"The Fight Between Carnival and Lent," 1559, Pieter Bruegel the Elder.

is human society undergoing a process of individuation?

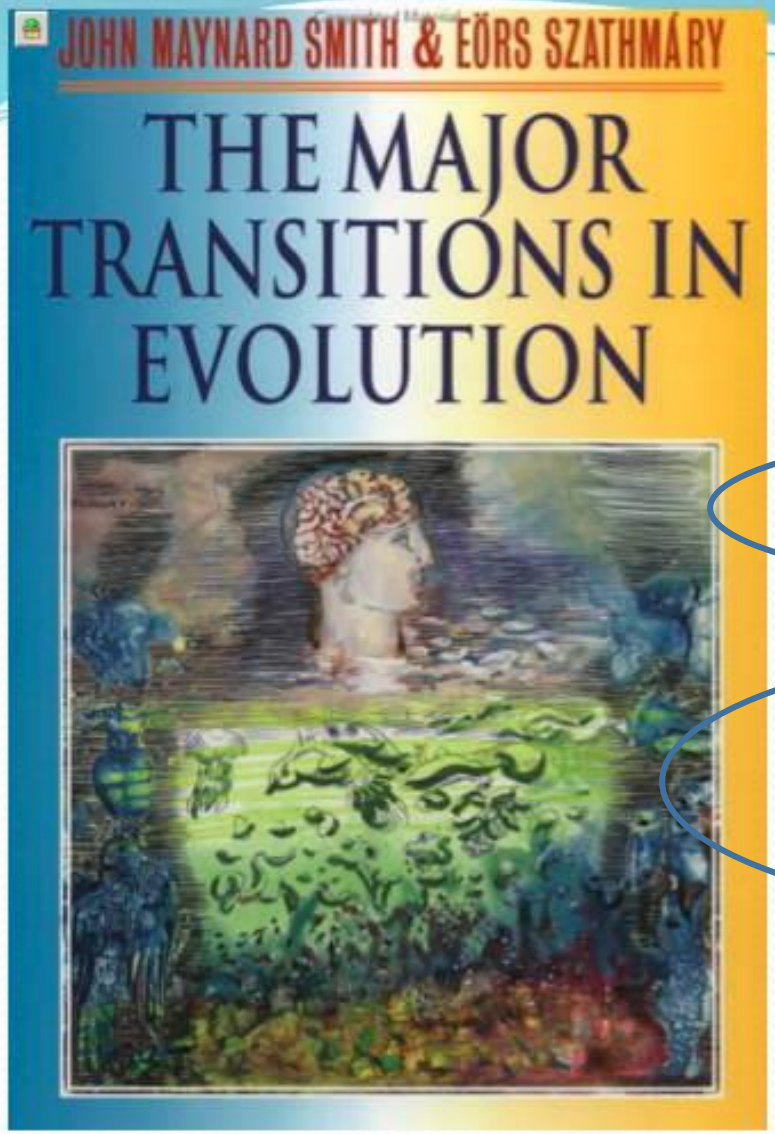
“Flemish Proverbs”, 1559, Pieter Bruegel the Elder.

THE EVOLUTION OF INDIVIDUALITY

LEO W. BUSS

1987

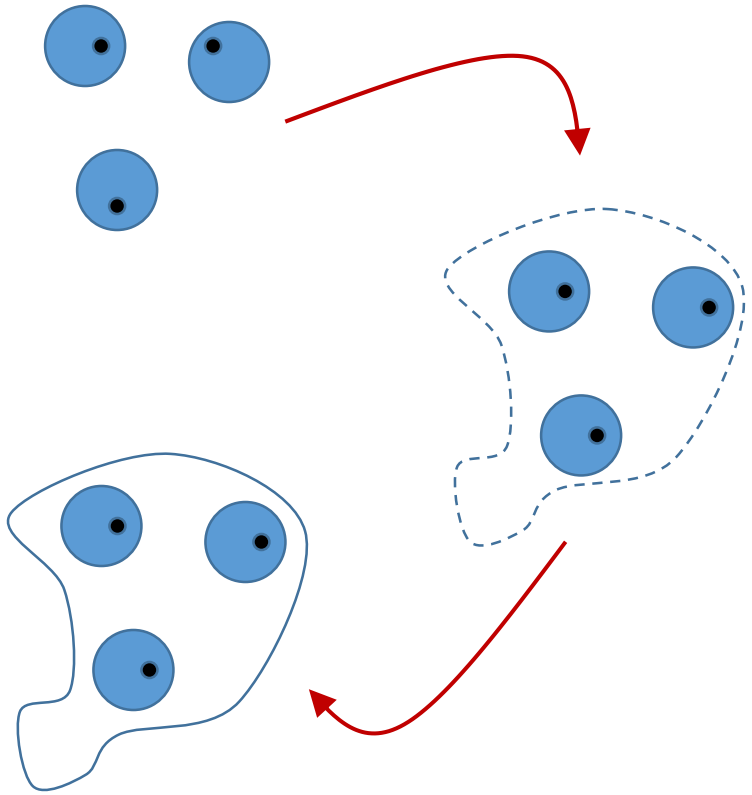
Transitions in Individuality



1. Replicating molecules -> Compartments
2. Independent replicators -> Chromosomes
3. RNA -> DNA + Protein
4. Prokaryotes -> Eukaryotes
5. Asexual clones -> Sexual populations
6. Protists -> Multicellular organisms
7. Solitary individuals -> Colonies
8. Primate societies -> Human language

