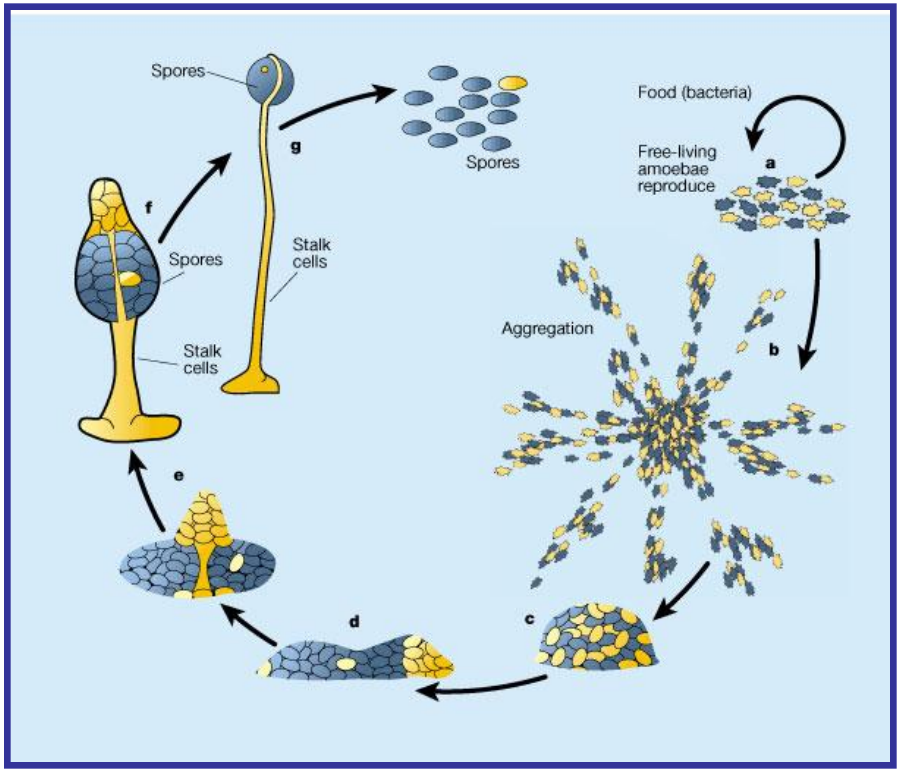
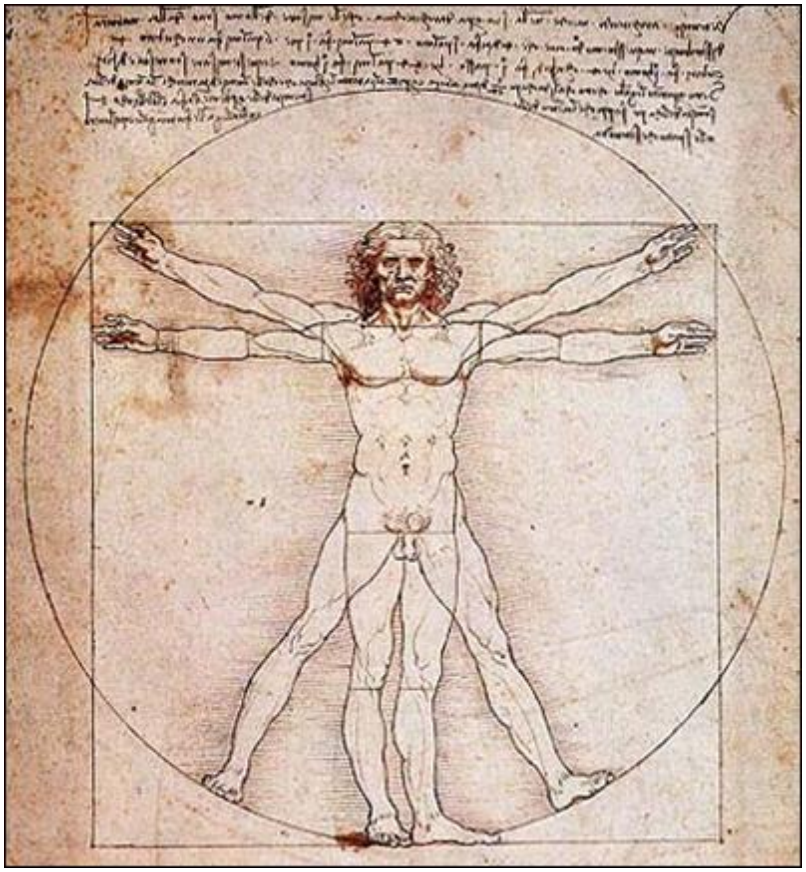
What is an organism?

David C. Queller
Joan E. Strassmann
Washington University in St. Louis



Paradigm organisms



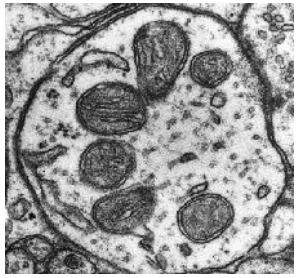
- Functional integration
- Physical contiguity
- Indivisibility
- Genetic uniformity
- Development from a single cell
- Genetic co-transmission
- Membership in the same species
- Early germ-soma separation
- Stable membership

Sociality and cooperation

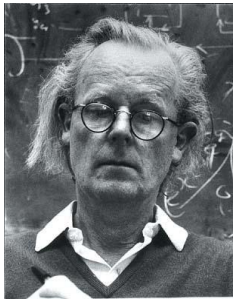
The major transitions of life have increased cooperation at higher levels while reducing conflict at lower ones

Gene

Prokaryotic cell



Eukaryote Cell



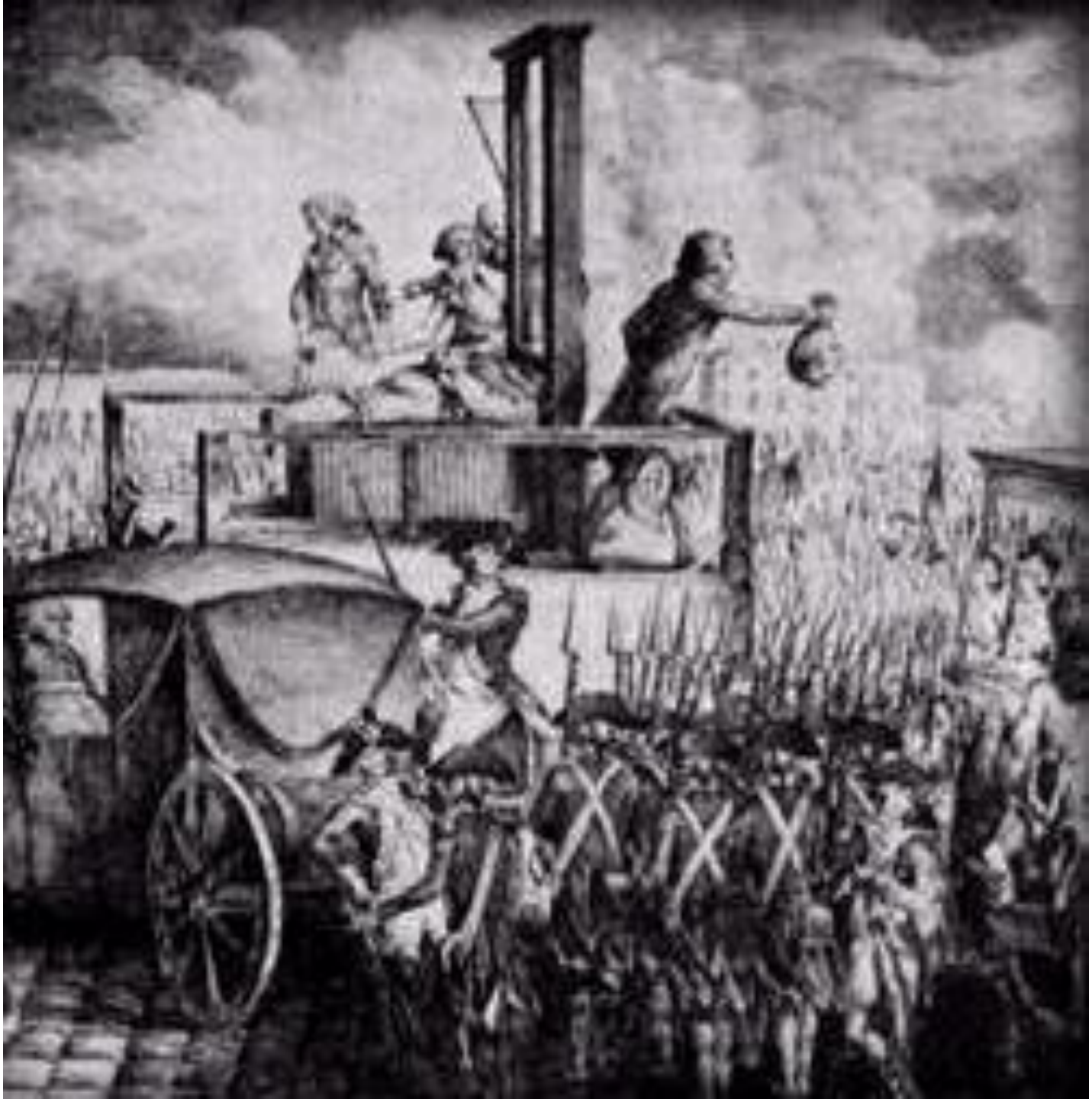
Individual

Superorganism

Liberté, egalité, fraternité

	Fraternal	**Egalitarian**
Examples	Individuals in colonies, Cells in individuals, Same organelles in cells	Nucleus and organelles, Sex, Genes in chromosomes
Units	Like, exchangeable	Unlike, not exchangeable
Reproductive division of labor	Yes	No
Initial advantage	Economies of scale	Division of labor
Control of conflicts	Kinship	Mutual dependence
Increase in complexity	Epigenesis	Symbiosis

Queller 1997 *Q. Rev. Biol.* 72:184-188



The social organism

High (*actual*) cooperation among parts
and
Low (*actual*) conflict among parts

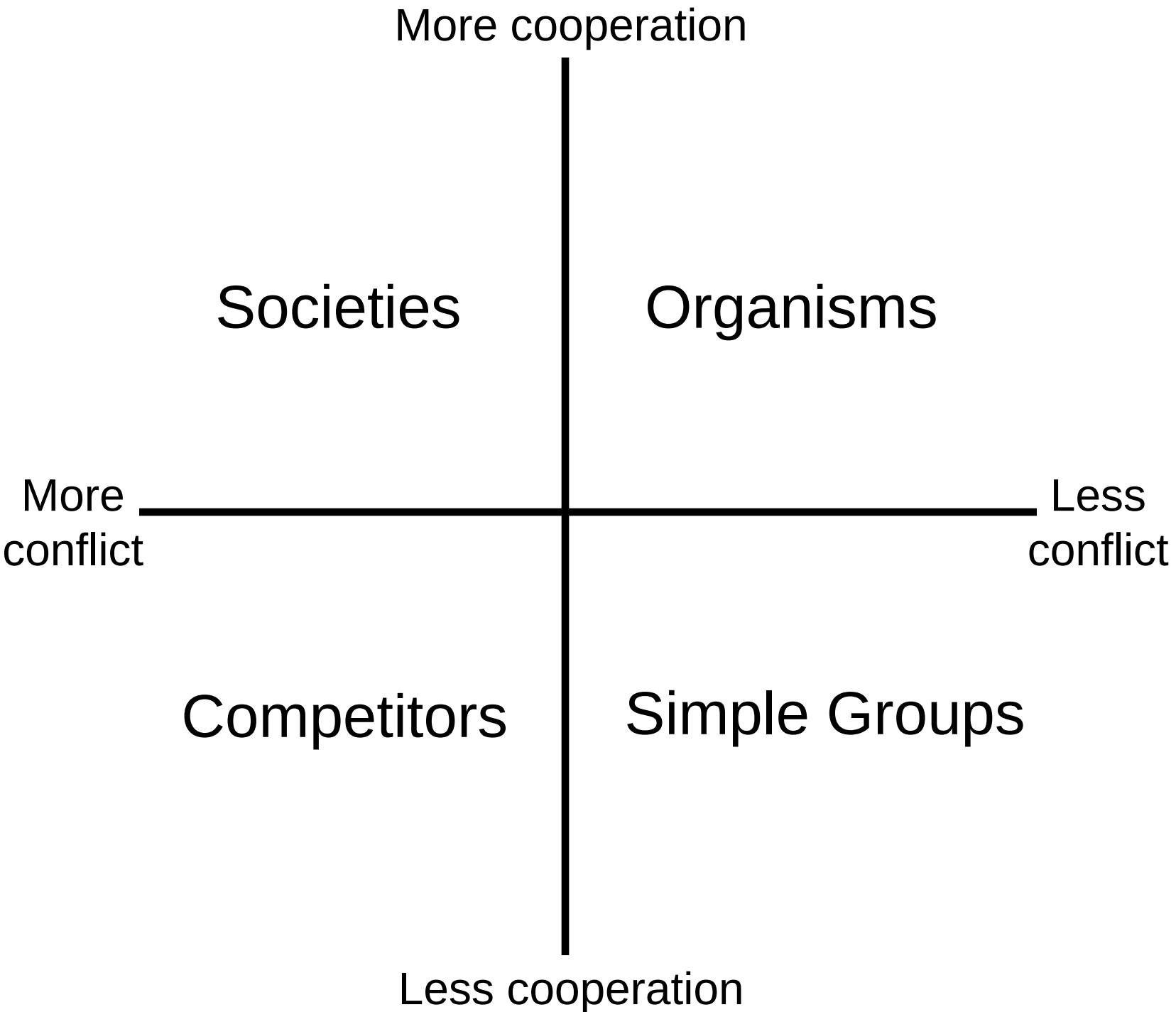
A consolidated bundle of adaptations

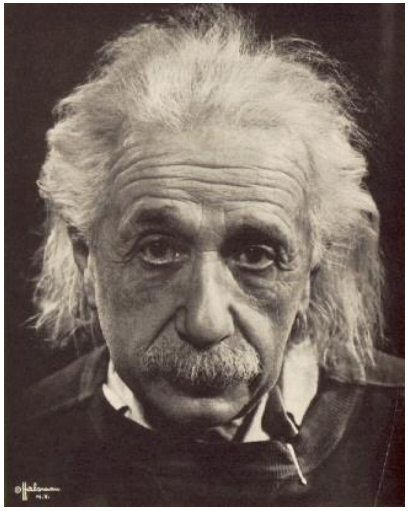
The organism is a unit of
near unanimous design

