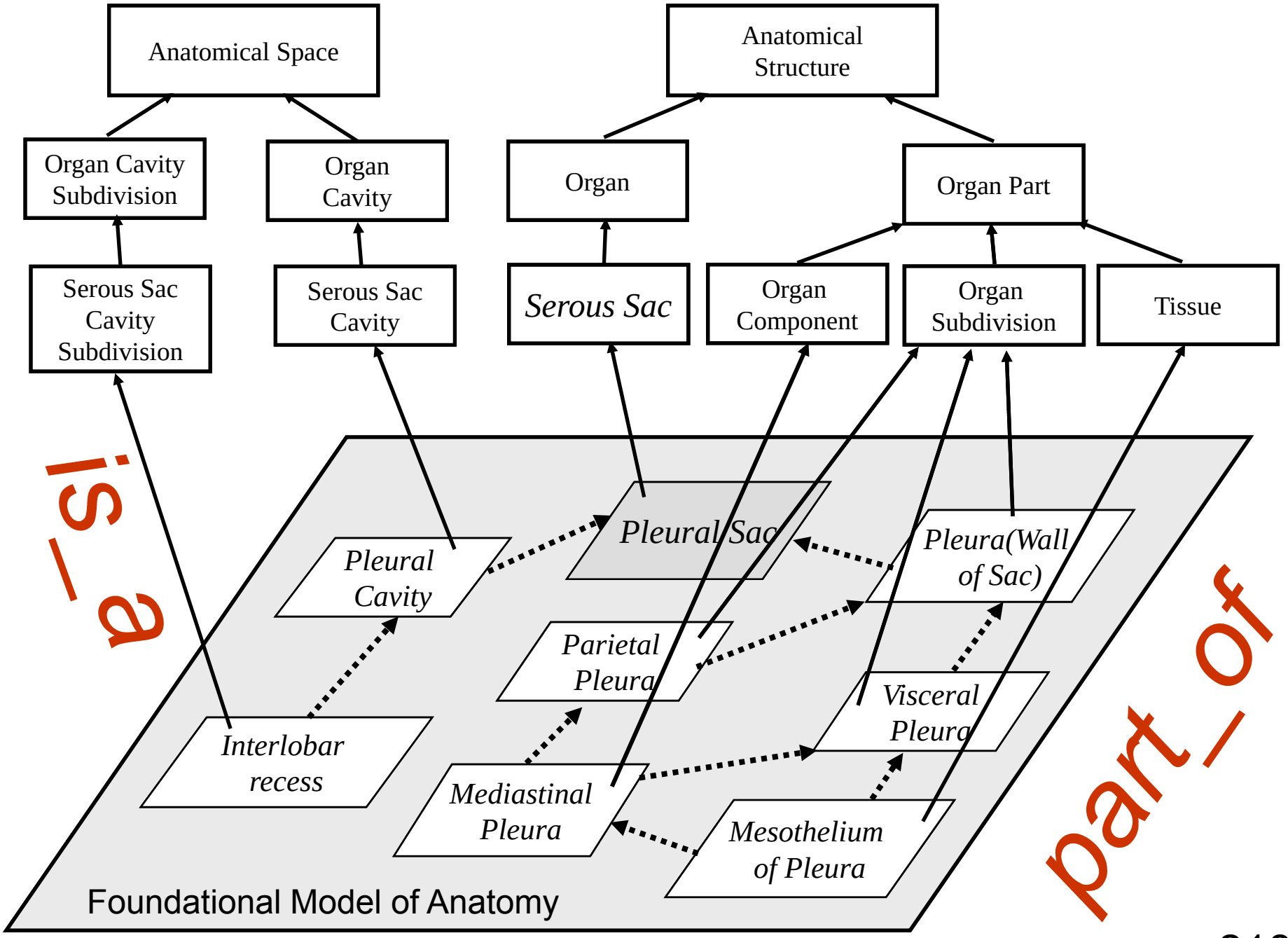
Still on the instance level

Instance-Level Relations

part_of, depends_on, realizes, ...

But ontologies are representations not of instances but of universals




Anatomical Space
Anatomical Structure
Organ Cavity Subdivision
Organ Cavity
Organ
Organ Part
Serous Sac Cavity Subdivision
Serous Sac Cavity
Serous Sac
Organ Component
Organ Subdivision
Tissue
is_a
Pleural Cavity
Pleural Sac
Pleura(Wall of Sac)
Parietal Pleura
Visceral Pleura
Interlobar recess
Mediastinal Pleura
Mesothelium of Pleura
part_of
Foundational Model of Anatomy

OBO Relation Ontology 1.0

Foundational	***is_a*** ***part_of***
Spatial	***located_in*** ***contained_in*** ***adjacent_to***
Temporal	***transformation_of*** ***derives_from*** ***preceded_by***
Participation	***has_participant*** ***has_agent***

"Relations in Biomedical Ontologies",
Genome Biology, April 2005

Kinds of relations

<universal, universal>: *is_a*, *part_of*, ...