Evolutionary transitions in individuality
=INDIVIDUATION

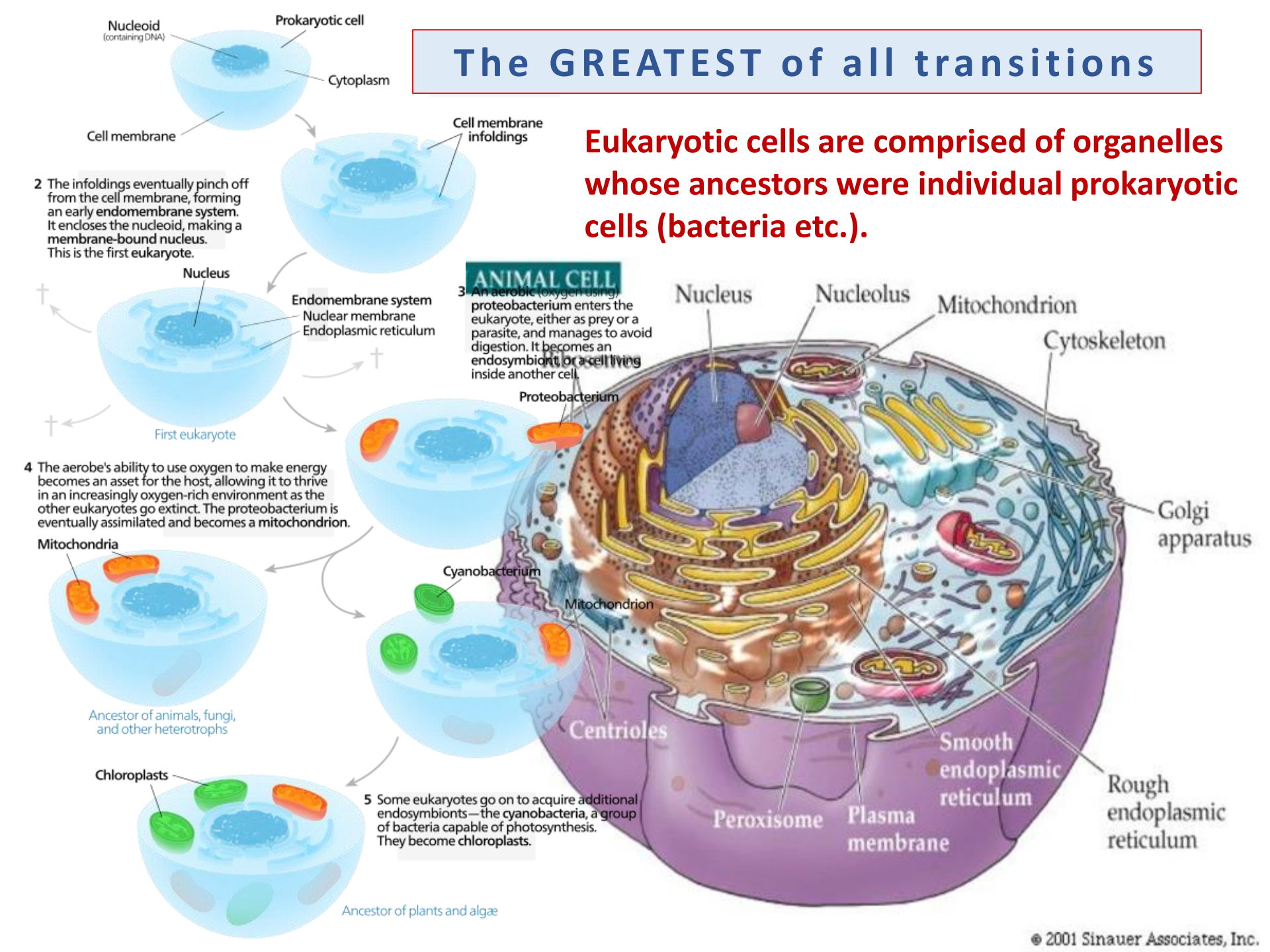
Biological units, previously existing as independent individuals, are incorporated within a higher level of organization, which becomes a new individual



Individual:
An entity capable of autonomous survival and reproduction

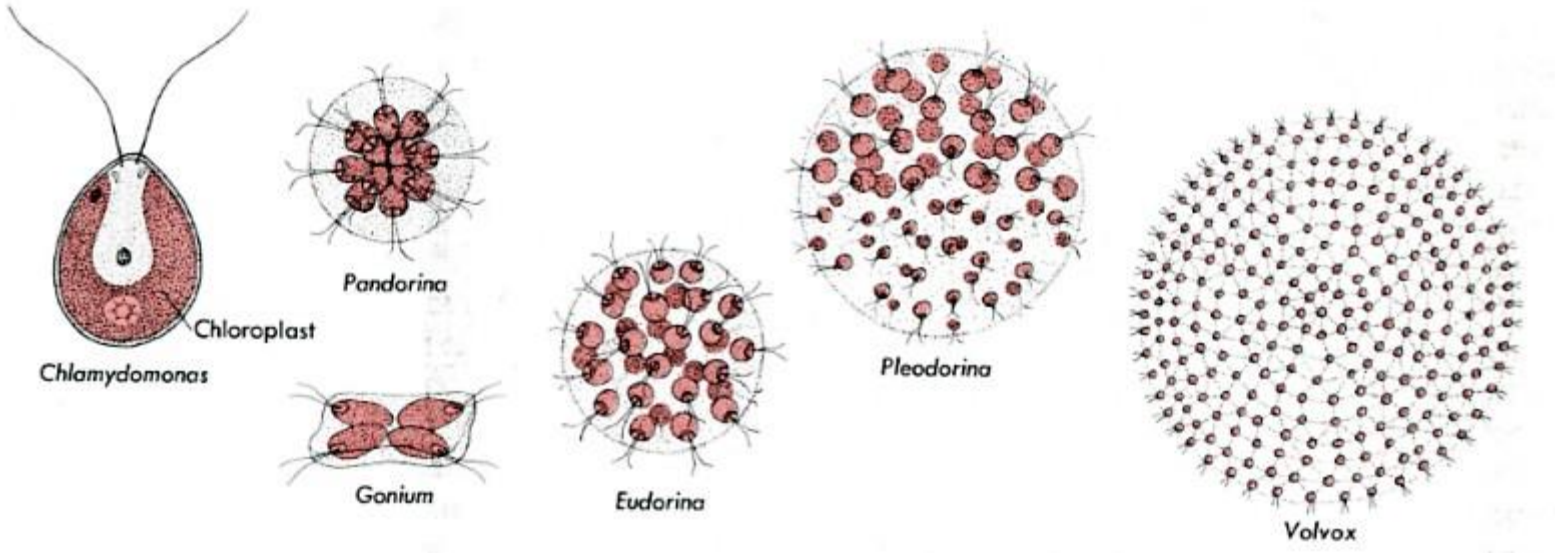
The GREATEST of all transitions

Eukaryotic cells are comprised of organelles whose ancestors were individual prokaryotic cells (bacteria etc.).



The origins of multicellular organsims

multicellular organisms are comprised of cells whose ancestors were individual unicellular organisms



Marine invertebrate colonies

The whole colony, composed of multicellular organsims, is (in some ways) a single individual

Insect colonies

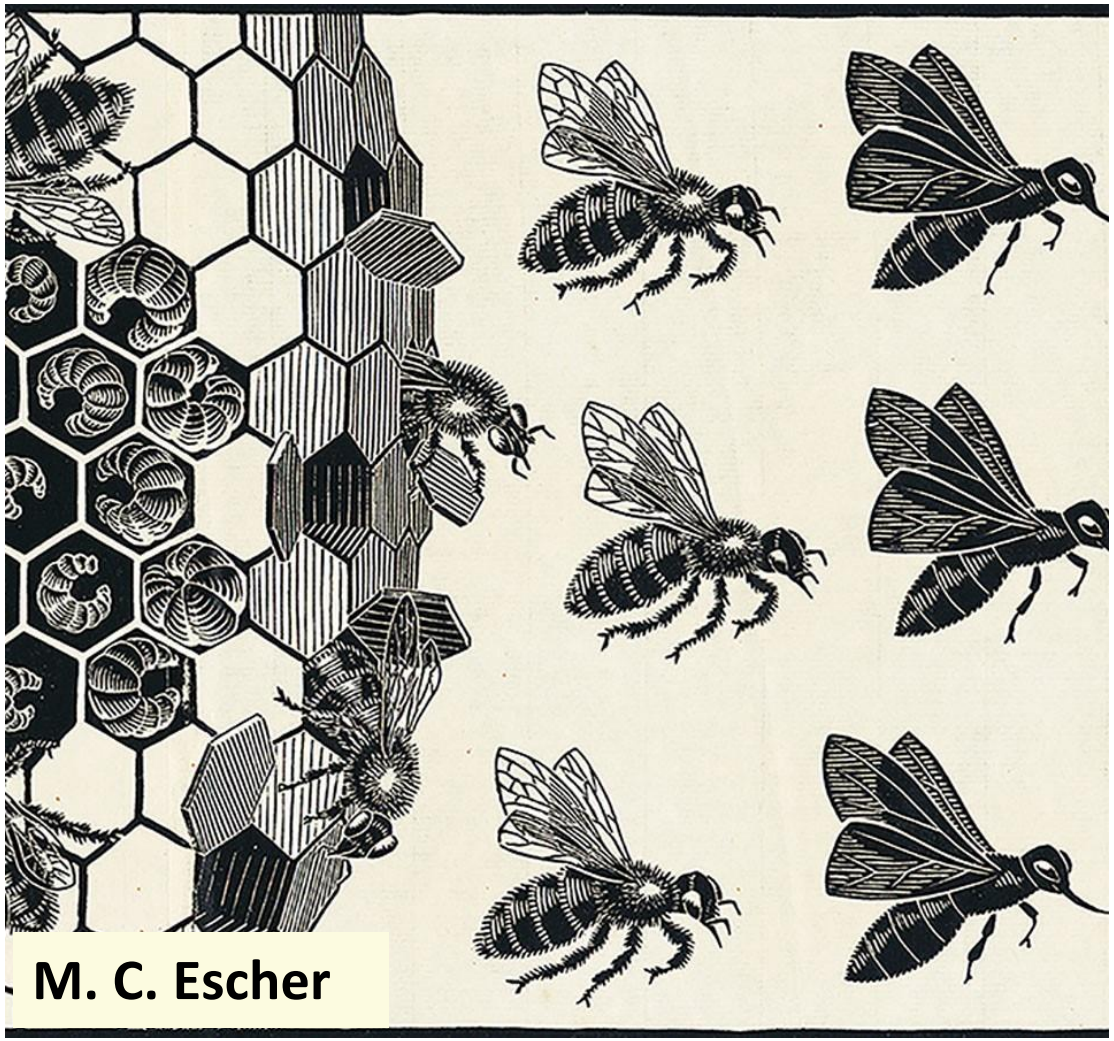
The whole colony is
(in some ways)
a single individual