Actual or potential cooperation and conflict

Potential cooperation and conflict can be assessed via degree of genetic similarity, degree of interdependence, degree of co-reproduction

But those are more properly viewed as theoretical explanations for actual behavior

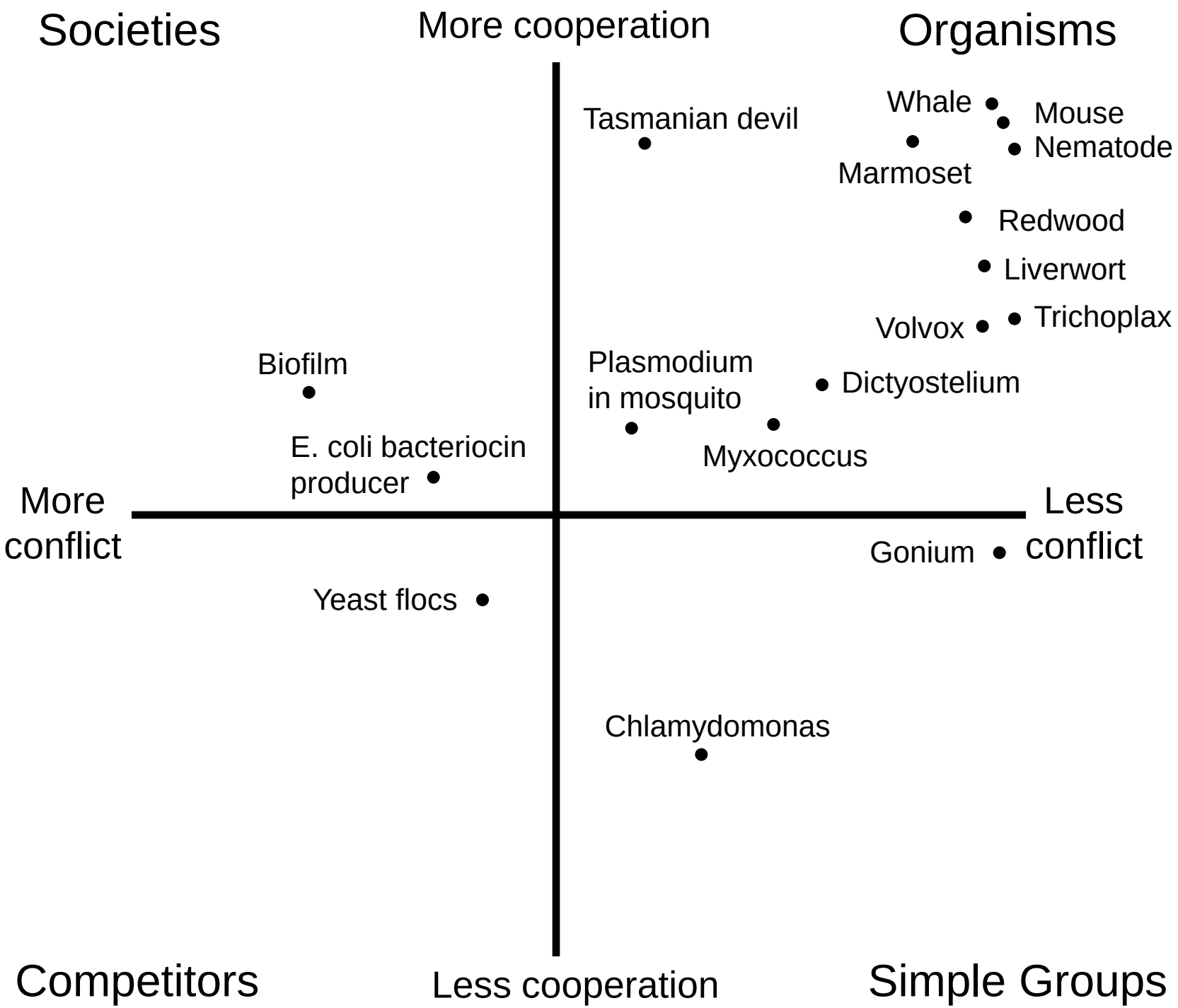

More cooperation
Societies
Organisms
More conflict
Less conflict
Competitors
Simple Groups
Less cooperation



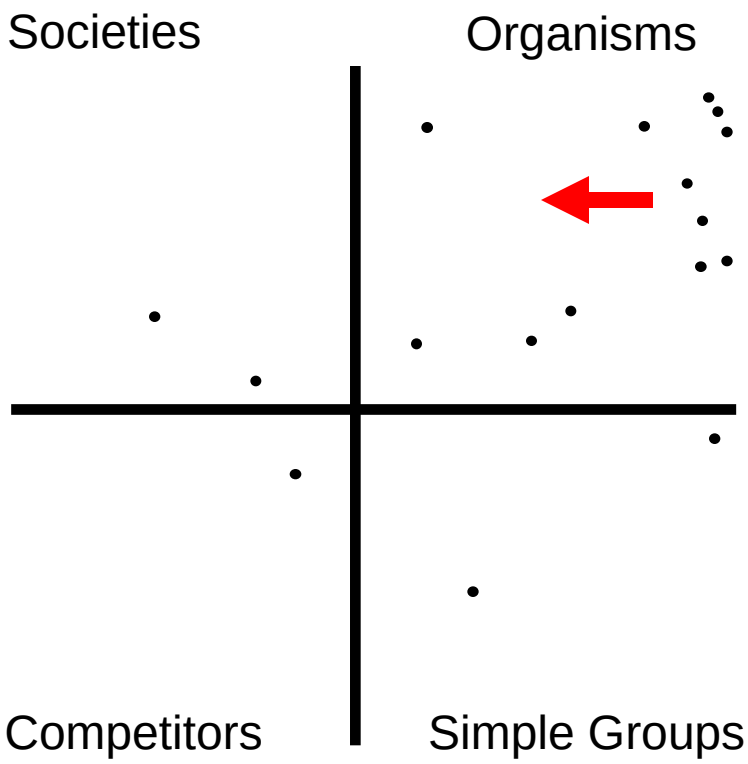
Why do we care?

- Highest form of social cooperation
- Most salient features of the organization of life
  - Adaptation - different from chemistry/physics
  - Tend to be bundled
- Major transitions

Groups of cells


Societies
More cooperation
Organisms
Tasmanian devil
Whale
Mouse
Nematode
Marmoset
Redwood
Liverwort
Volvox
Trichoplax
Biofilm
Plasmodium
in mosquito
Dictyostelium
E. coli bacteriocin
producer
Myxococcus
More
conflict
Less
conflict
Gonium
Yeast flocs
Chlamydomonas
Competitors
Less cooperation
Simple Groups