<instance, universal>: this explosion
instance_of the universal *explosion*

<instance, instance>: Mary's heart
part_of Mary

Key idea

To define ontological relations like

part_of, *develops_from*

we need to take account not only of universals but also of their *instances* at specific *times*

(→ link to Electronic Health Record)

Key idea

To define ontological relations like

part_of, *develops_from*

we need to take account of both universals and their *instances* and *time*

(→ link to Electronic Health Record)

part_of
for occurrent universals is atemporal

A part_of B =def.

given any particular ***a,***

if ***a*** is an instance of *A*,

then there is some instance ***b*** of *B*

such that

a is an **instance-level part_of *b***

part_of
for continuant universals is time-indexed

A part_of B =def.

given any particular ***a*** and any time ***t,***

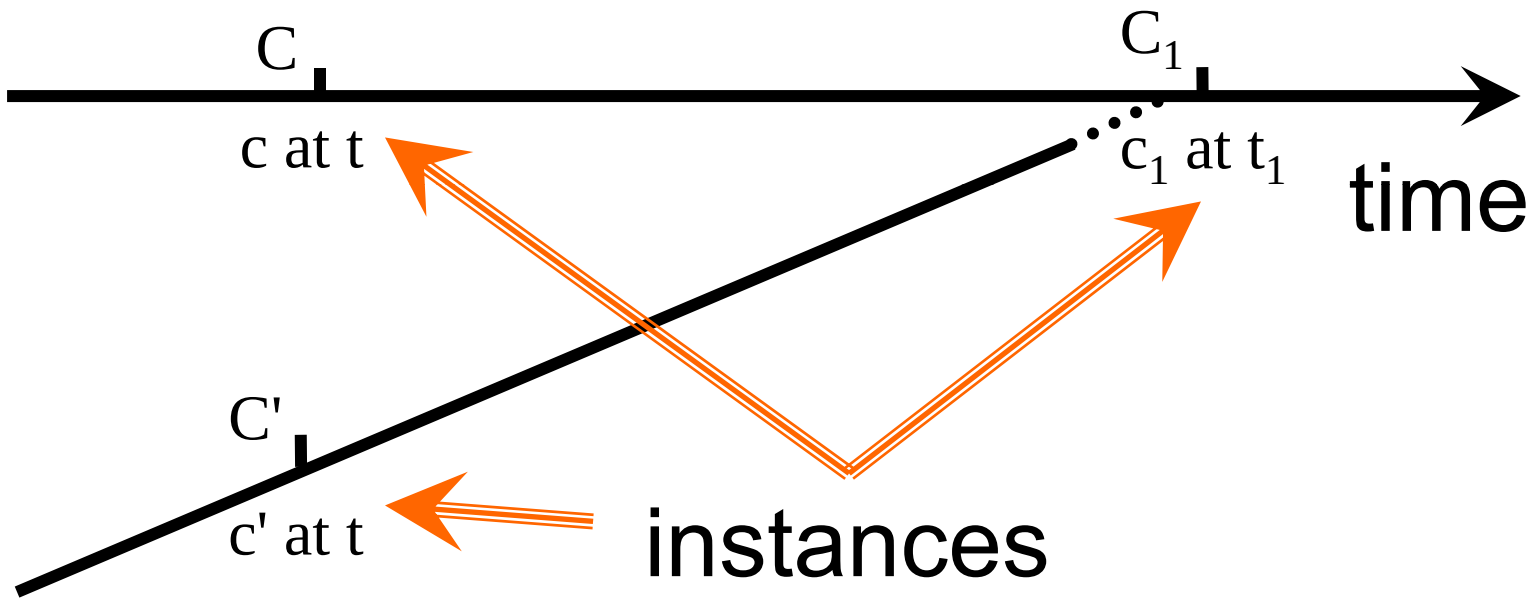
if ***a*** is an instance of *A* at ***t***,

then there is some instance ***b*** of *B*

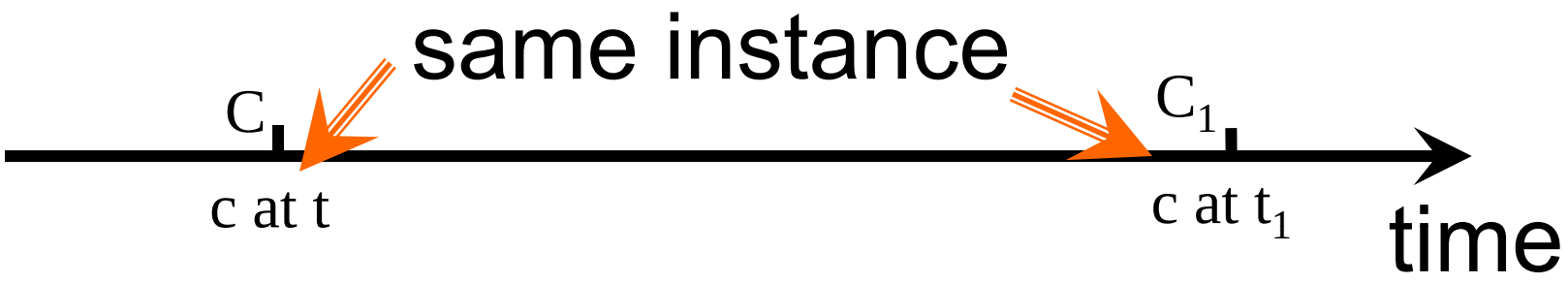
such that

a is an **instance-level part_of *b*** at ***t***

derives_from
(ovum, sperm → zygote ...)