Workers can be viewed as mobile equivalents of somatic cells in an organism.

- A single termite could not survive on its own, not even the queen.
- Only the colony as a whole is capable of survival and reproduction.
- The vast majority of the colony members do not reproduce.

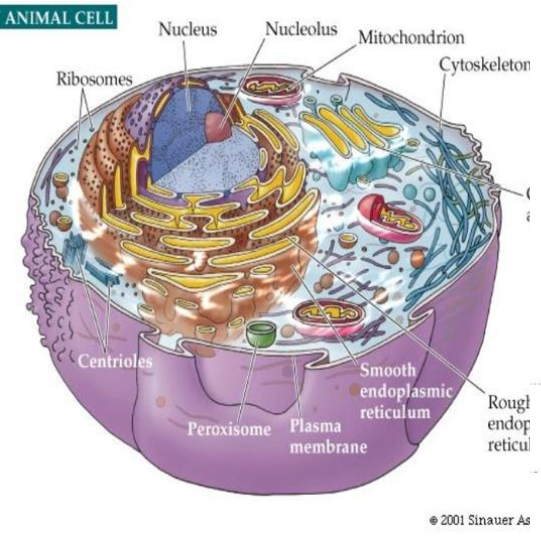
PART A:
Operationalizing major transitions

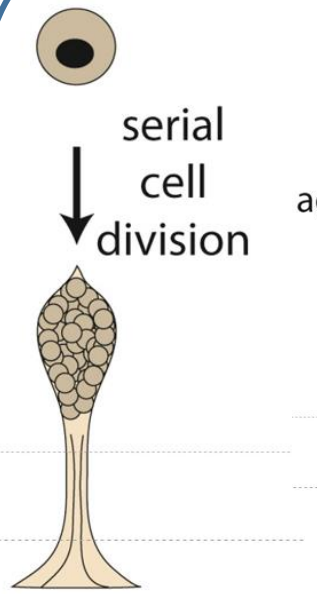
Yohay Carmel and Ayelet Shavit

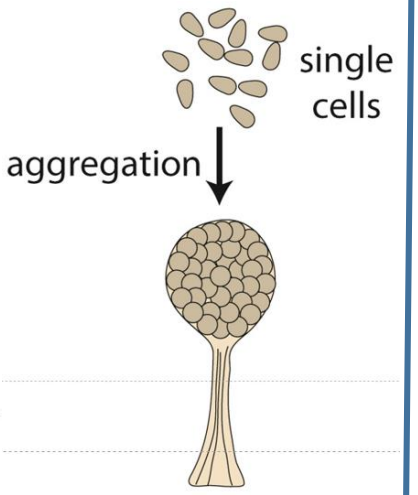


Comparing between transitions in individuality

	Eukarioticity	Multicellularity	Coloniality
Events	**single**	**numerous**	**numerous**
Partners	**different**	**identical**	**similar**
Motility of units	**-**	**-**	**+ (in some cases)**







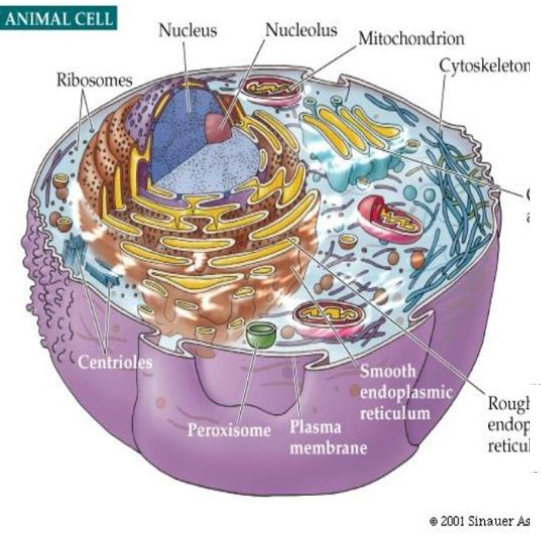
Comparing between transitions

Each transition was unique and
Substantially different from other transitions

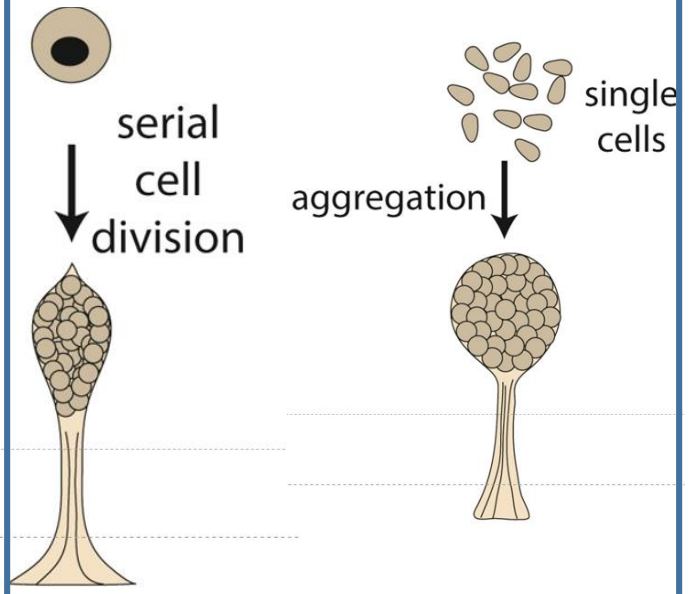
In view of these deep differences, what is the merit of comparing between major transitions ?

similarities may indicate essential elements in the process.