Currently ignoring conflict *between genes*



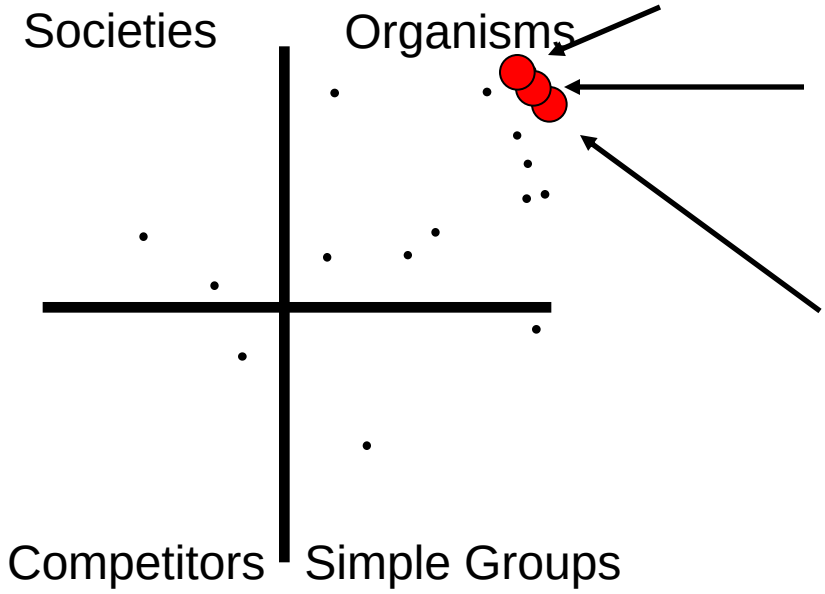
Meiotic drive

Imprinting

Transposition

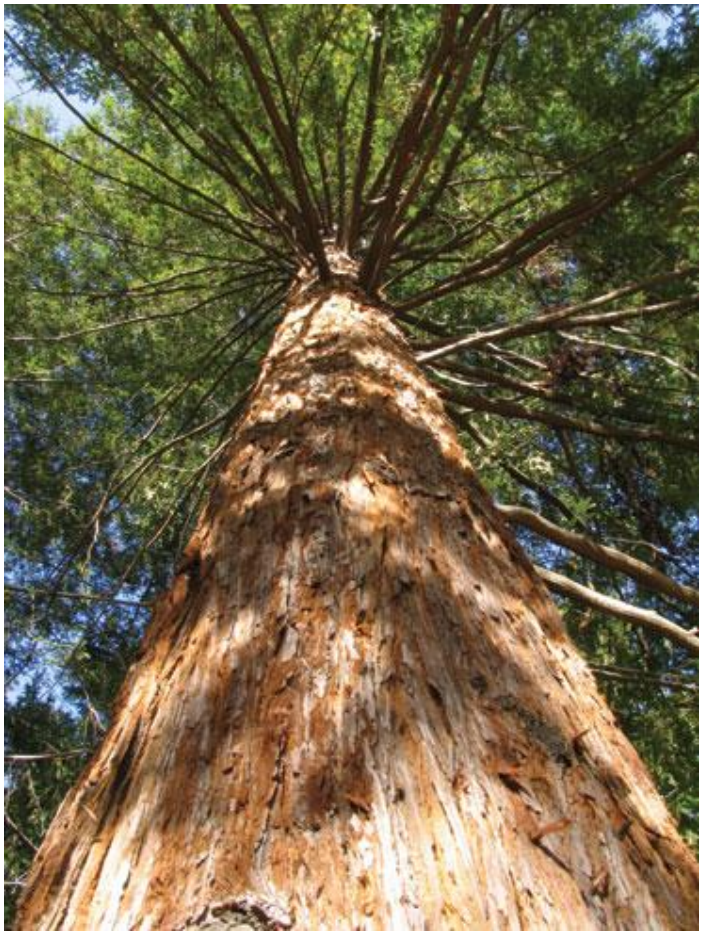
Cytoplasmic male sterility

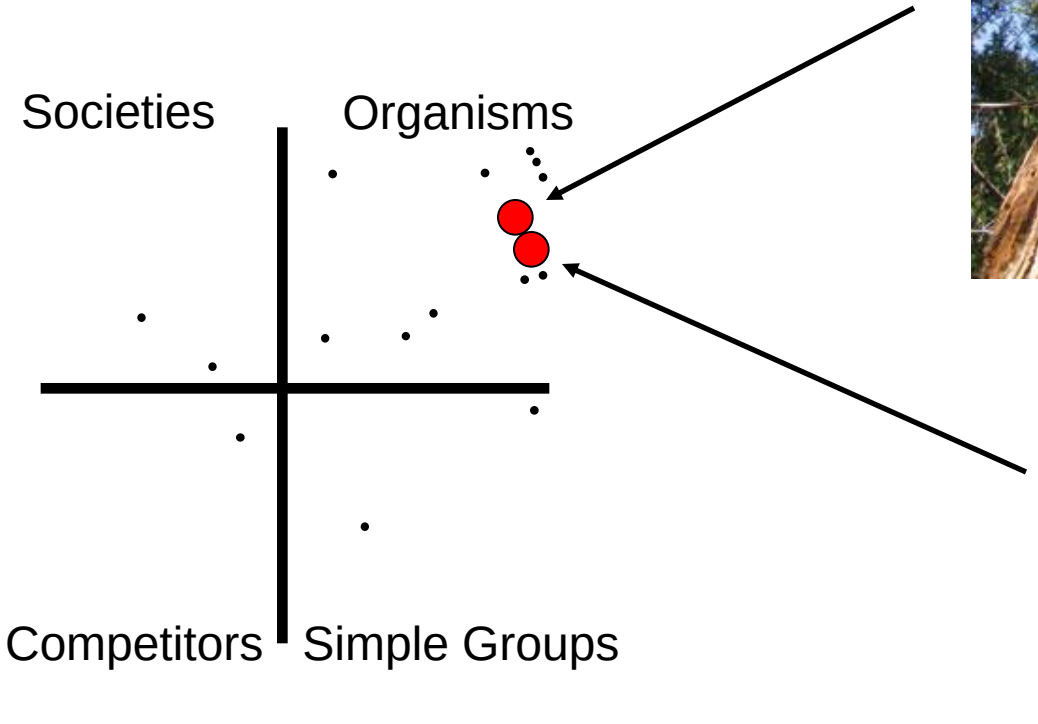
Whale
Mouse
Nematode



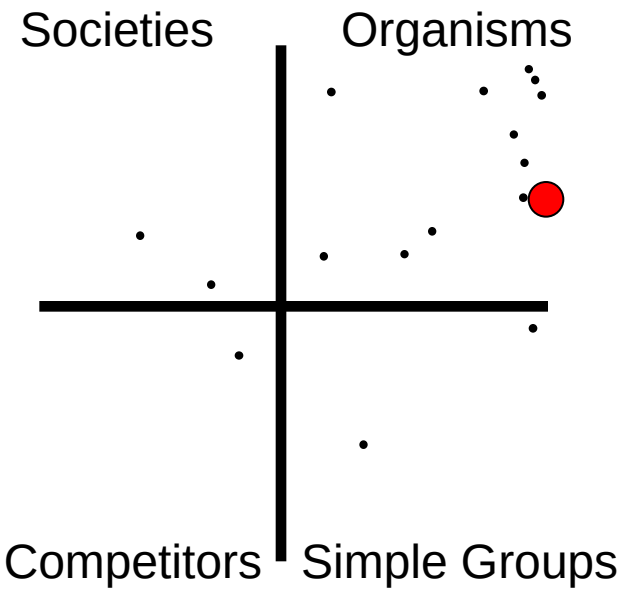
Only cell conflicts considered

Redwood, Liverwort

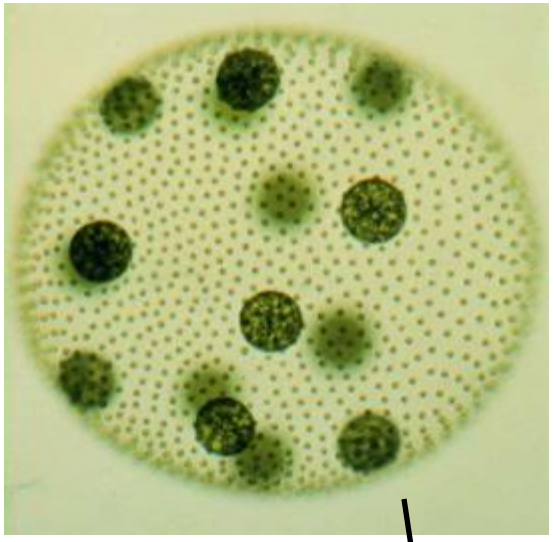


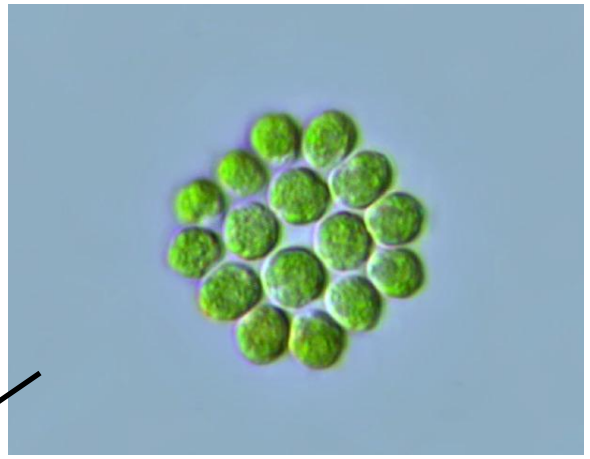


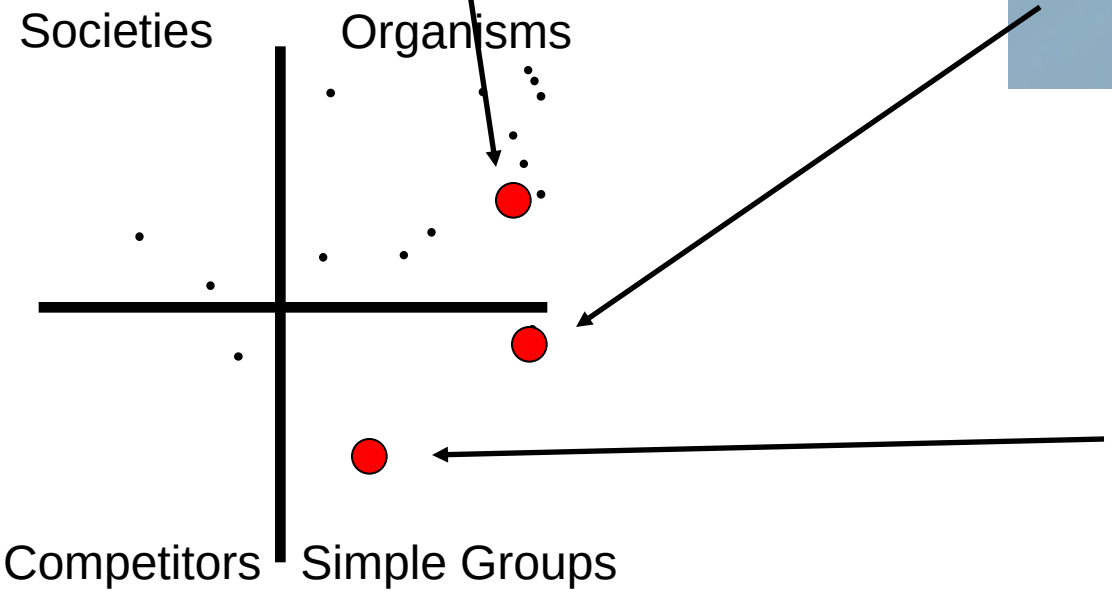
Trichoplax

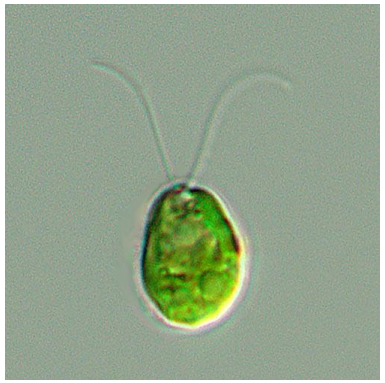


Volvox, Gonium, Chlamydomonas

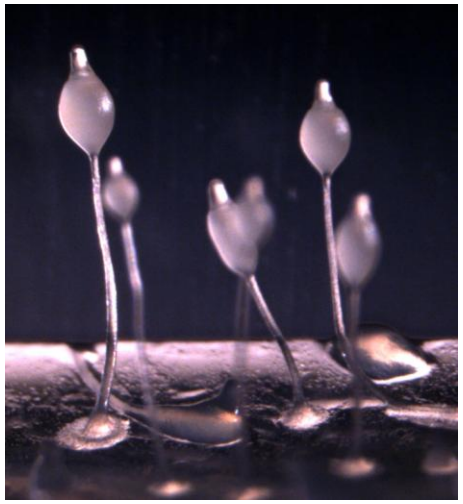


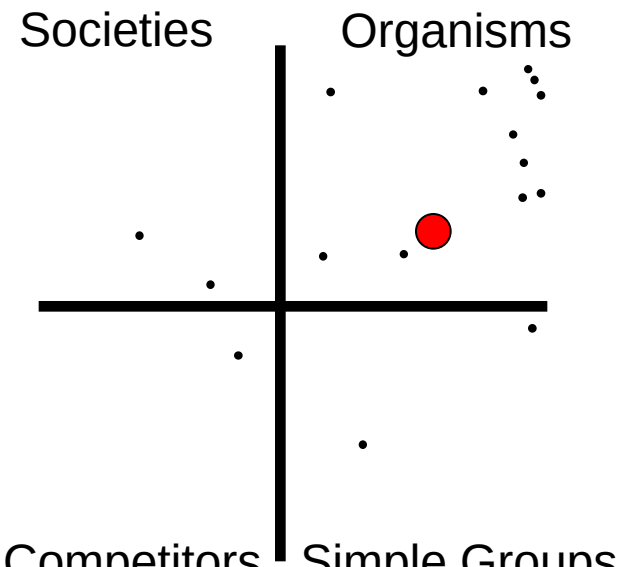


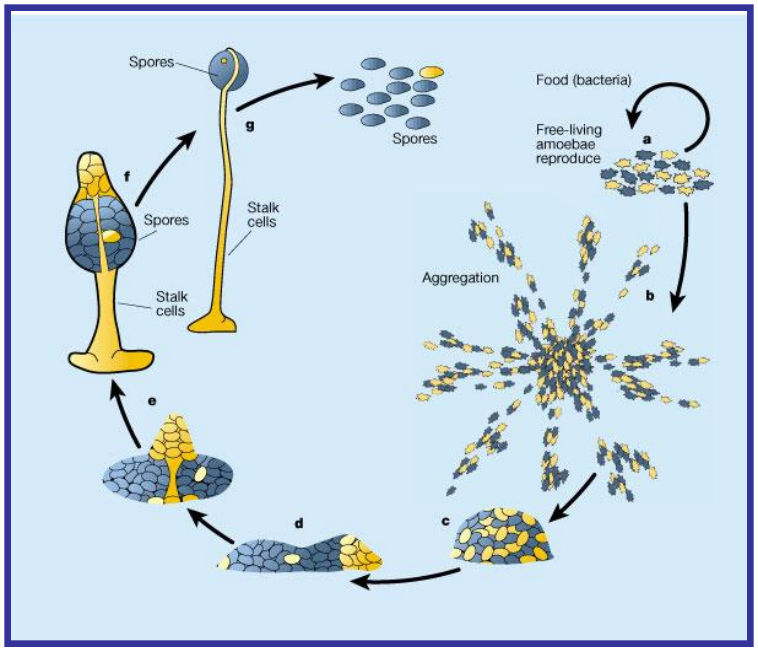




Dictyostelium

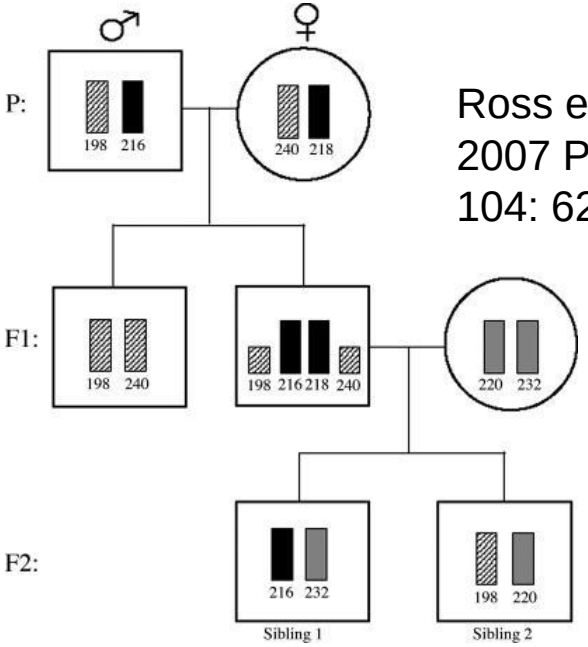




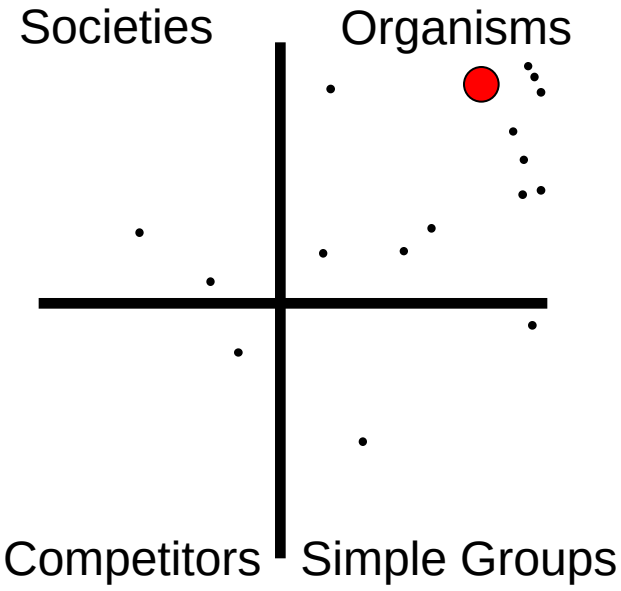


Organism by aggregation

Marmosets

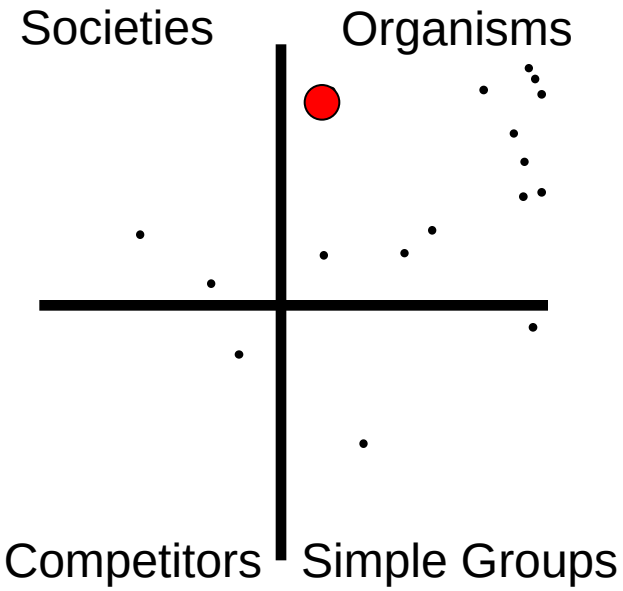


Ross et al
2007 PNAS
104: 6278



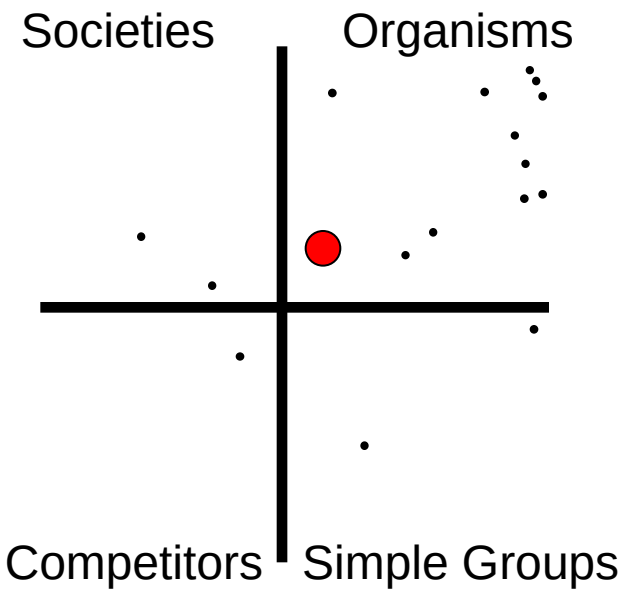
Fraternal twins chimeric
Some within-individual conflict?