transformation_of



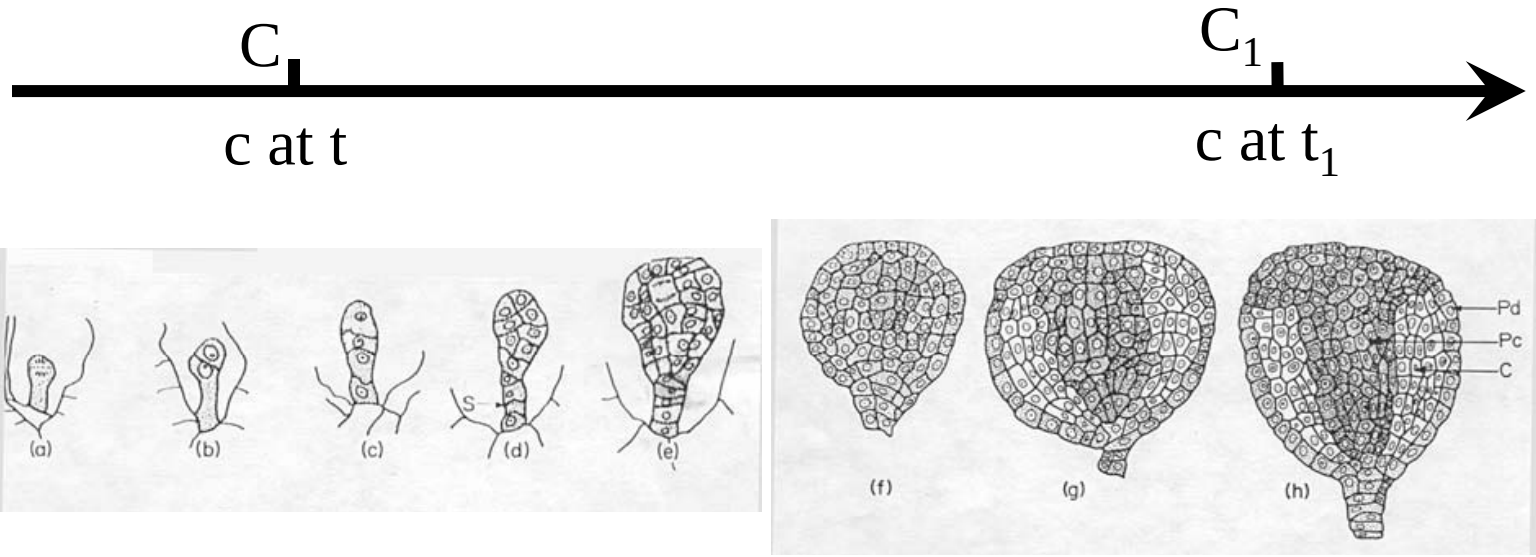
pre-RNA → mature RNA

child → adult

transformation_of

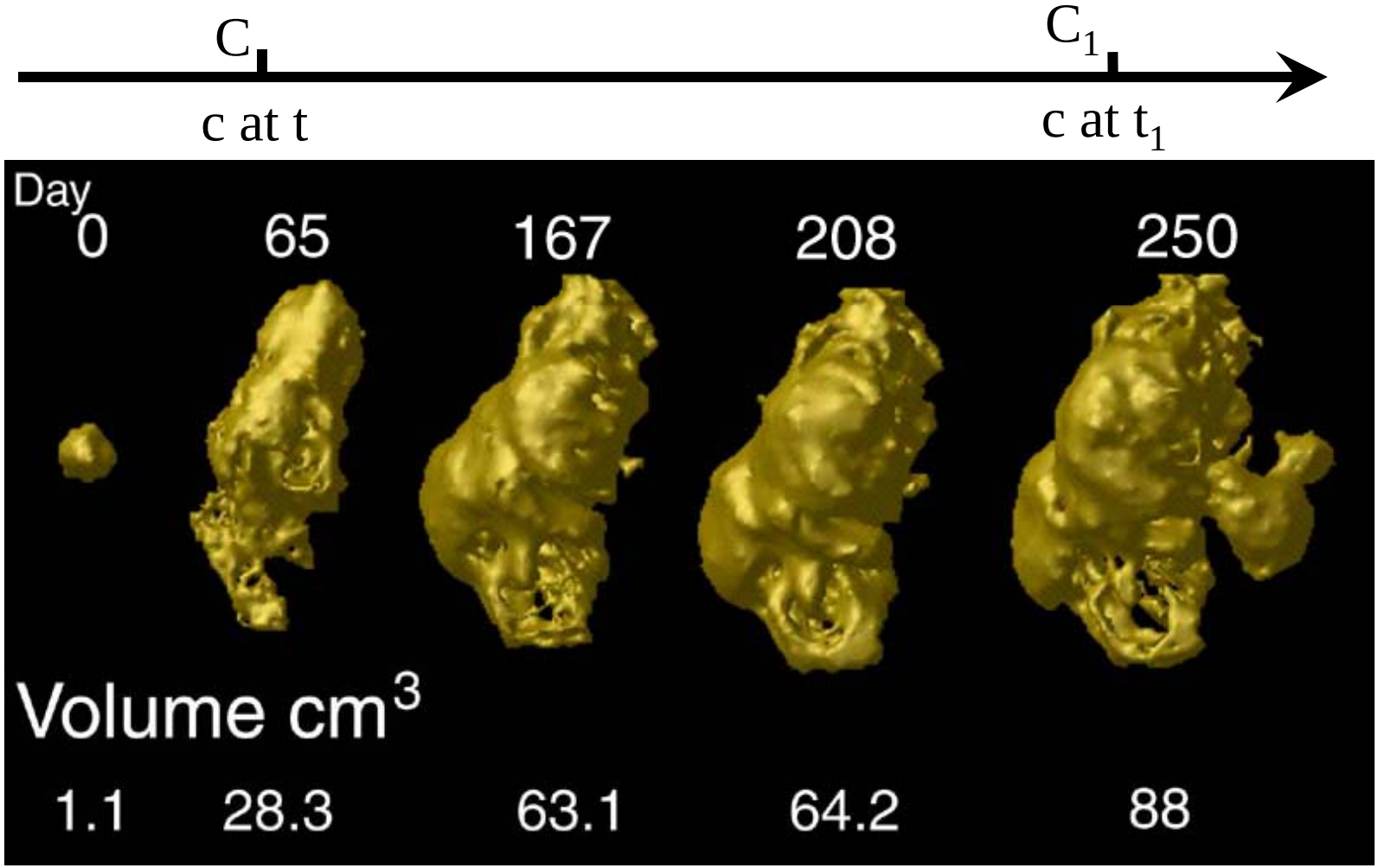
C_2 *transformation_of* C_1 =def. any instance of C_2 was at some earlier time an instance of C_1