Eukarioticity



Multicellularity

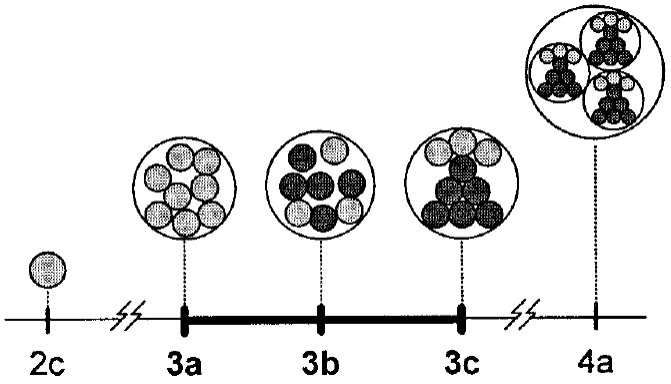


Coloniality

The goal: a quantitative description of transitions in individuality

The means:
operationalization* of this concept

*Operationalization: characterizing a fuzzy concept using **a set of measurable parameters**

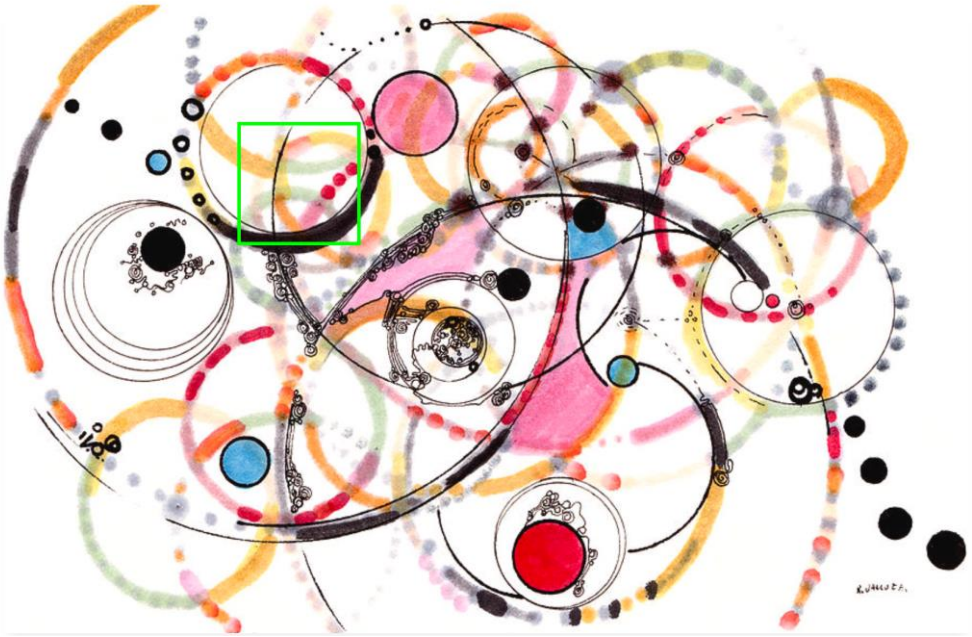


McShea 2001, Paleobiology

complexity-based operationalization

ETIs are characterized by increasing complexity

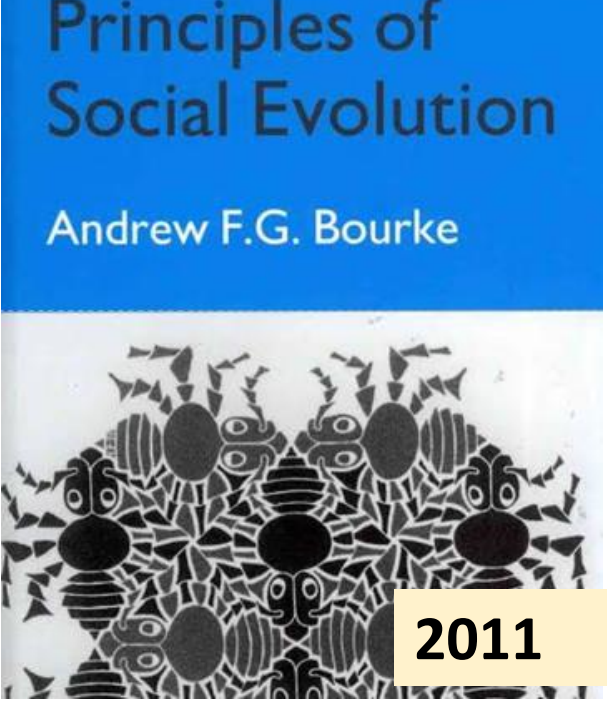
How to quantify complexity in living systems?

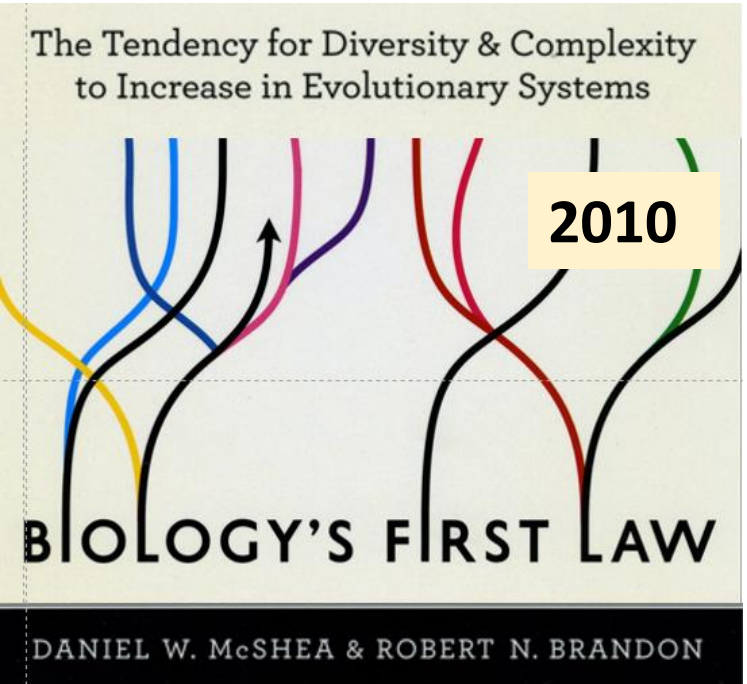


Buss 1987, *Evolution of individuality.*

Maynard Smith & Szathmary 1995 *The major transitions in evolution*.

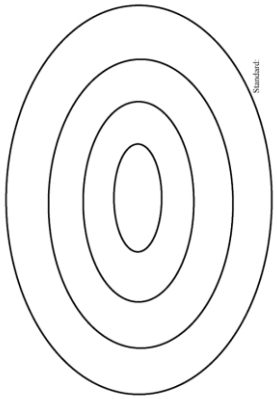
Operationalization Scheme for living systems -- inspired by three books

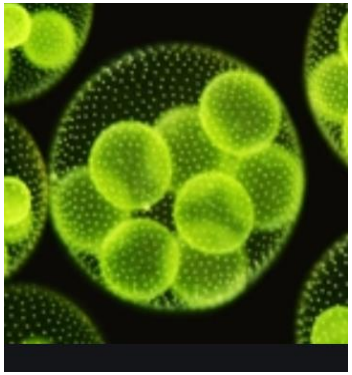




Operationalization Scheme for living systems

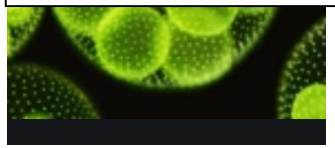
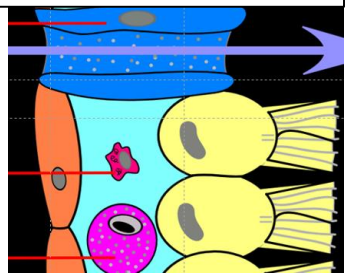
system size (number of units in lower level)	**connectivity** between units	**differentiation / heterogeneity** between units	**system depth** (number of levels)





Combining suggestions of McShea 2001, McShea & Brandon 2010, Herrera-Paz 2014, and Hanschen… and Michod 2017.