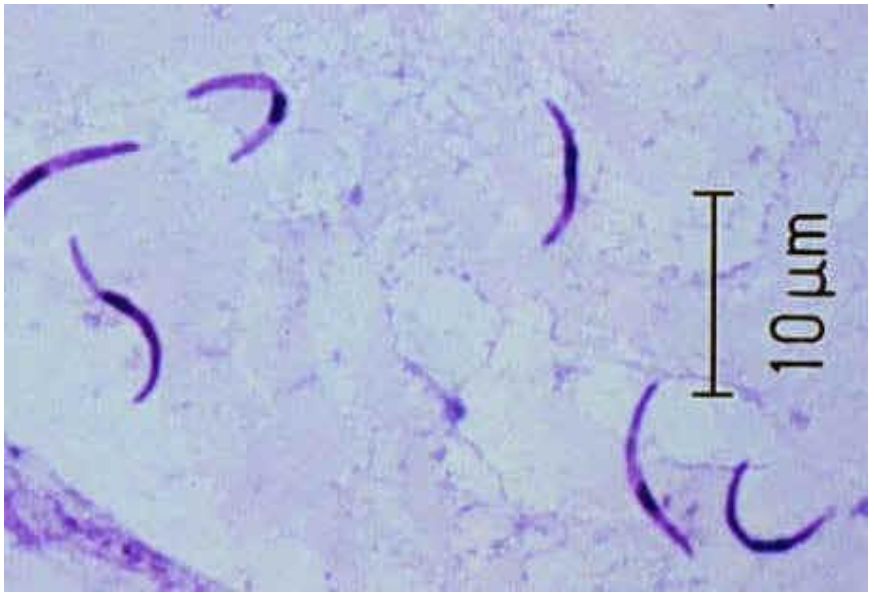
Tasmanian devil



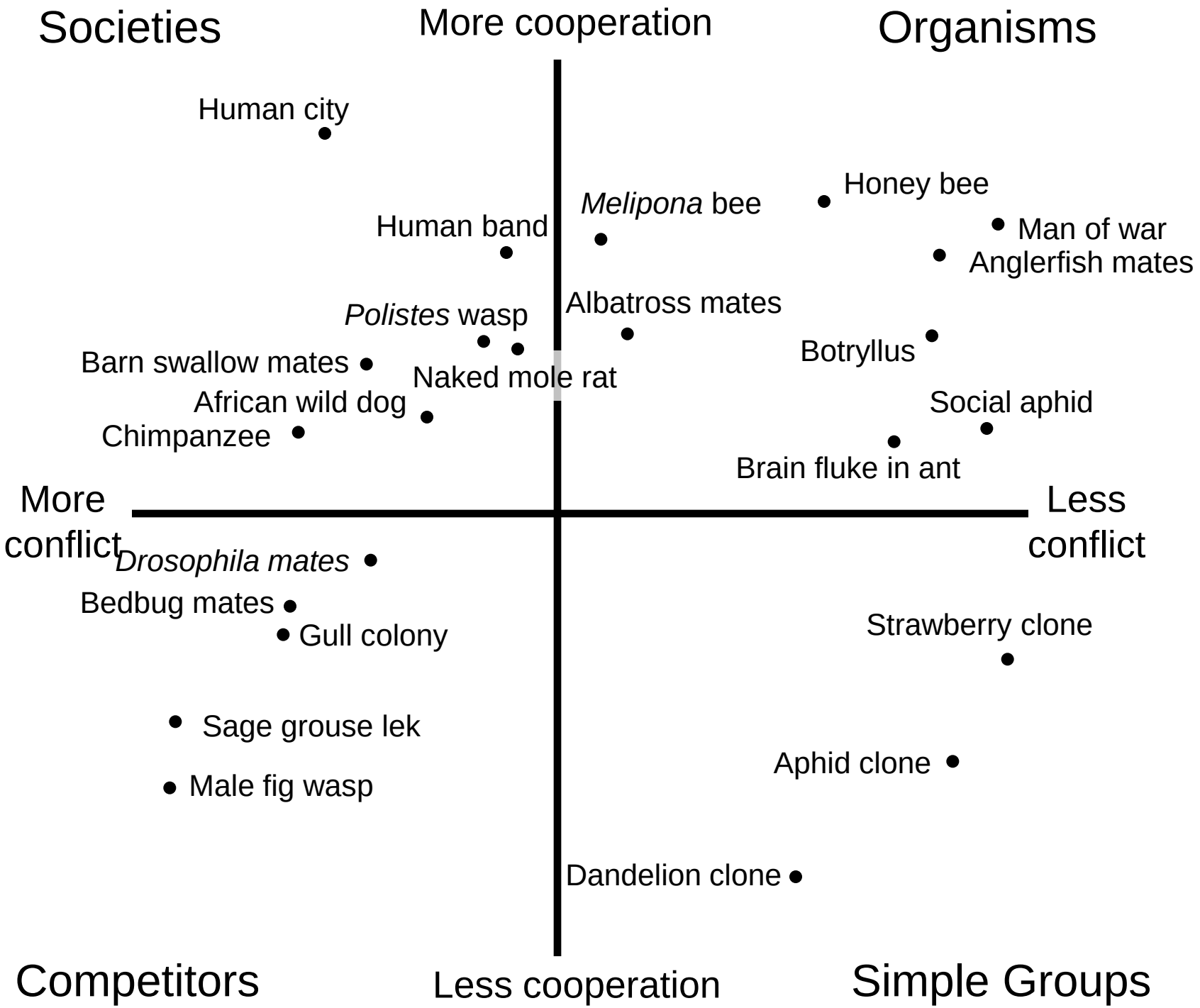
Contagious facial cancer

Plasmodium (malaria) in mosquito vector

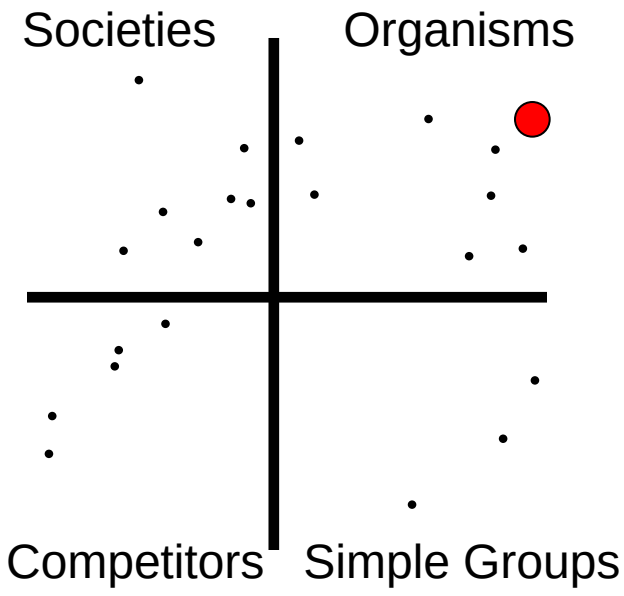


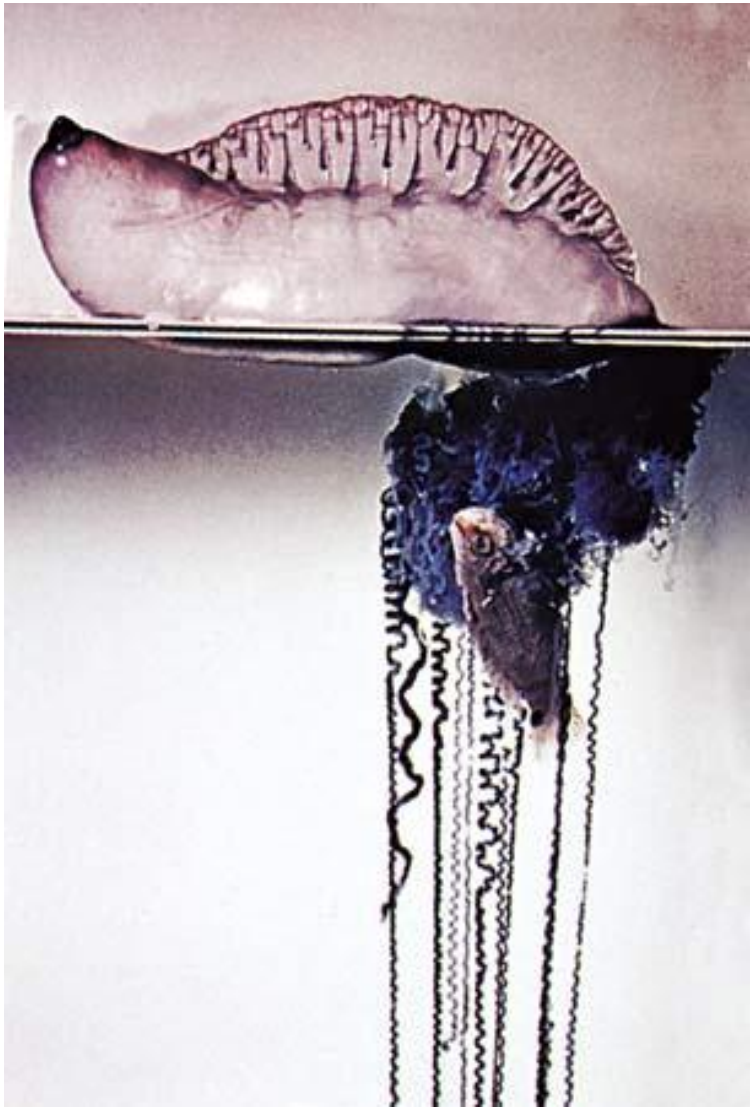


Groups of multicellular individuals


Societies
More cooperation
Organisms
Human city
Human band
Melipona bee
Honey bee
Man of war
Anglerfish mates
Albatross mates
Polistes wasp
Barn swallow mates
Naked mole rat
Botryllus
African wild dog
Chimpanzee
Social aphid
Brain fluke in ant
More conflict
Less conflict
Drosophila mates
Bedbug mates
Gull colony
Strawberry clone
Sage grouse lek
Aphid clone
Male fig wasp
Dandelion clone
Competitors
Less cooperation
Simple Groups