- fetus *transformation_of* embryo
- larva *transformation_of* pupa
- adult *transformation_of* child



embryological development

tumor development



is_a **(for occurrents)**

A ***is_a*** *B* =def

For all *x*, if *x* **instance_of** *A* then *x* **instance_of** *B*

cell division ***is_a*** *biological process*

is_a (for continuants)

A ***is_a*** *B* =def

For all *x*, *t* if *x* **instance_of** *A* **at** *t* then *x* **instance_of** *B* **at** *t*

abnormal cell is_a cell

adult human is_a human

but not: *adult is_a child*

These definitions should support cross-ontology reasoning

Whichever *A* you choose, the instance of *B* of which it is a part will be included in some *C*, which will include as part also the *A* with which you began

The same principle applies to the other relations in the OBO-RO:

located_at, *transformation_of*, *derived_from, adjacent_to*, etc.

A part_of B, *B part_of C ...*

The **all-some** structure of the definitions in the OBO-RO allows

cascading of inferences

(i) within ontologies

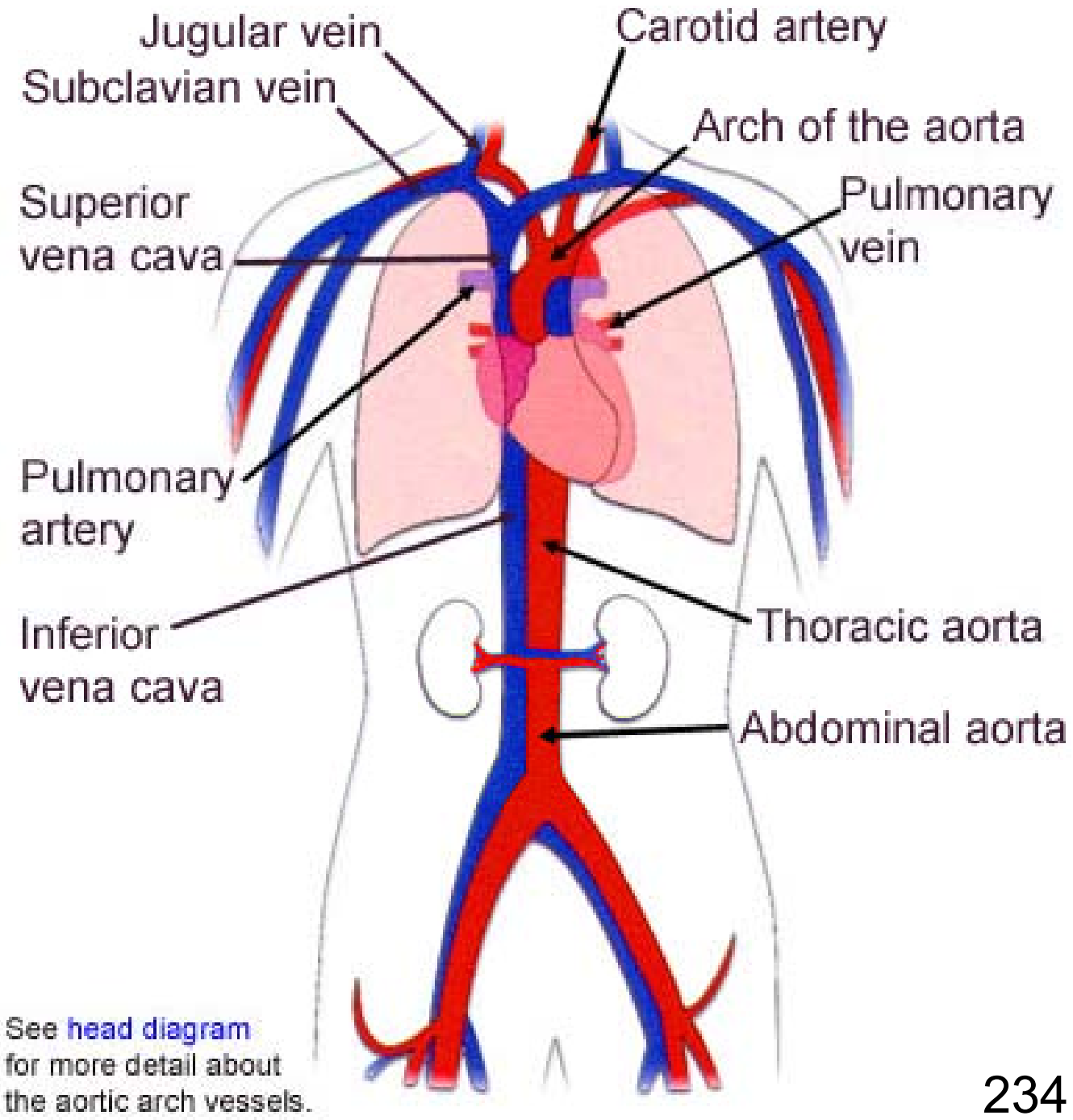
(ii) between ontologies

(iii) between ontologies and EHR repositories of instance-data

Continuity

Attachment

Adjacency



Modes of Connection

Modes of connection:

- *attached_to* (muscle to bone)
- *synapsed_with* (nerve to nerve, nerve to muscle)
- *continuous_with* (= share a fiat boundary)

a **continuous_with** ***b***
= *a* and *b* are continuant instances which share a fiat boundary

This relation is always symmetric at the instance level:

if *x* **continuous_with** *y* , then *y* **continuous_with** *x*

continuous_with
(relation between universals)

A continuous_with B =Def.