Operationalization Scheme for ETIs

System size (number of units in lower level)	**Connectivity** between units	**Differentiation** between units	**System depth** (number of levels)
System size	**Inseparability**	**Reproductive specialization**	**Non-reproductive Specialization**
The number of lower-level units 	the incapacity of lower-level units to survive and complete life cycles separate from the higher level	certain units of the system reproduce, others are incapable of reproduction 	there are at least two types of somatic units 

The transition to multicellularity -- Volvocines

General	Specific case-studies	System size (size of the individual)	Inseparability	Reproductive specialization	Non-reproductive Specialization
Algae	Tetrabaena	4	–	–	–
	Gonium sp.	16	+	–	–
	Pandorina	8-16	+	–	–
	Eudorina	32-64	+	–	–
	Pleodorina	128	+	+	–
	Volvox	10^4	+	+	–

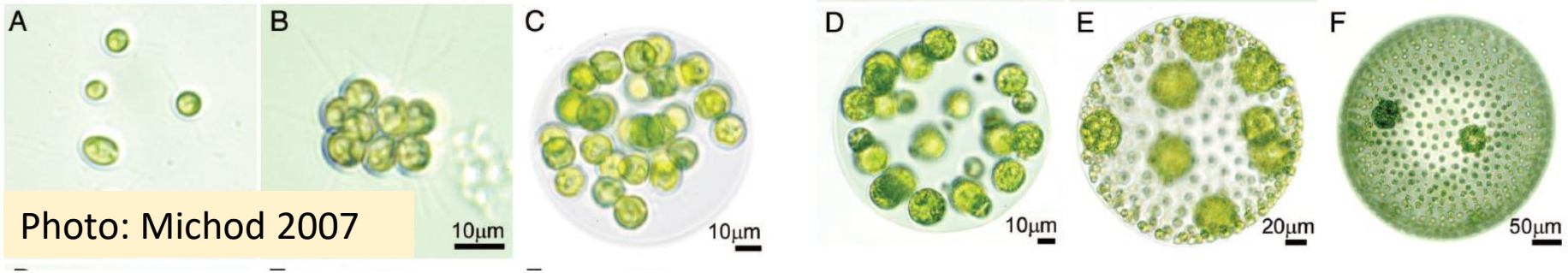
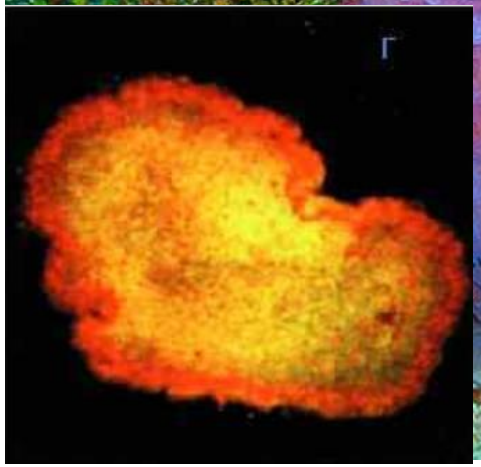


Photo: Michod 2007

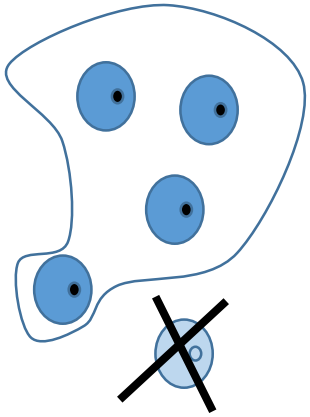
Multi-cellular organisms – others

General	Specific case-studies	System size (# of cells)	Inseparability	Reproductive specialization	Non-reproductive Specialization
Other Organisms	Slime molds	10^6	–	–	–
	Trichoplax	10^7	(?)	+	+
	sponges	10^{10}-10^{12}	+	+	+
	mammals	10^{10}-10^{15}	+	+	+



colonial organisms

General	Specific case-studies	System size (colony size)	Inseparability (queen replacement impossible)	Reproductive specialization (sterile workers)	Non-reproductive Specialization (worker polymorphism)
Eusocial colonies	Allodapine bees	10^1	–	–	–
	Halictine bees	10^2	–	–	–
	Naked mole rats	10^2	–	–	–
	Bumble bees	10^2	+	+/–	–
	Vespinae wasps	10^3	+	+	–
	Honey bees	10^4-10^5	+	+	–
	Termites	10^6	+	+	+
	Ants	10^6-10^9	+	+	+



Part a: conclusions

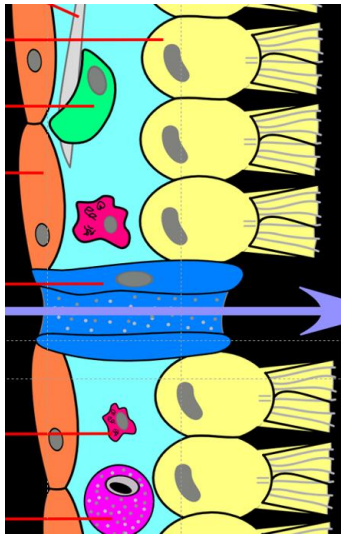
inseparability:

- Appears early in the process, either before- or together with reproductive specialization.
- Marks the turning point: a group becomes a new individual of a higher hierarchical level
- It ties together the fitness of all inseparable lower-level units, and assigns it to the fitness of the newly emerged higher-level individual
- Thus, it dictates conflict resolution
- It may be major driving force through the transition.

Part a: conclusions 2/2

size

- Size is a major predictor of complexity during ETIs.



non-reproductive specialization:

- Appears late in the process, only in systems > 10^6

PART B: Application to human society

“Flemish Proverbs”, zooming in. 1559, Pieter Bruegel the Elder.

An immense potential for cooperation

Mass singing
0:30—3:00

Playing and Marching
01:30—3:00

Dancing prisoners

humans as super-cooperators

human psychology is characterized by numerous behaviours that **make colonial life structures possible*, such as:**

Identification with a group

Integration of individuals via:

Unity of action

Commun-ication

Mechanisms to resolve individual-society conflicts in favor of the higher level

*Kesebir, 2012, How and When Human Groups Are Like Beehive. *Personal. Soc. Psychol. Rev.*

On the other hand…

Human societies are also characterized by selfishness, conflict, and competition. They differ from superorganisms in fundamental ways.

'Are We Stalled Part Way Through A Major Evolutionary Transition From Individual To Group?'
Stearns, *Evolution* 2007.