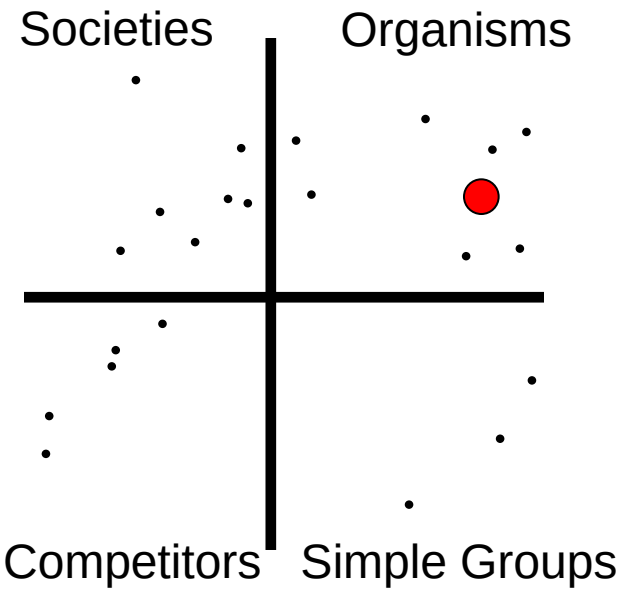
Portuguese man of war



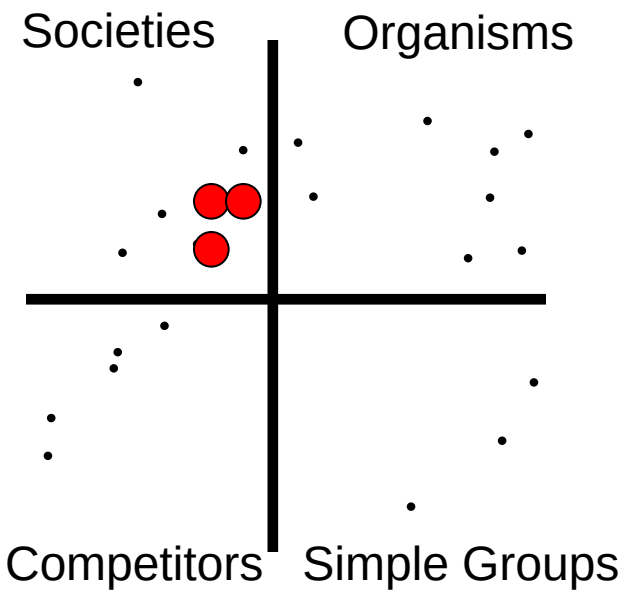


Organism made of many animals

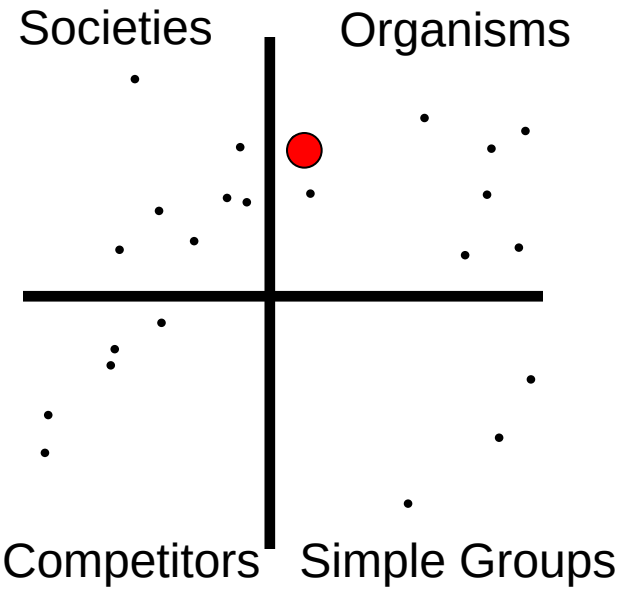
Botryllus



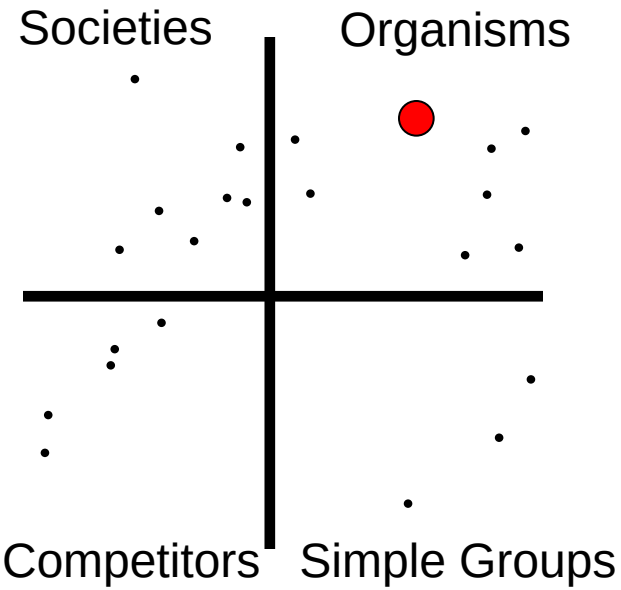
Polistes
Naked mole rats
African wild dogs