for every instance *x* of *A* at *t*
there is some instance *y* of *B at t* such that
x **continuous_with** *y at t*

continuous_with as a relation between universals is not always symmetric

Consider *lymph node* and *lymphatic vessel:*

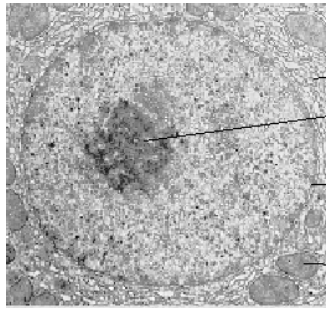
Each lymph node is continuous with some lymphatic vessel, but there are lymphatic vessels (e.g. lymphs and lymphatic trunks) which are not continuous with any lymph nodes

instance level

this nucleus is adjacent to this cytoplasm

implies:

this cytoplasm is adjacent to this nucleus



universal level

nucleus adjacent_to cytoplasm

Not: *cytoplasm adjacent_to nucleus*

Adjacent_to as a relation between universals is not always symmetric

Consider

seminal vesicle adjacent_to urinary bladder

Not: *urinary bladder adjacent_to seminal vesicle*

Applications

Expectations of symmetry e.g. for interactions may hold only at the instance level

if *A* interacts with *B*, it does not follow that *B* interacts with *A*

if *A* is expressed simultaneously with *B*, it does not follow that *B* is expressed simultaneously with *A*

transformation_of

A transformation_of B =Def.