Well… no. Not stalled at all.
Not even for one minute.

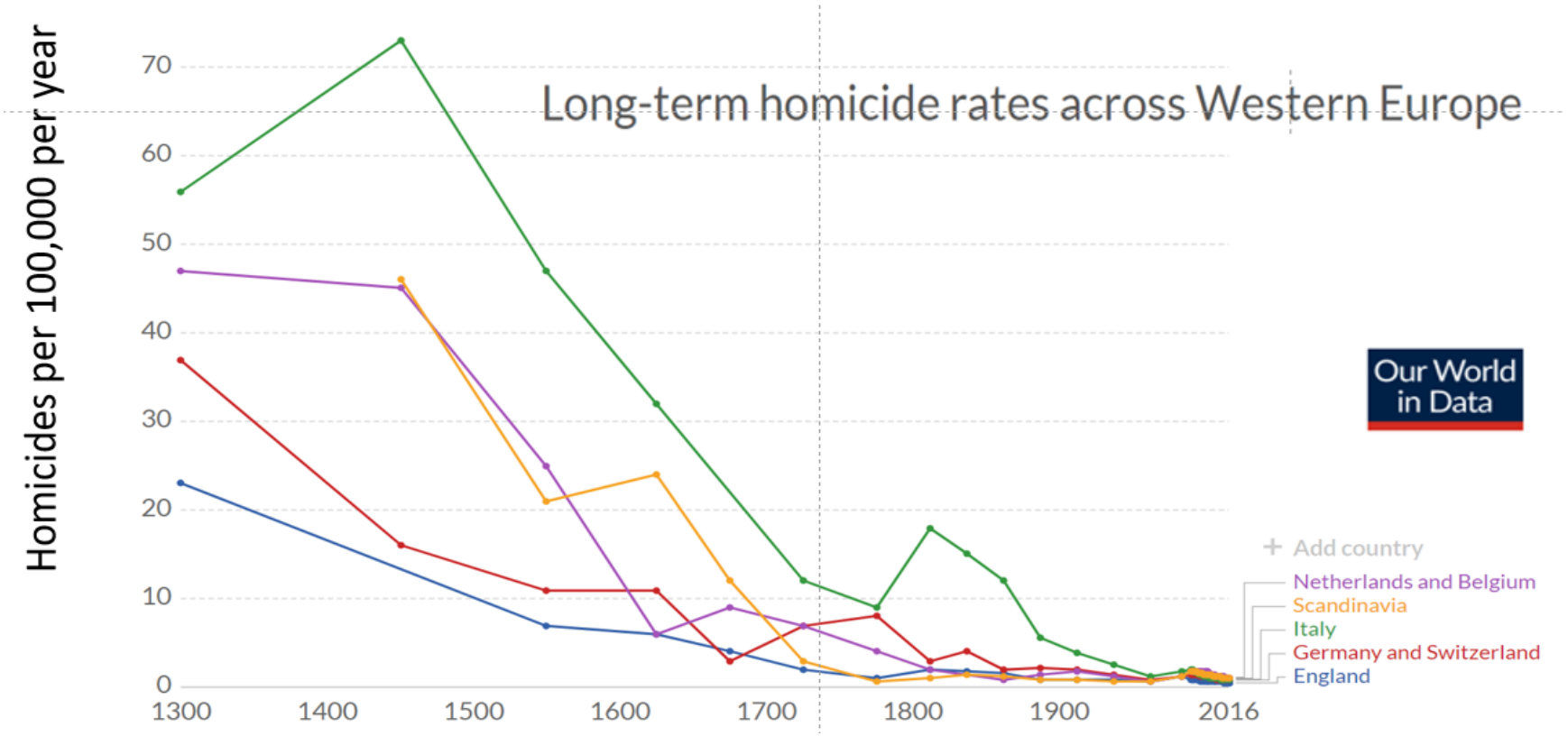
Cultural- and Socio-technological evolution

An evolutionary transition may take millions of years to complete

cultural- and socio-technological evolution operates much faster

BUT…

People may change radically -- as society changes



Society as a primeval organism

Some subsystems are clear analogies of organismic subsystems

Public transportation
(circulation systems)

Electronic communication
(nervous system)

Legal system, policing, defense forces
(immune system)

History of human systems

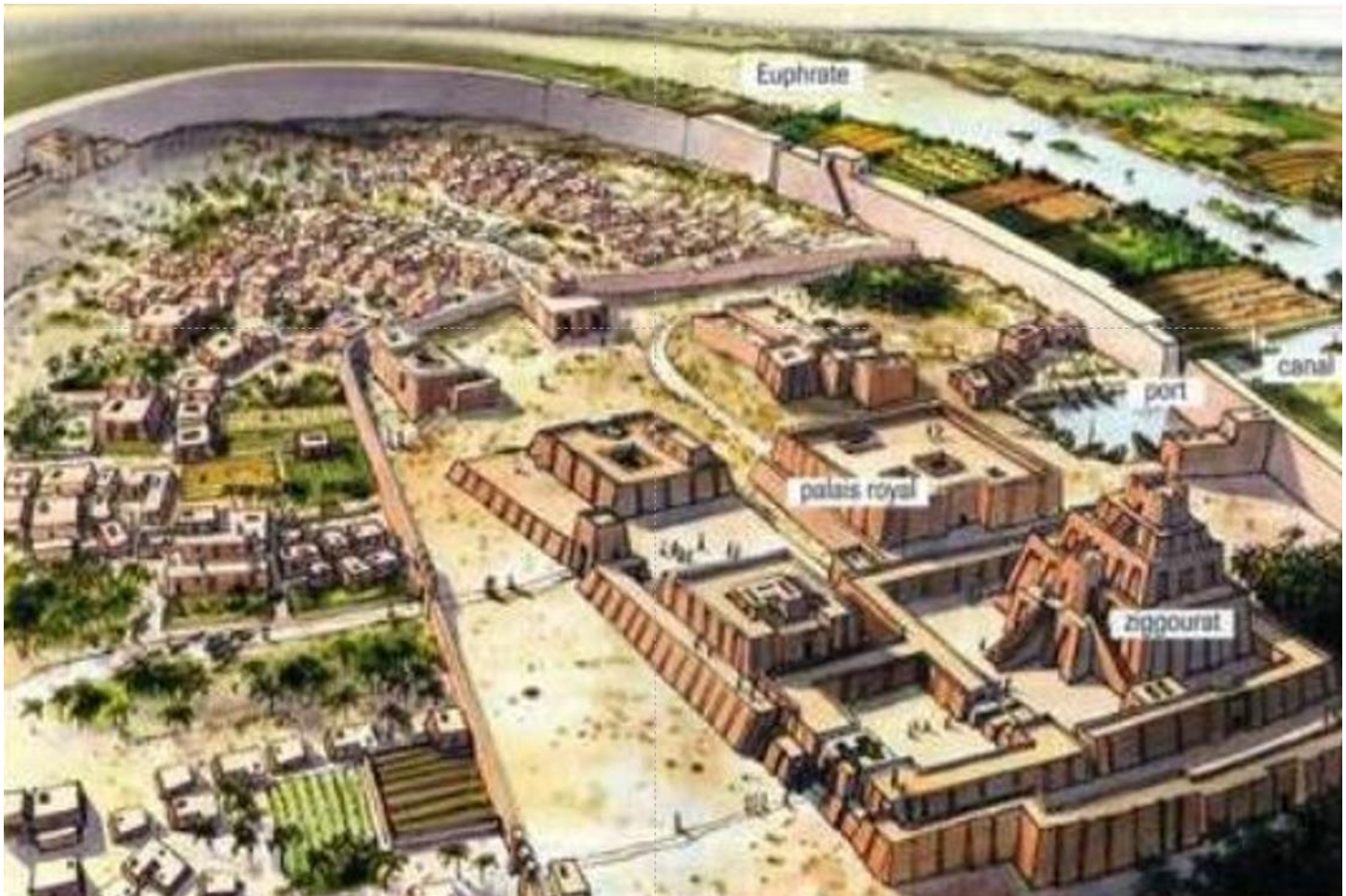
During the last 10,000 years, human society becomes ever more complex:

- Network of ties is denser
- Society is larger
- Division of labor and specialization increase
- Inseparability* increases

*Inseparability is the incapability of an individual or of a small subgroup to survive on their own as an independent entity, disconnected from the rest of the society.