Melipona stingless bees

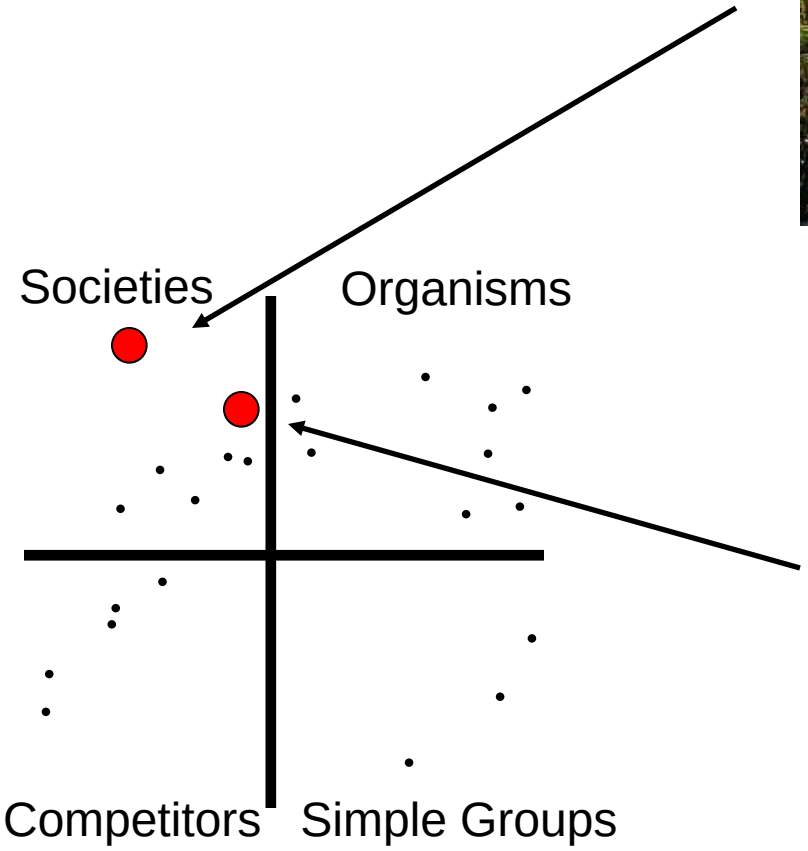


Honey bee

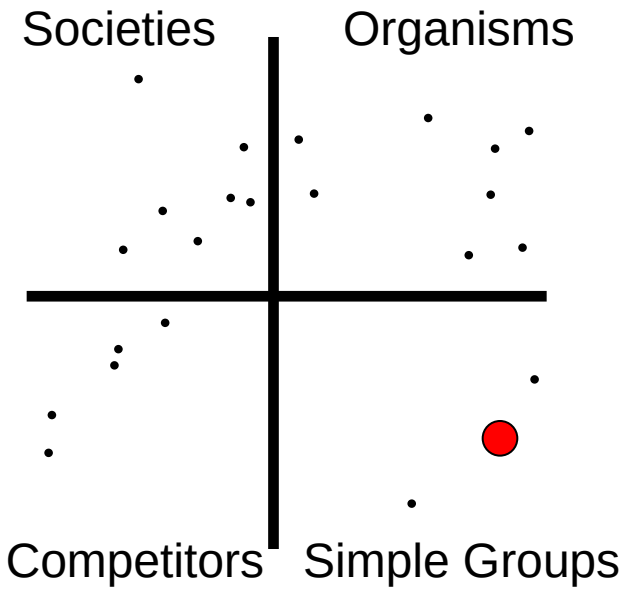


Superorganism = Organism

Human city
Human tribe

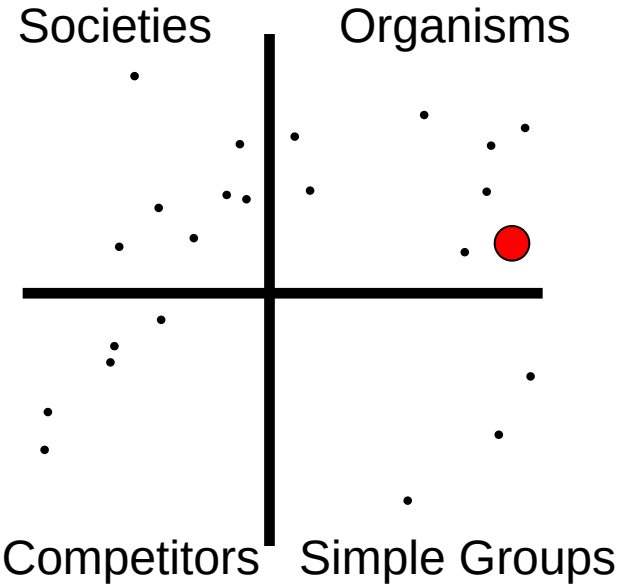


Aphid clone



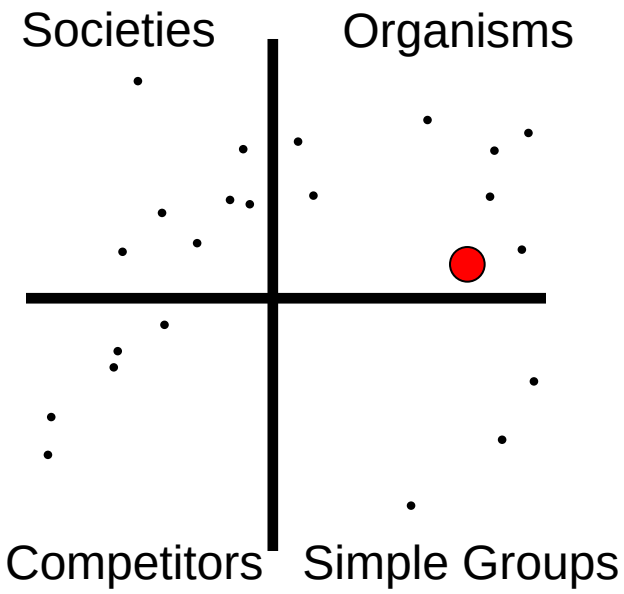
X

Social aphid clone



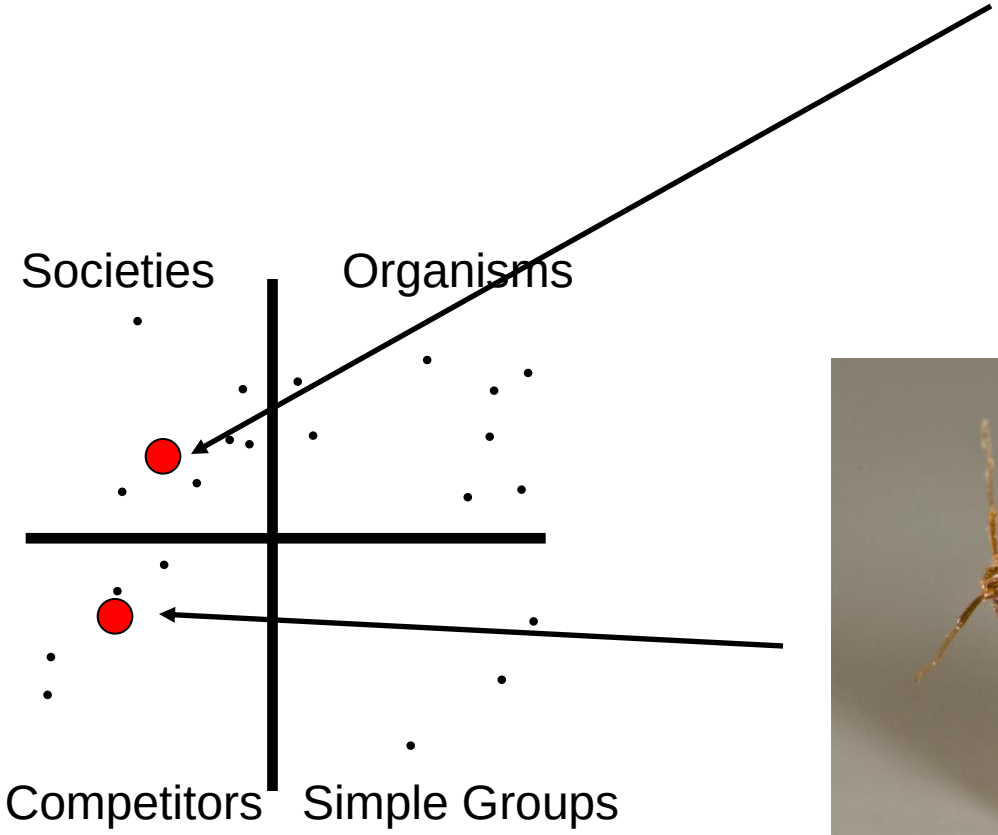
Superorganism, disconnected parts

Brain flukes in ant

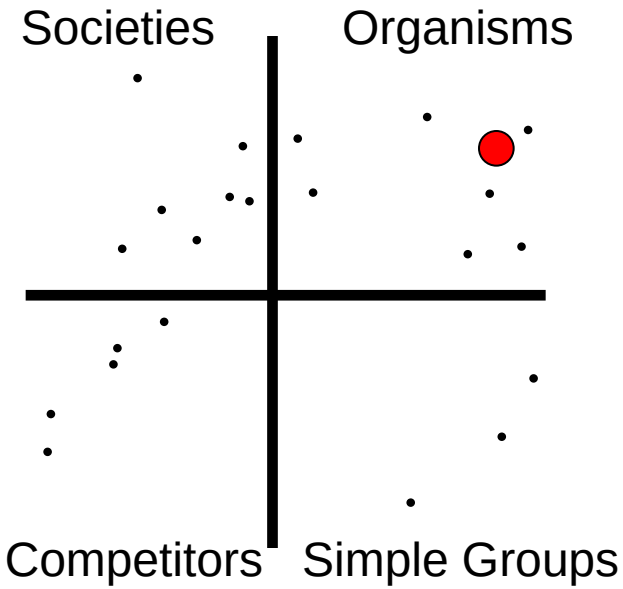


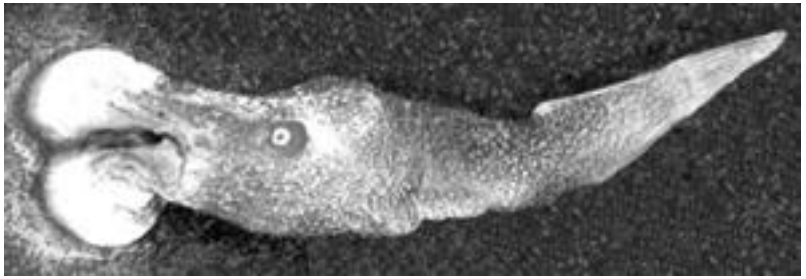
Dicrocoelium dendriticum

Barn swallow mates
Bedbug mates

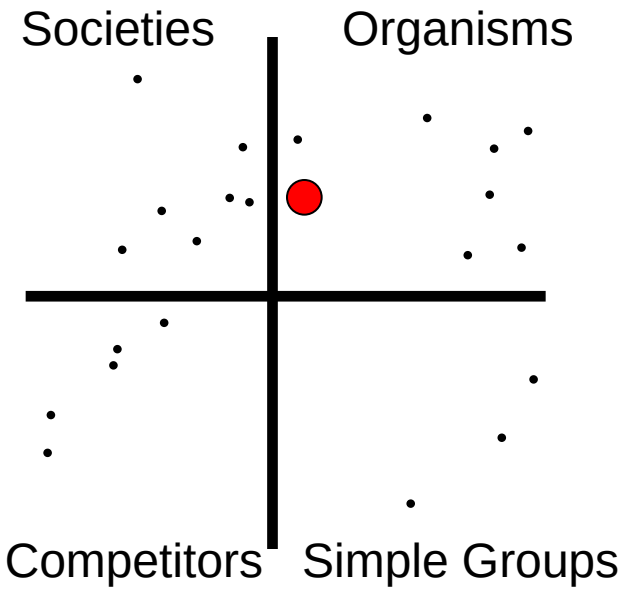


Anglerfish mates





Albatross mates

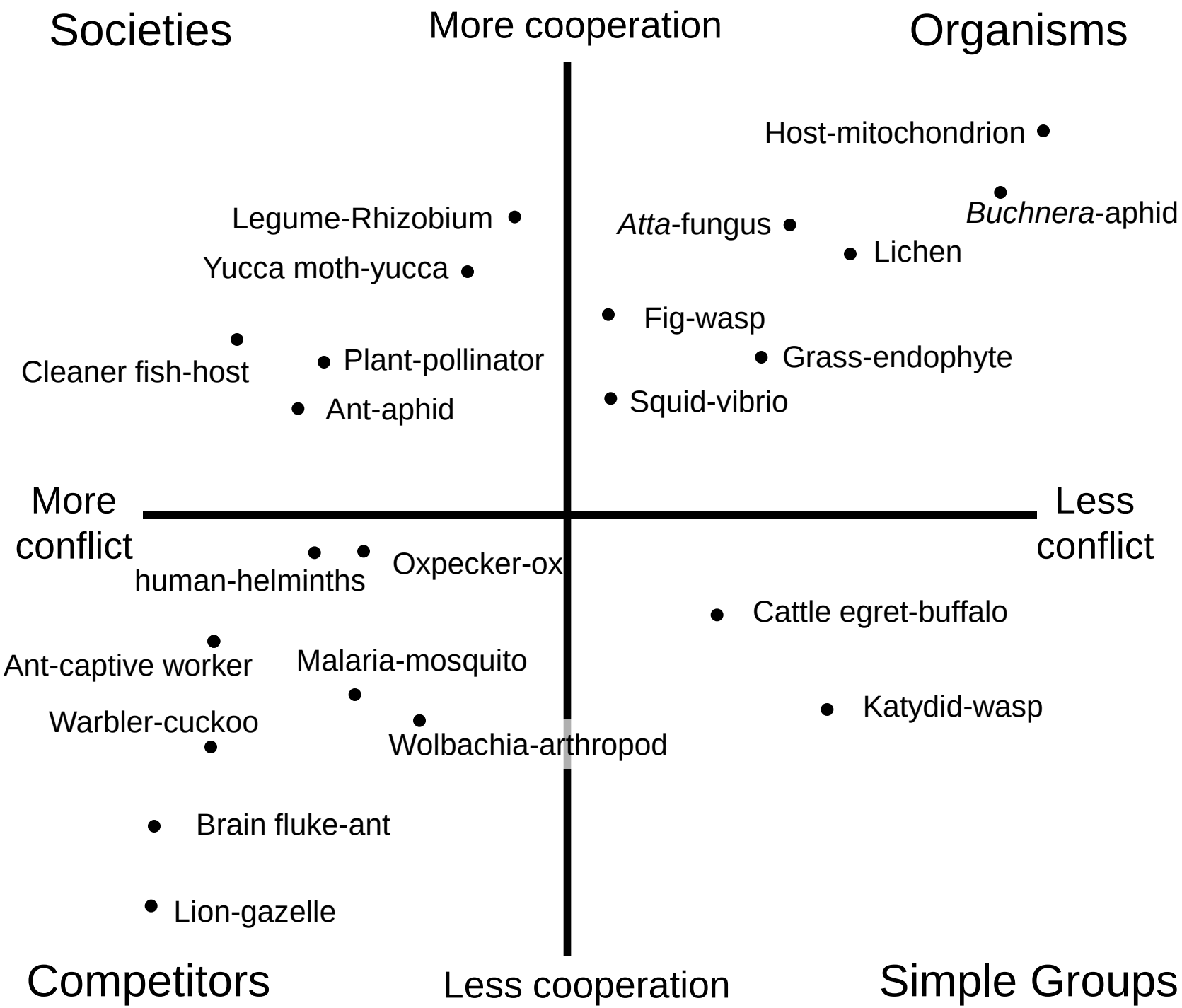


Can an organism really form from two unrelated individuals?

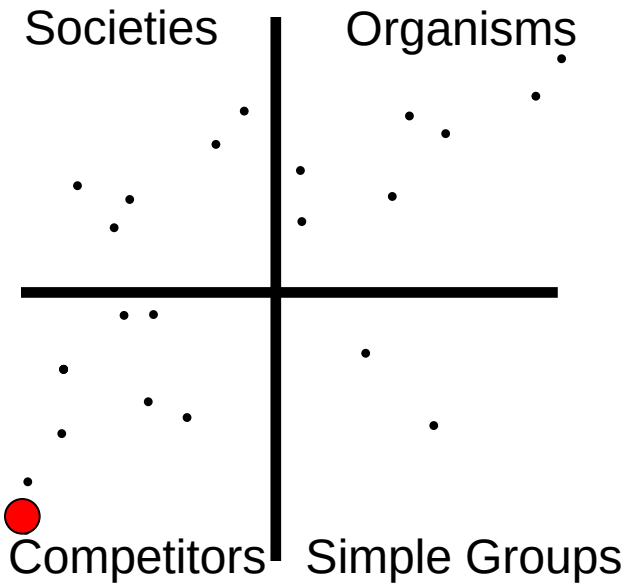
Yes.

Two-species groups

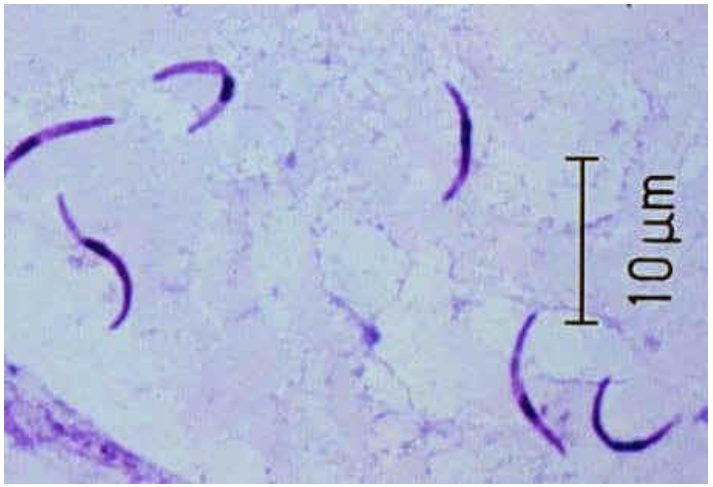
(no kinship)

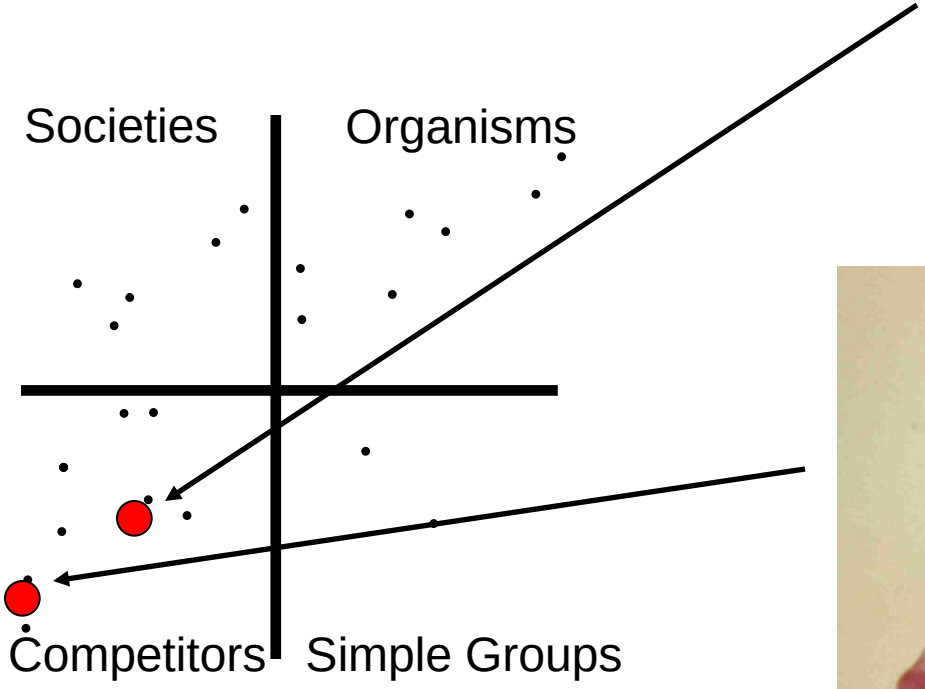

Societies
More cooperation
Organisms
Host-mitochondrion
Buchnera-aphid
Legume-Rhizobium
Atta-fungus
Lichen
Yucca moth-yucca
Fig-wasp
Cleaner fish-host
Plant-pollinator
Grass-endophyte
Ant-aphid
Squid-vibrio
More conflict
Less conflict
human-helminths
Oxpecker-ox
Cattle egret-buffalo
Ant-captive worker
Malaria-mosquito
Katydid-wasp
Warbler-cuckoo
Wolbachia-arthropod
Brain fluke-ant
Lion-gazelle
Competitors
Less cooperation
Simple Groups