Every instance of *A* was at some earlier time an instance of *B*

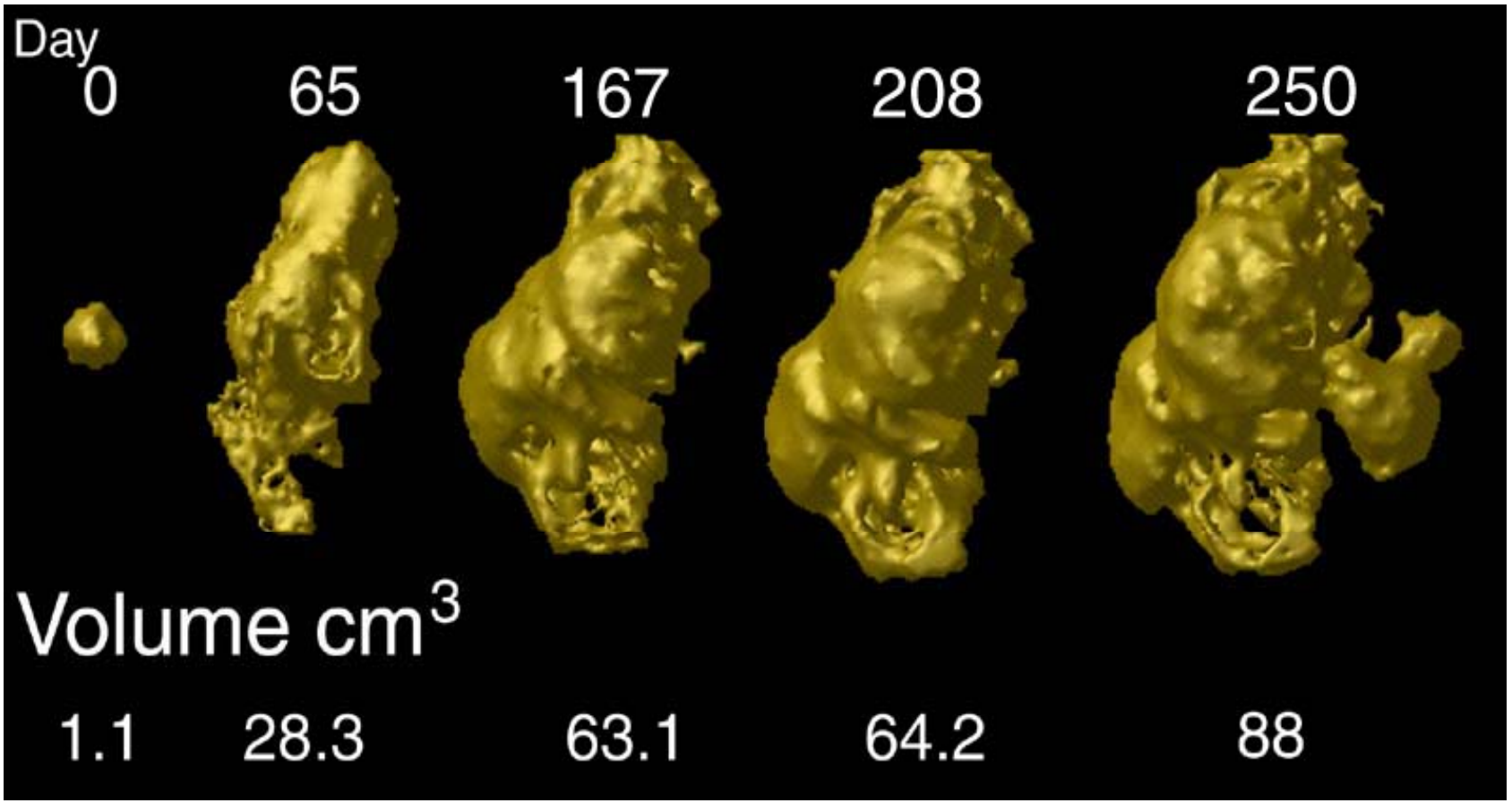
– *adult transformation_of child*

transformation_of

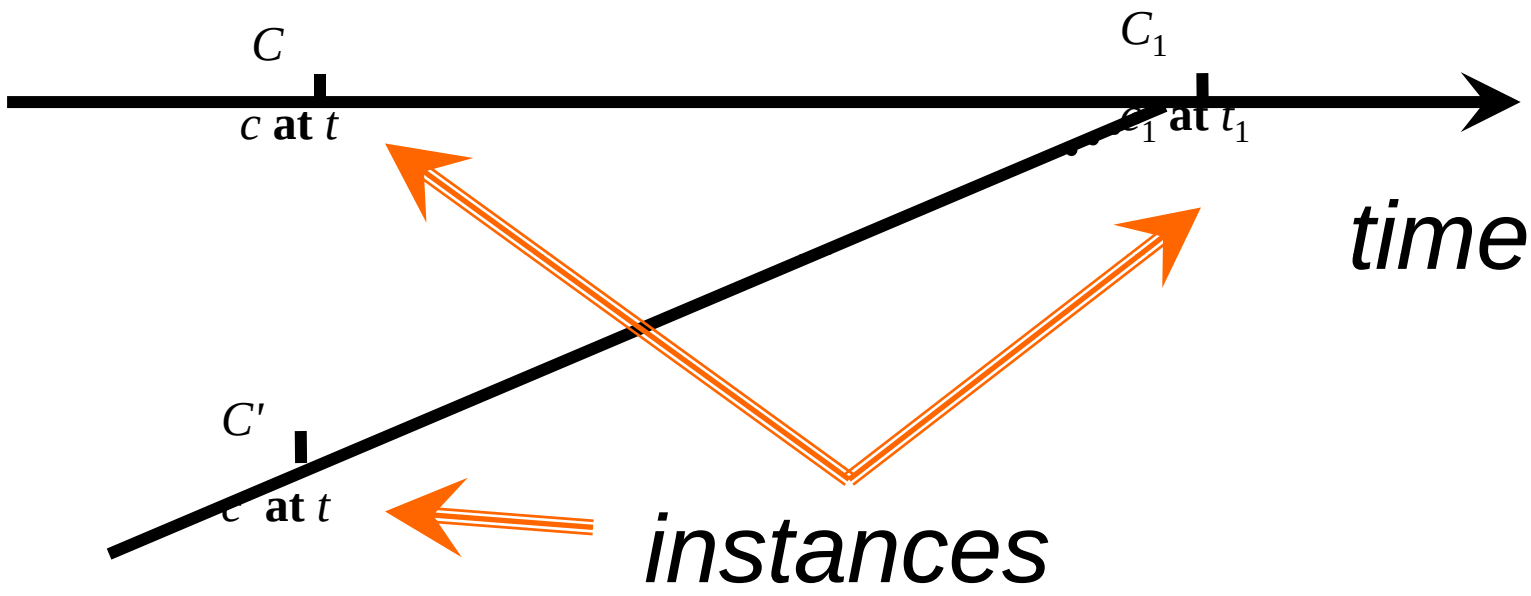
pre-RNA → **mature RNA**

child → **adult**

tumor development



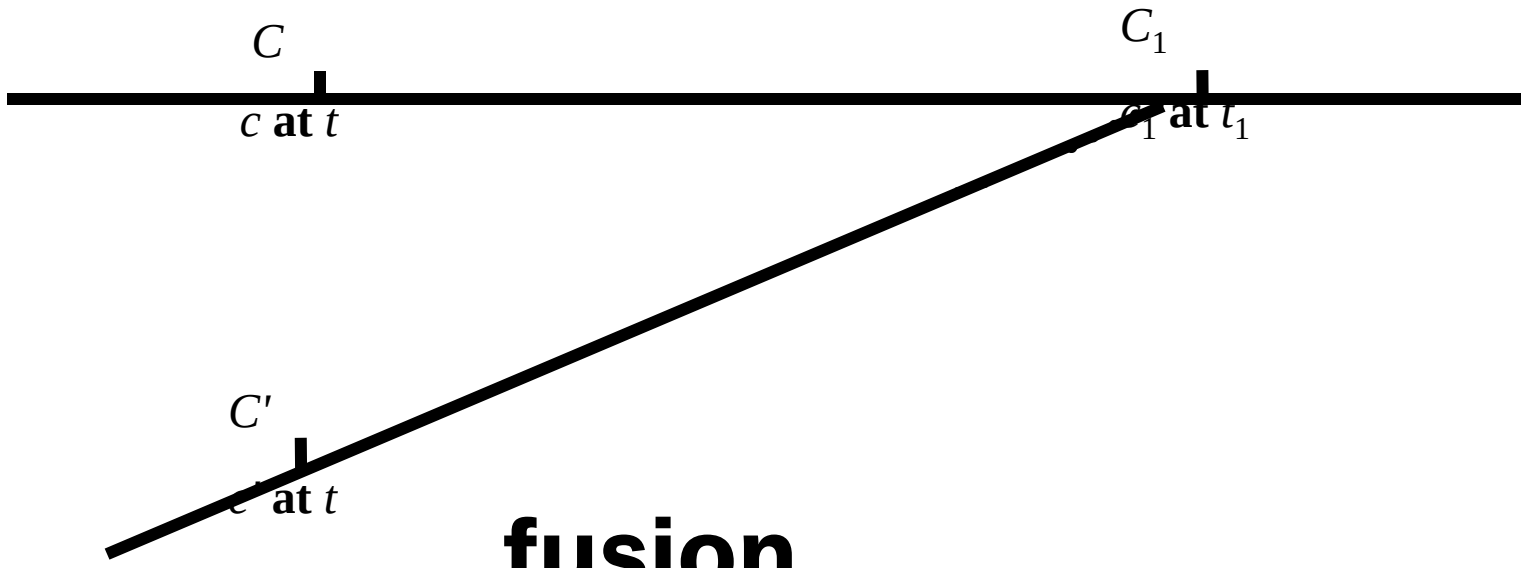
derives_from



zygote derives_from *ovum*

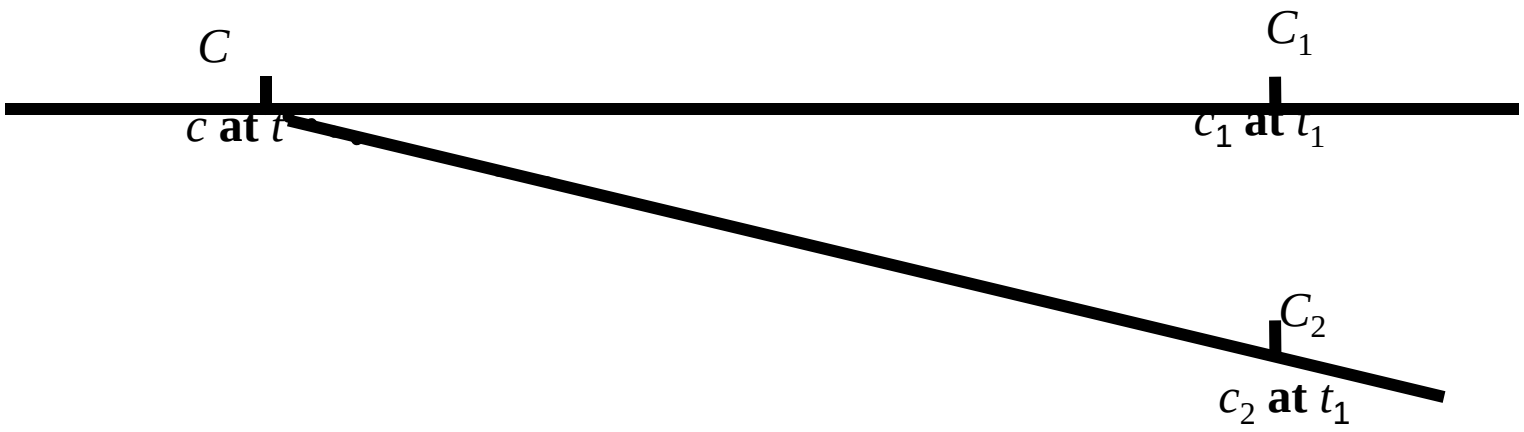
sperm

two continuants fuse to form a new continuant



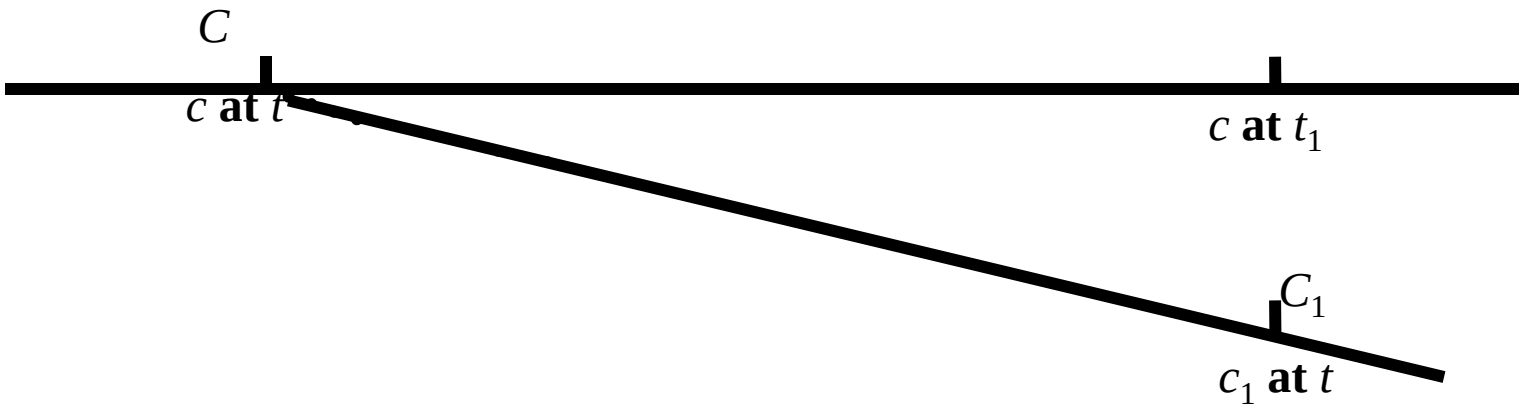
fusion

one initial continuant is replaced by two successor continuants



fission

one continuant detaches itself from an initial continuant, which itself continues to exist



budding

Primitive Relations

- c **instance_of** C **at** t - a primitive relation between a continuant instance and a universal which it instantiates at a specific time
- p **instance_of** P - a primitive relation between a process instance and a universal which it instantiates holding independently of time
- c **part_of** c1 **at** t - a primitive relation between two continuant instances and a time at which the one is part of the other
- p **part_of** p1, r **part_of** r1 - a primitive relation of parthood, holding independently of time, either between process instances (one a subprocess of the other), or between spatial regions (one a subregion of the other)

Primitive Relations