Hunter-gatherer societies, $10^2 - 10^3$

First Mesopotamian city-states, ~3000 BC, 10^4



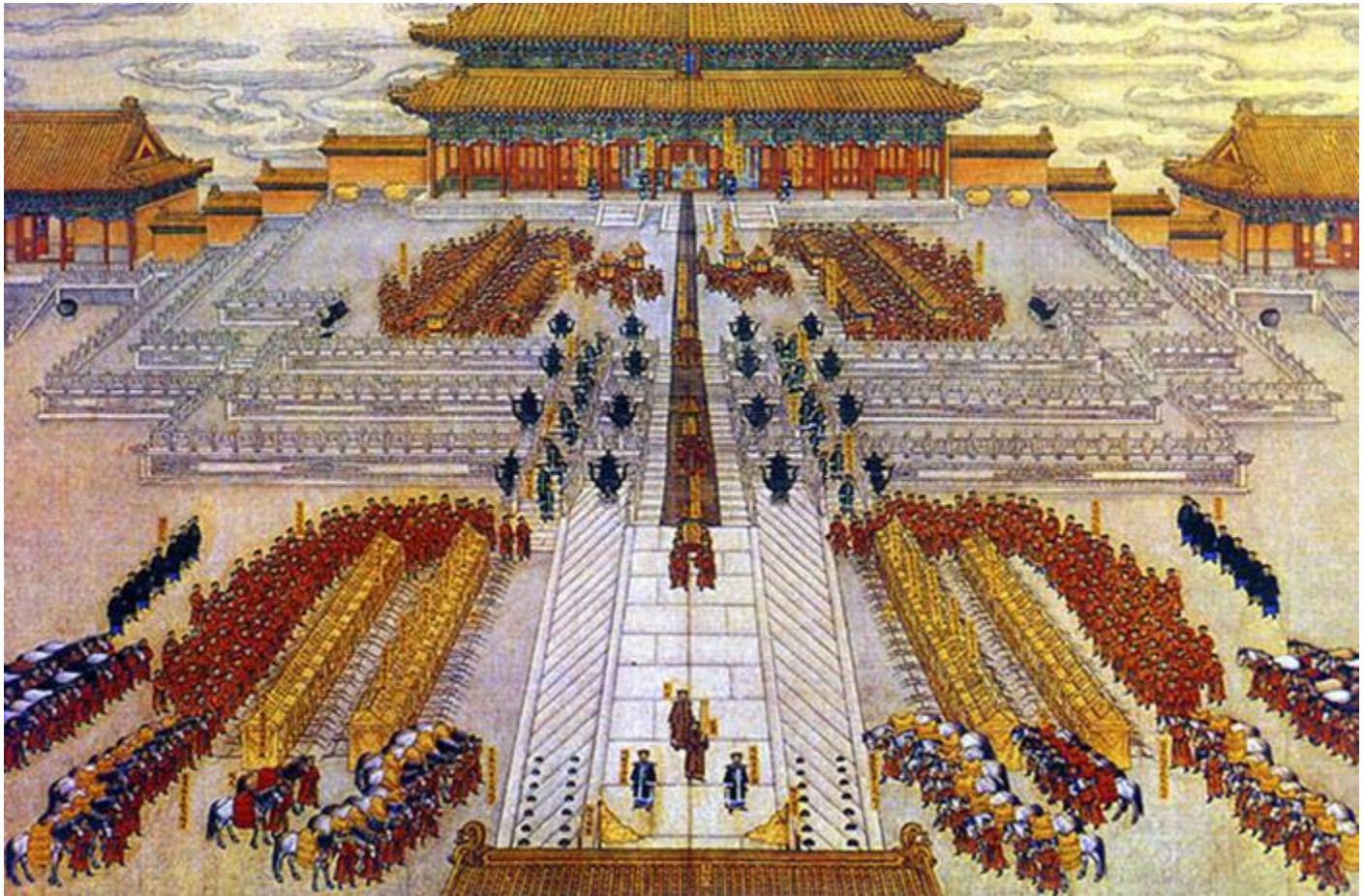
Sumer, ~2500 BC, 10^5

Akkadian Empire, ~2300 BC, 10^6

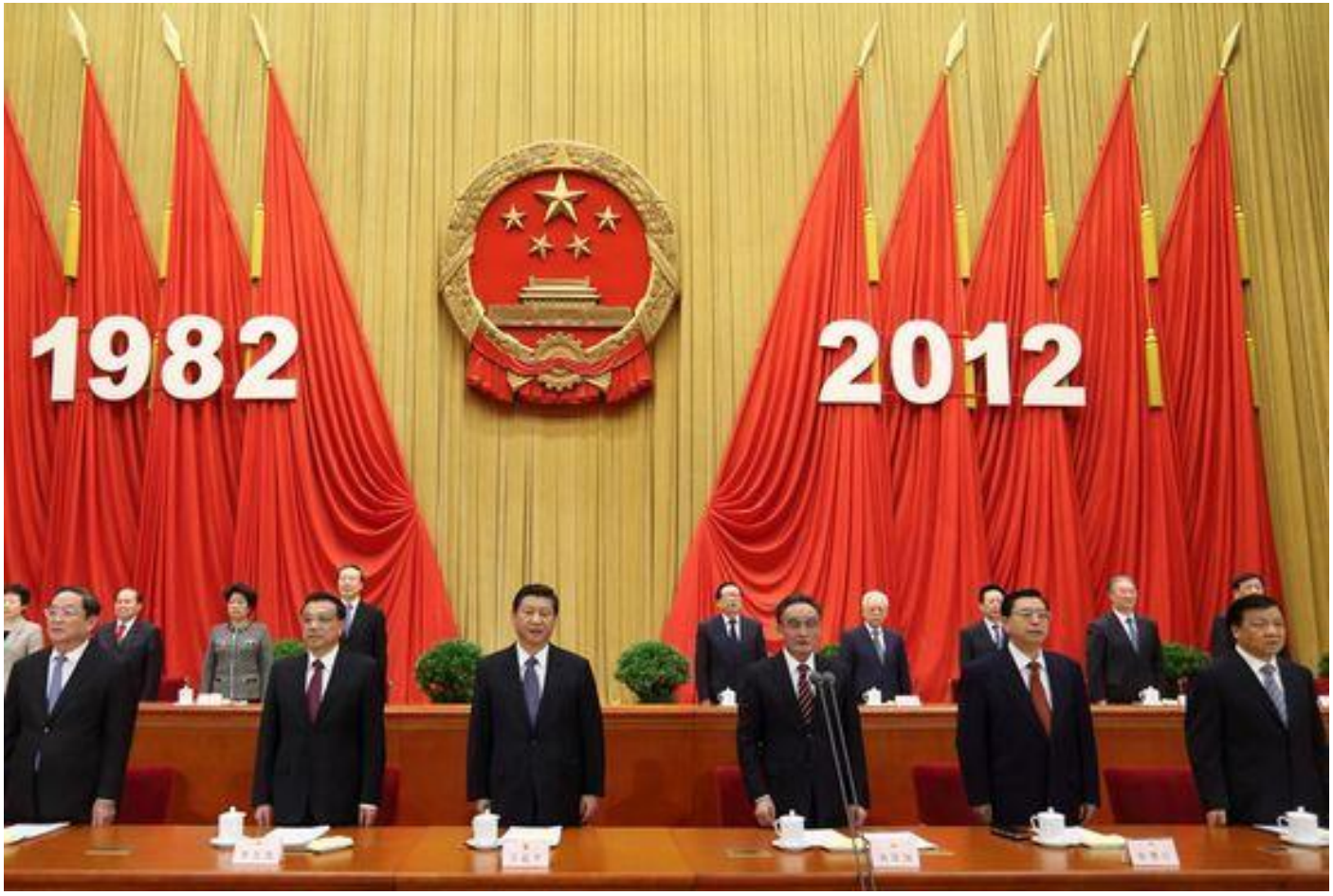
The Persian Empire, ~500 BC, 10^7, est. 17-35 millon