Lion - gazelle

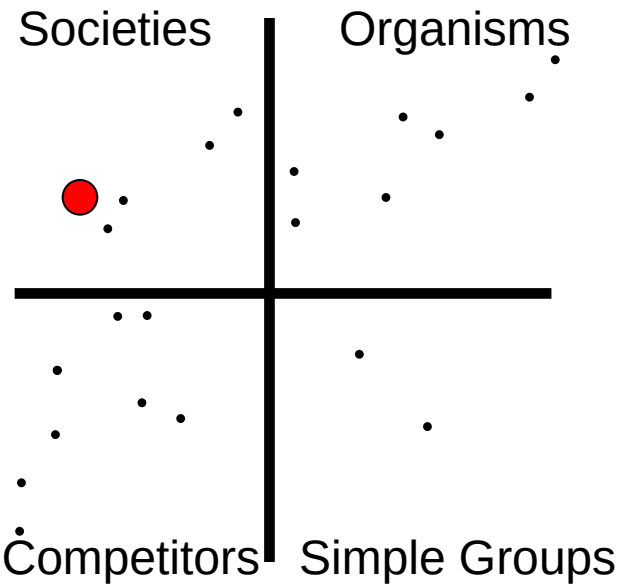


Plasmodium (malaria) - mosquito
Brain fluke - ant

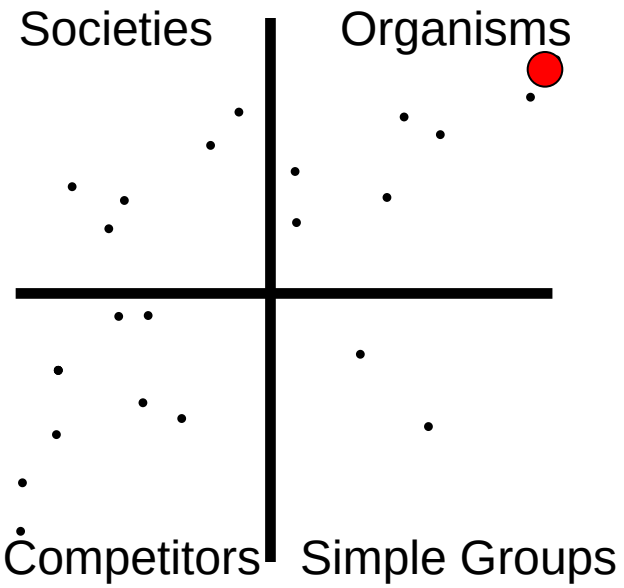


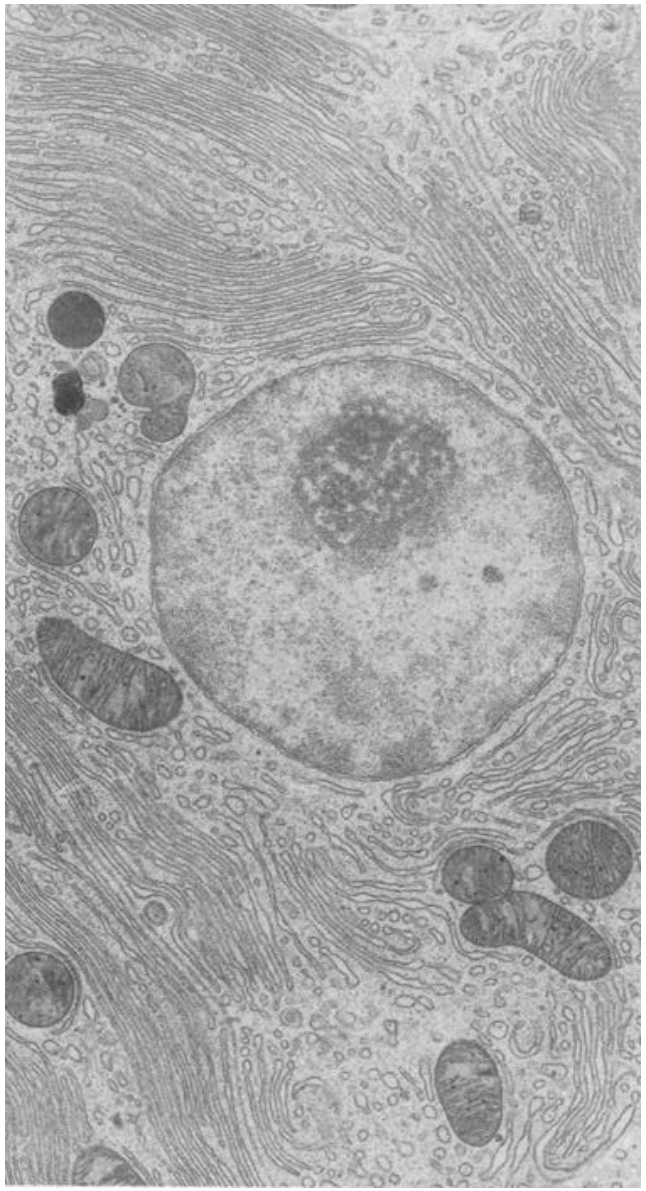


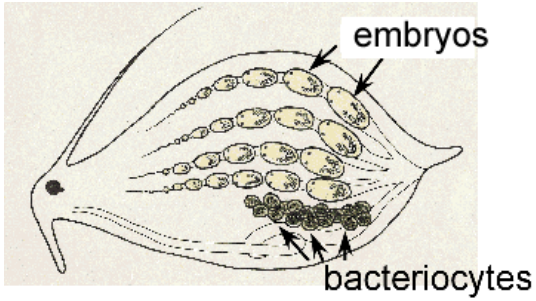
Cleaner fish - client

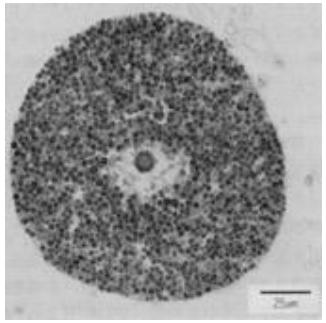


Mitochondrion - host

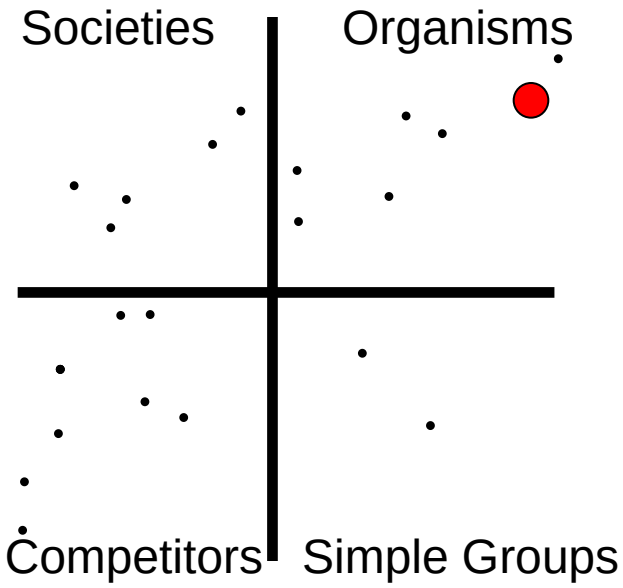








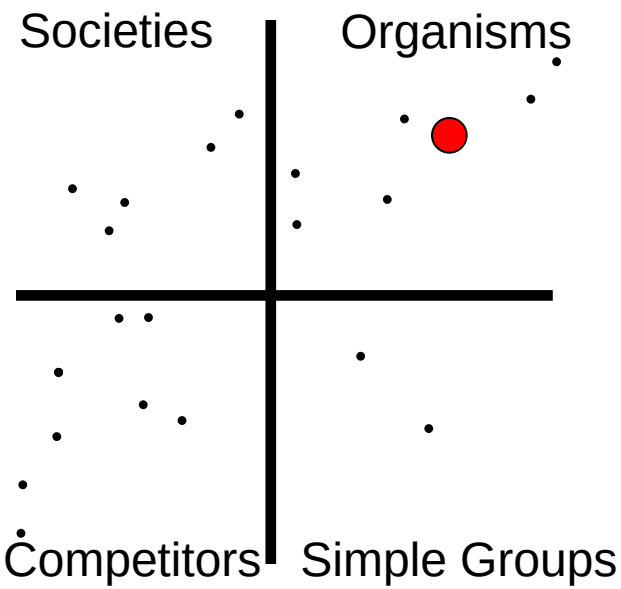
Buchnera - aphid



Infects some only cells

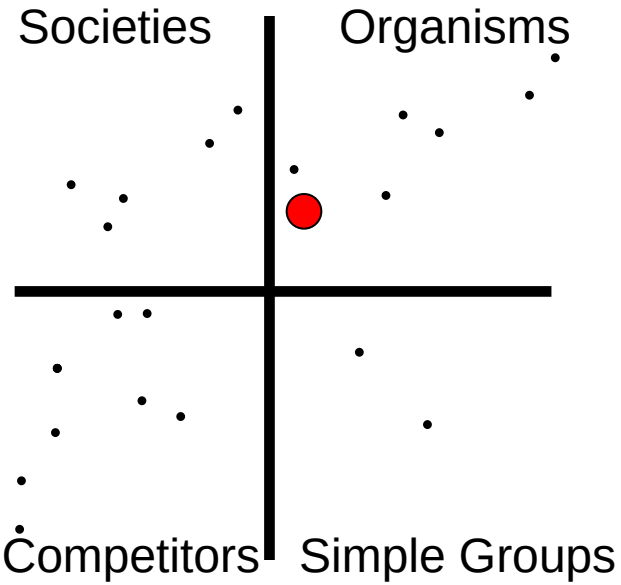
Lichens

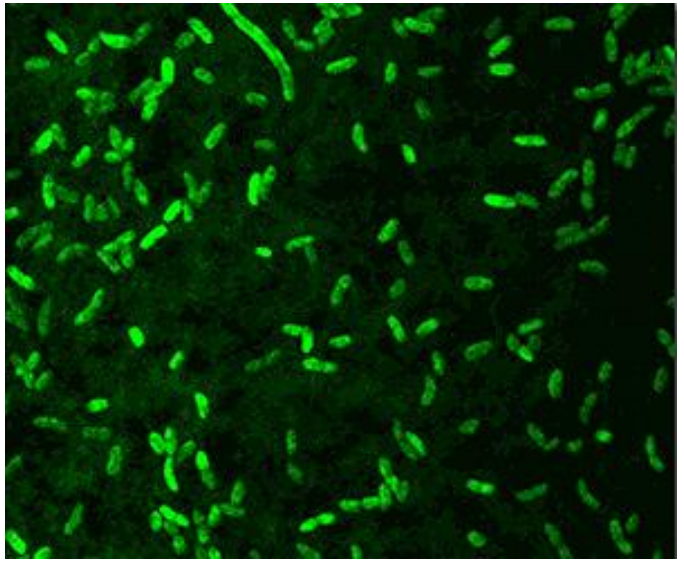
Photos:Stephen/Sylvia Sharnoff



Do not necessarily cospeciate

Squid - Vibrio





Not vertically transmitted

Rhizobium - legume

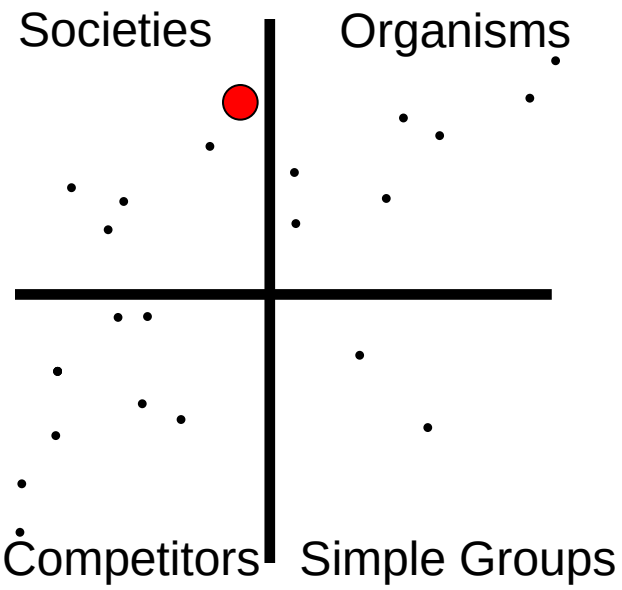
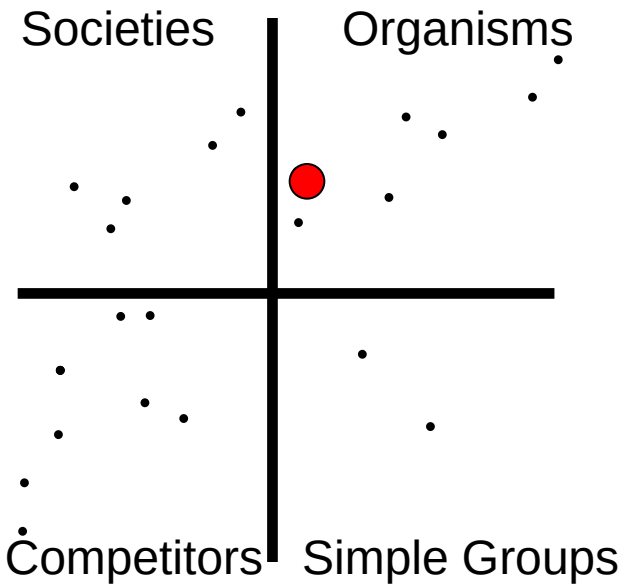
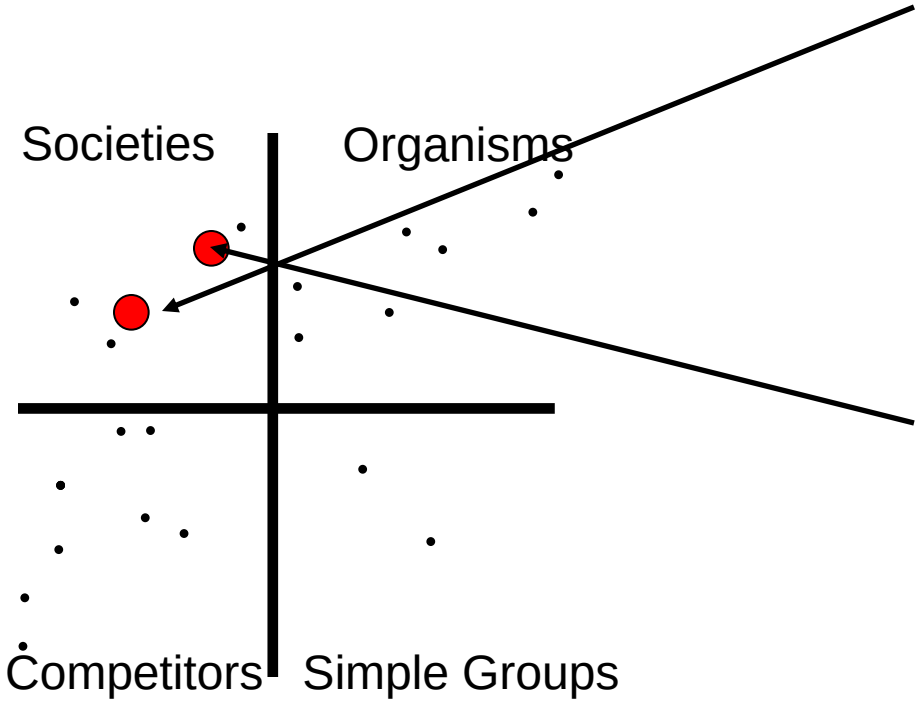


Fig - Fig wasp



Plant - pollinator Yucca - yucca moth



High cooperation and low conflict are not the same

Organismic cooperation but high conflict: (societies)

- Human societies
- Rhizobium-legume

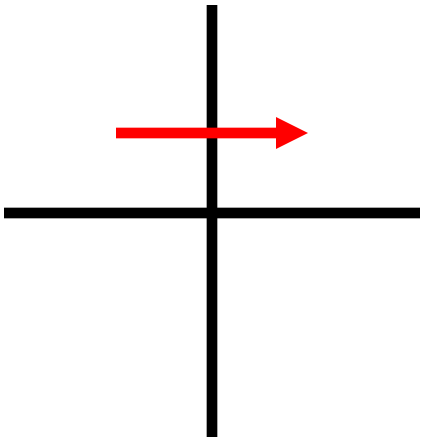
Organismic lack of conflict but low cooperation (simple groups):

- Aphid clone
- Cattle egret - buffalo

Can get organisms from either

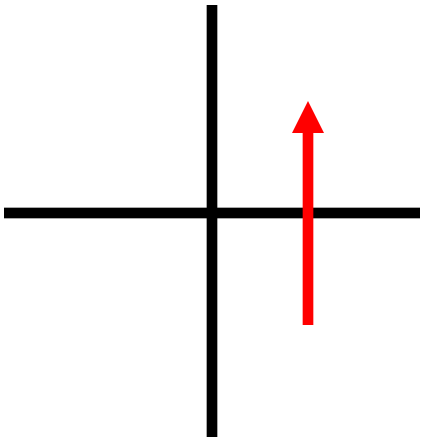
From societies by reduction of conflict:

- Honeybees
- Fig - fig wasp

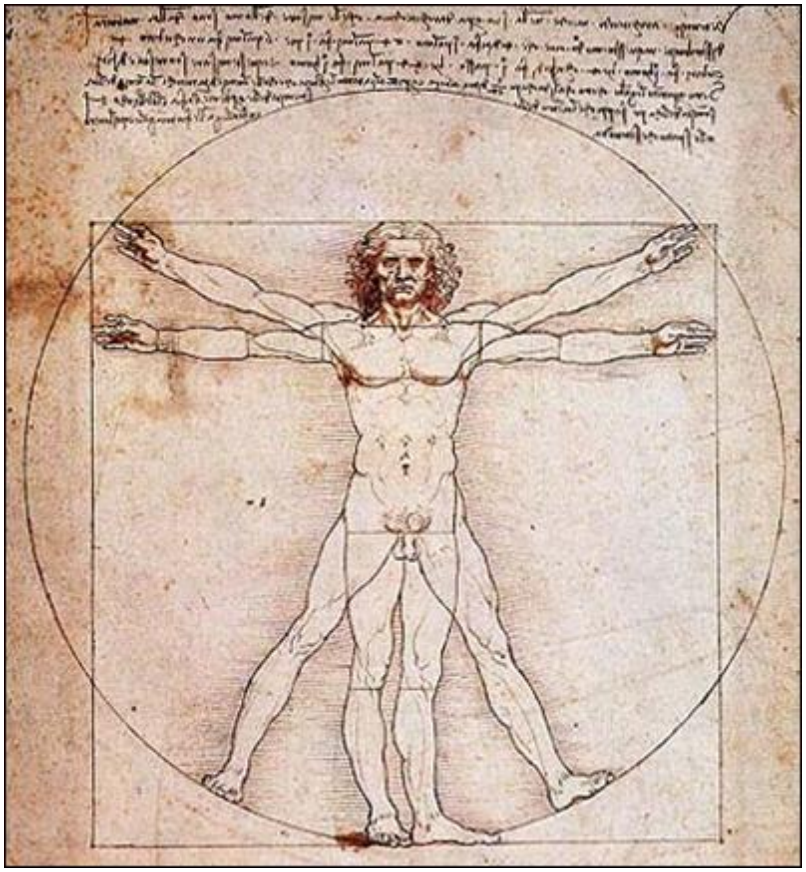


From simple groups by adding cooperation:

- Volvox
- Social aphids



Paradigm organisms



- Functional integration
- Physical contiguity
- Indivisibility
- Genetic uniformity
- Development from a single cell
- Genetic co-transmission
- Membership in the same species
- Early germ-soma separation
- Stable membership

Not required: Physical contiguity

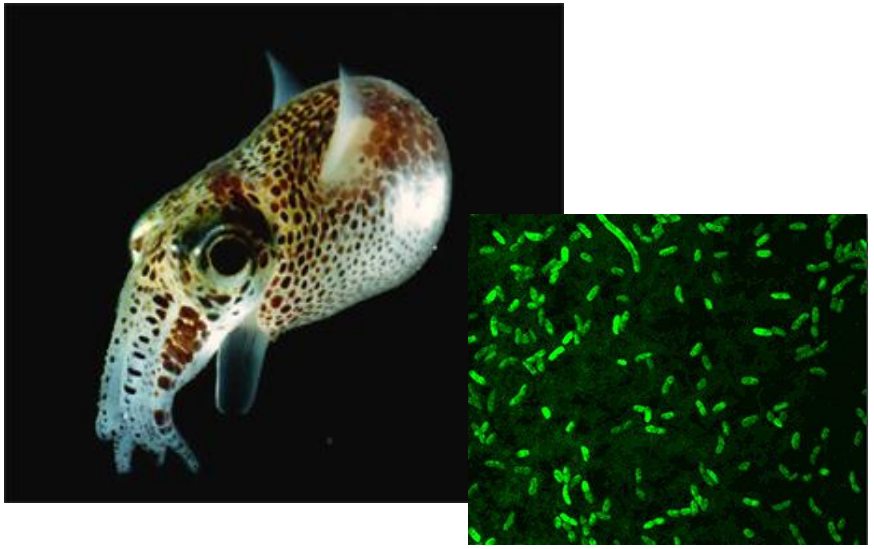
Honey bee

Brain fluke in ant

Albatross mates

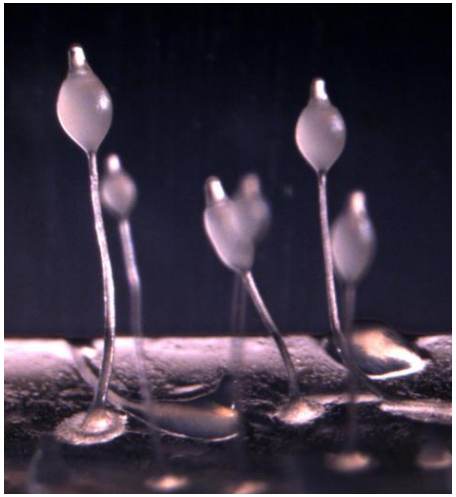
Not required: Indivisibility

Honey bee



Squid - Vibrio

Not required:
Genetic uniformity

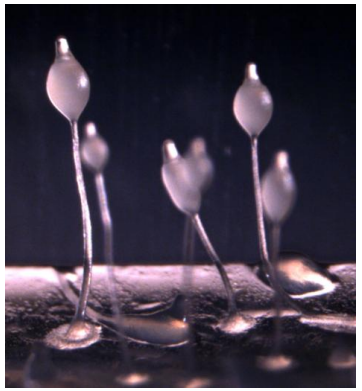


Dictyostelium

Anglerfish mates

Honey bee

Not required:
Development from a single cell



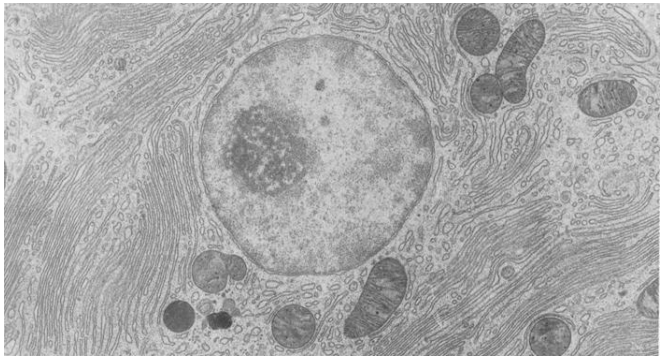
Dictyostelium

Anglerfish mates

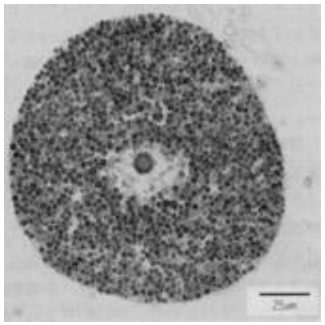
Lichens

Not required: Same species

Mitochondrion - host



Aphid - Buchnera



Lichens

Not required:
Genetic co-transmission (long-term cospeciation)

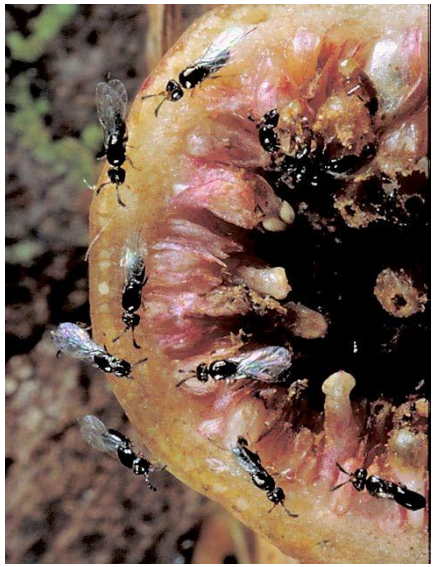
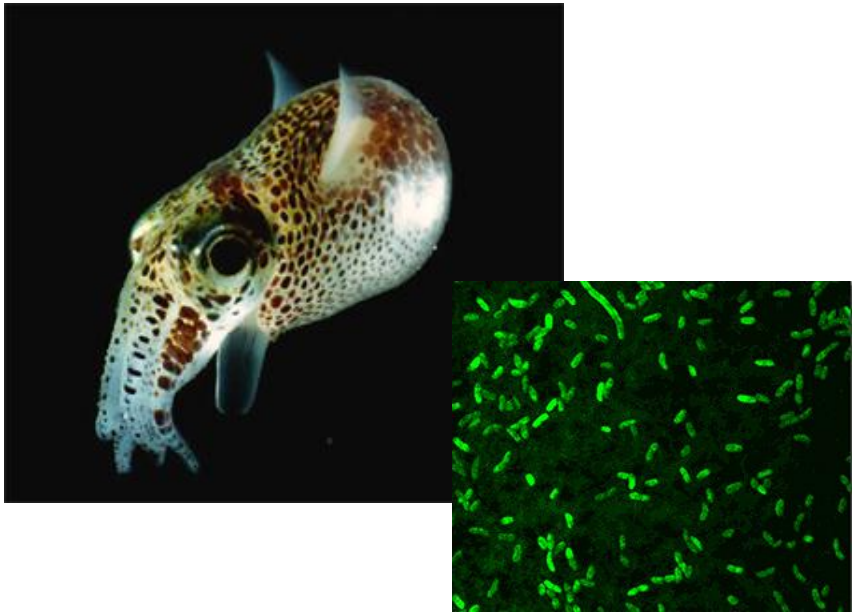


Fig - fig wasp

Lichens

Not required:
Genetic co-transmission (short-term)

Lichens



Squid - Vibrio

Factors favoring organismality:

Synergistic benefits of cooperation:

Fraternal:

Accelerated returns

Egalitarian:

Complementary functions

Common Reproduction:

Fraternal:

Clonality

Kin recognition

Egalitarian:

Co-replication

Partner fidelity feedback

Conflict resolution

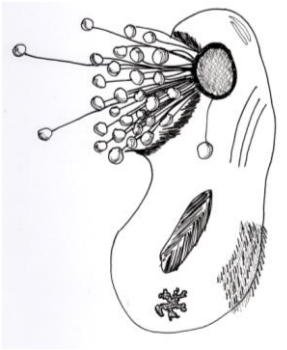
Majority party has power

Power apportioned among "committees"

Organismality:

High cooperation
Low conflict

Outcome of organismality: bundles of adaptation



Division of labor

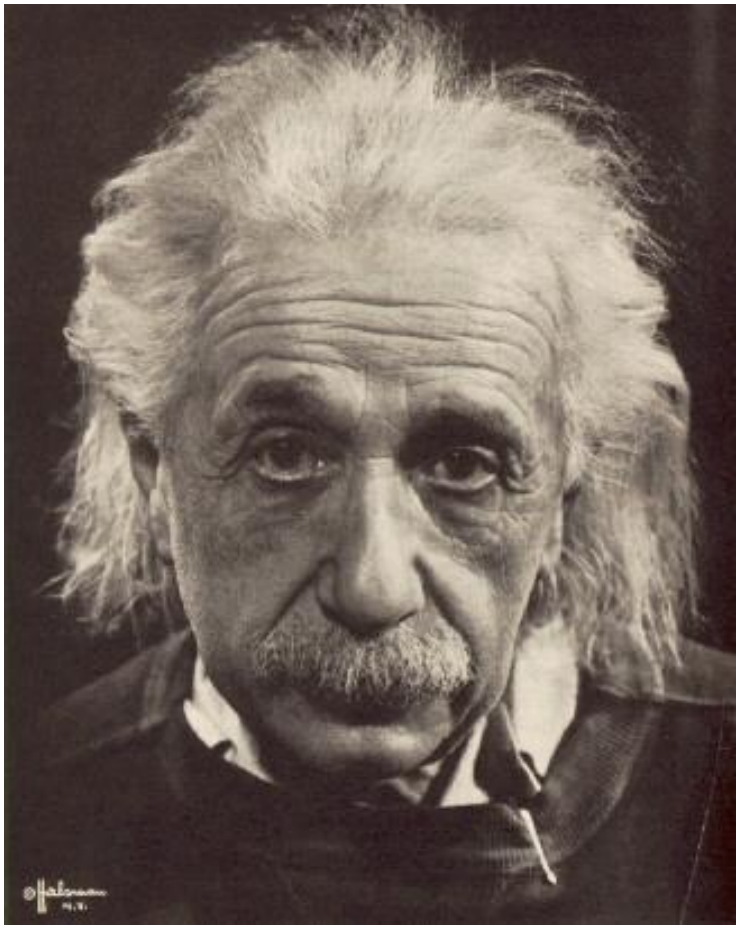
Homeostasis

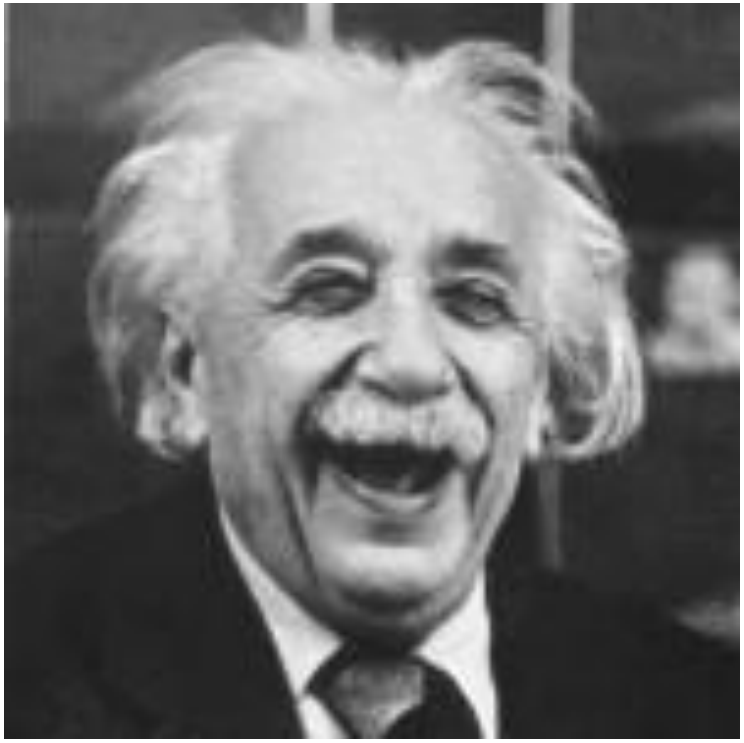
Indivisibility

Subordination of the parts to the whole

Coordinated development

Coordinated reproduction





Major transition