- c **located_in** r **at** t - a primitive relation between a continuant instance, a spatial region which it occupies, and a time
- r **adjacent_to** r1 - a primitive relation of proximity between two continuants
- t **earlier** t1 - a primitive relation between two times
- c **derives_from** c1 - a primitive relation involving two distinct material continuants c and c1
- p **has_participant** c **at** t - a primitive relation between a process, a continuant, and a time

Defined Instance-Level Relations

p **occurring_at** t =def. for some c, p **has_participant** c **at** t.

p **preceded_by** p1 =def. for all t, t1, if p **occurring_at** t and p1 **occurring_at** t1, then t1 **earlier** t

Defined Instance-Level Relations

t **first_instant** p =def. p **occurring_at** t, and for all t1, if t1 **earlier** t, then not p **occurring_at** t1

t **last_instant** p =def. p **occurring_at** t and for all t1, if t **earlier** t1, then not p **occurring_at** t1 p

Overlaps on the level of instances

x **overlaps** y **at t** =def. there is some z such that z is **part_of** x **at t** and z is **part_of** y **at t**

Overlaps on the level of universals

X *overlaps* Y =def. for every t and every x, if x **instance_of** X at t, then there is some instance y of Y at t such that (x **overlaps** y at t)

Note that it can be the case that X *overlaps* Y as thus defined, even though Y does not *overlap* X.