Not much changed during the next 2000 years, Rome and China fluctuated below 100 millions

China, ~1500 AD, 10^8



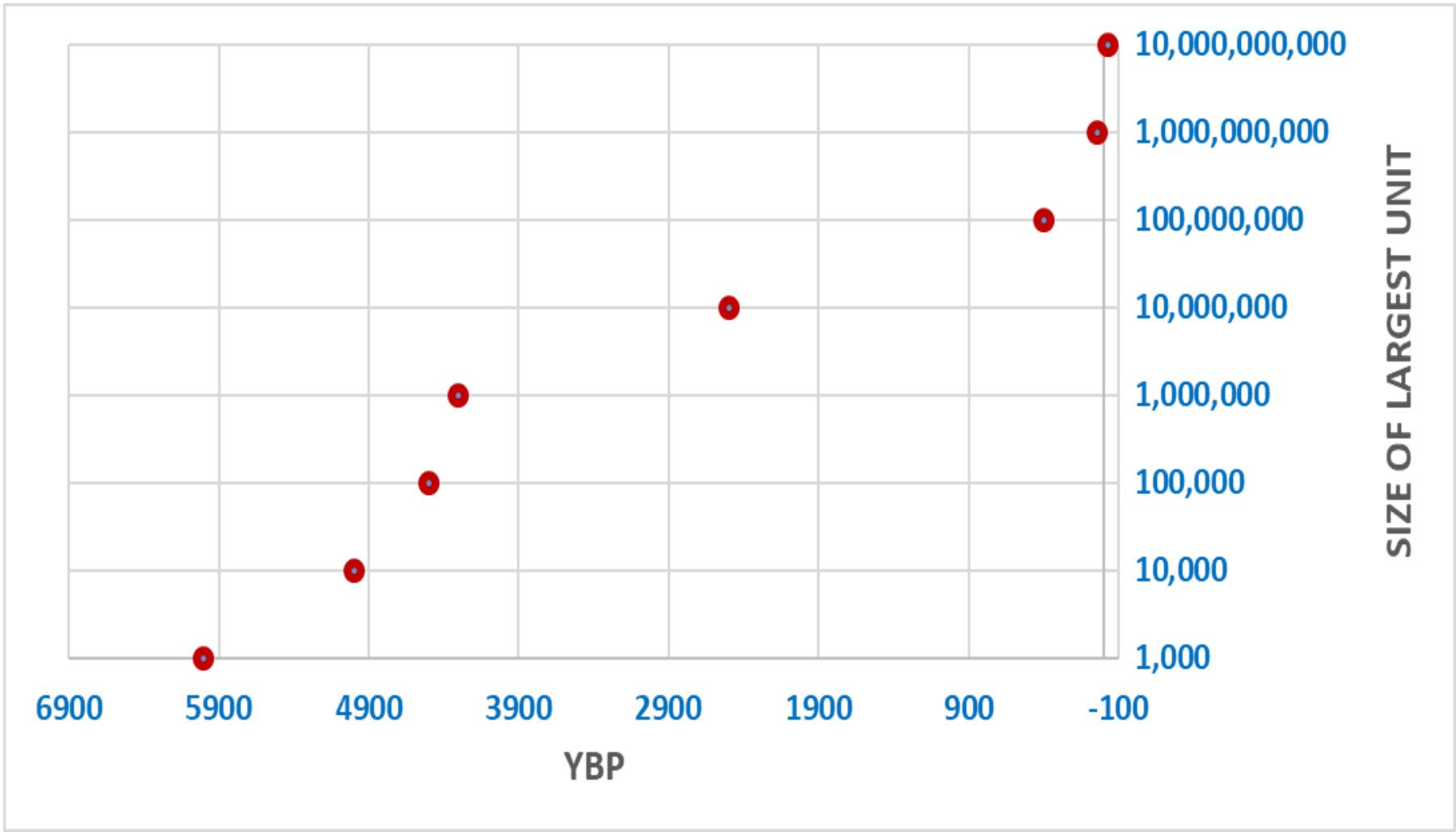
China, 1982, 10^9



The global village, 2050, 10^{10}

GOAL: to evaluate human societies across time in the context of major transitions

Let us look at the largest socio-economic-administrative unit at any given time



GOAL: to evaluate human societies across time in the context of individuation

system complexity
during the history of human societies

System size	Inseparability	Reproductive specialization	Non-reproductive Specialization

Change in human societies

General	Specific case-studies	System size (largest social unit)	Insep-arability	Reproductive specialization	Non-reproductive Specialization
Human societies	10000 BC	10^2-10^3	–	–	V
	3000 BC	10^4	–	–	V
	2500 BC	10^5	–	–	V
	2300 BC	10^6	–	–	V
	500 BC	10^7	–	–	V
	1500 AD	10^8	–	–	V
	1982 AD	10^9	V	–	V
	2050 AD	10^{10}	V	–/?	V

PART B: CONCLUSIONS

With time, human society is becoming more complex and more individuated.

By now, society has **V** for three of four indicators of individuation:

size, inseparability, and nonreproductive specialization.

We are individuals, living in an age of individuality.

The notion that humans may give up individuality and become incorporated within a higher level entity, seems inconceivable.

Our individual freedom may be growing in recent centuries.

We move freely all over the globe; we **feel** as autonomous as we could possibly be.

Yet, ask any cell:

‘are you autonomous?’

– ‘you bet I am!’.

PREDICTIONS

We could argue about this process endlessly.
Alternatively, we can make predictions and see how well they fit reality.

Here is a single example of a testable prediction:

Human—society conflicts of interest would increasingly be resolved in favor of the collective.