Thus uterine tracts *overlaps* urinogenital sysem

but not uriongenital system *overlaps* uterine tract (because of male urinogenital systems)

Proposed new relations on the level of universals

about – between an information object and an object to which it refers

inheres_in

depends_on

output_of

has_input

has_function

has_quality

realization_of

from http://www.bioontology.org/wiki/index.php/RO:Main_Page

New relations

A *depends_on* B =def. every instance of A is such that it cannot exist unless some instance of B exists

apoptosis depends_on cell

death depends_on organism

…

New Gene Ontology 'Regulates' Relations

def: "A relation between a process and a process. A regulates B if the unfolding of A affects the frequency, rate or extent of B. A is called the regulating process, B the regulated process“

A regulates B =def. A is a process type and B is a process type and every instance of A is such that its unfolding affects the frequency, rate or extent of some instance of B.

Positive and Negative Regulation

positively_regulates def: "A regulation relation in which the unfolding of the regulating process *increases* the frequency, rate or extent of the regulated process"

negatively_regulates def: "A regulation relation in which the unfolding of the regulating process *decreases* the frequency, rate or extent of the regulated process"

The Granularity Gulf

most existing data-sources are of fixed, single granularity

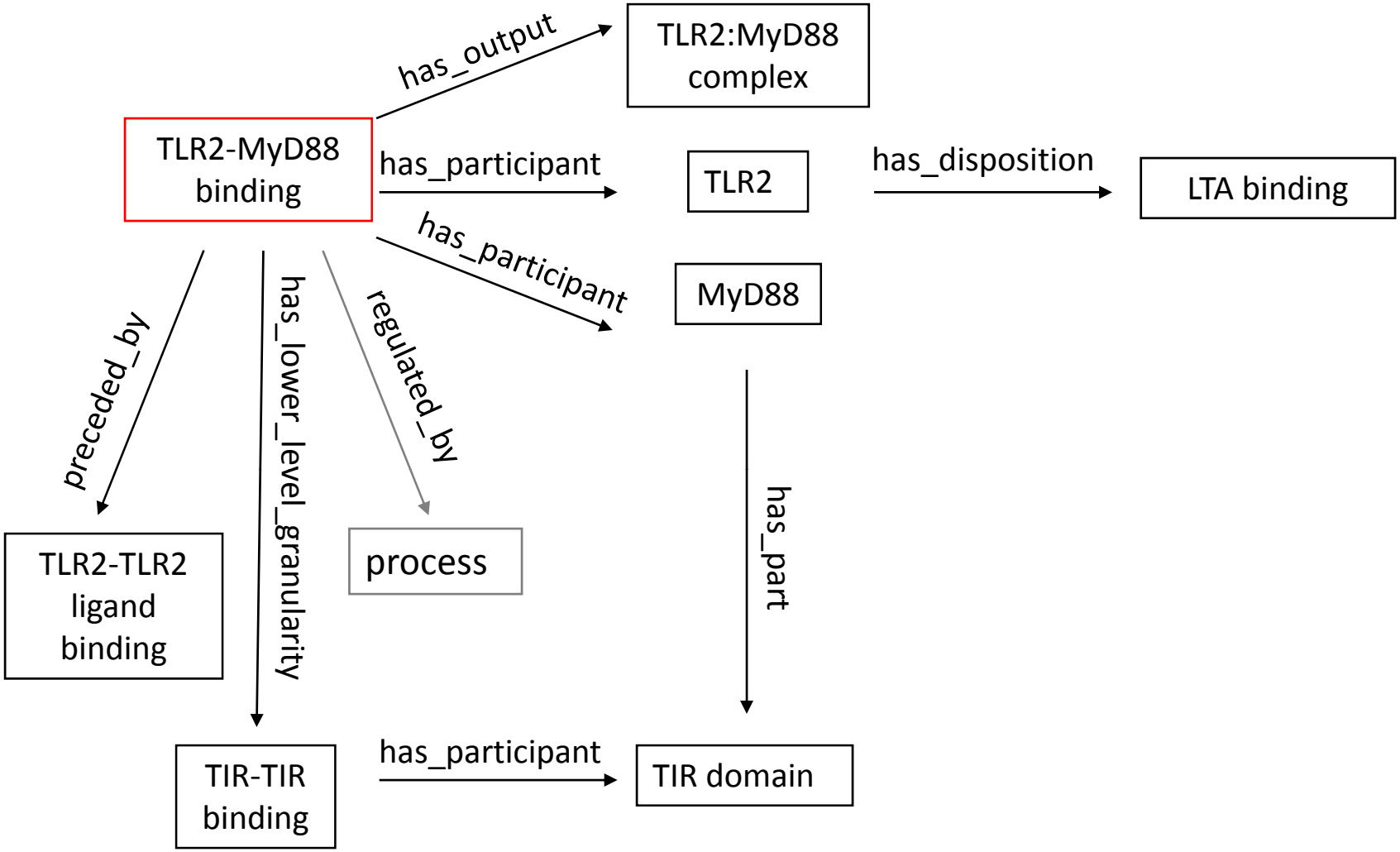
many (all?) clinical phenomena *cross* granularities

Advantages of the methodology of enforcing commonly accepted coherent definitions

promote quality assurance (better coding)

guarantee automatic reasoning across ontologies and across data at different granularities

yields connection to times and instances in EHR



TLR-2 signalling pathway

with thanks to Lindsay Cowell