Thinking about multicellular organisms

Learning objectives:

1) To understand how biologists figure out life cycles;
2) To appreciate the advantages and the challenges of evolving into large multicellular organisms; and
3) To understand the consequences of size.

Keep the worksheet as a study guide

Major themes in eukaryotes so far

Protists – endosymbiosis – process, evidence, bioenergetics, consequences
general eukaryotic features; major groups
life cycle and origin of sex
eukaryotic pathogens

Diffusion – physical process, evolutionary constraint

Plants – life cycle
phylogenetic tree – adaptations to land environment

Fungi – growth form and nutritional strategy
root symbionts with early plants and agricultural crops
fungal pathogens and human significance

GAE Part 1. Modeling Life Cycles

Previous GAE's – constructed different models for biological energy flow, phylogeny, endosymbiosis, and diffusion

Life cycle diagram – simple model of the major stages in the life of an organism.

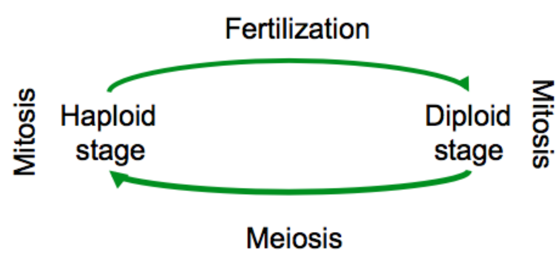
One approach – evolutionary reasoning explains why a life cycle has certain features. For example, the plant life cycle exhibits alternating haploid (1n) and diploid (2n) generations

Why the haploid gametophyte (1n) stage?_______________

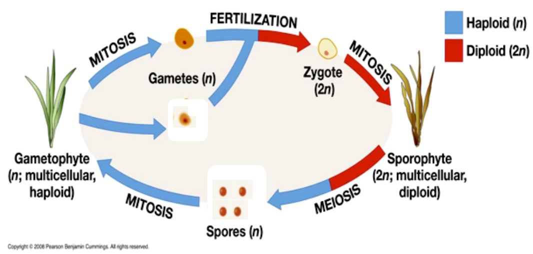
Why the diploid sporophyte (2n) stage? _______________

Complementary approach – mechanistic reasoning focuses on the processes involved in the cycle.

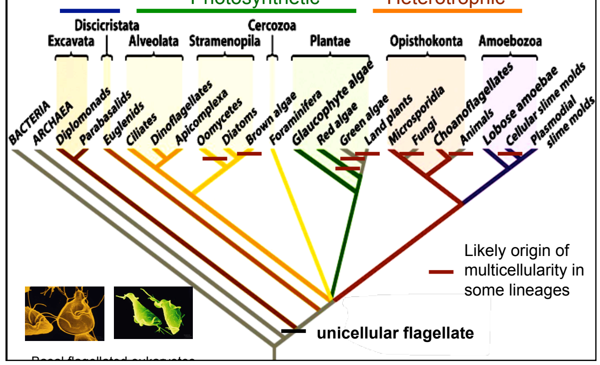
Generalized sexual life cycle in eukaryotes



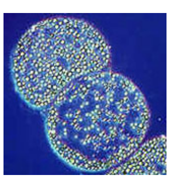
Generalized plant life cycle



Independent origins of eukaryotic multicellularity - > 20 origins



Question - Why are unicellular organisms constrained in their ability to develop large sizes?



Thiomargarita

Valonia

Thiomargarita - the largest known unicellular prokaryote (0.75 mm in diameter). It grows buried in sulfide-rich ocean sediments.

Valonia - a very large unicellular eukaryote (5 cm in diameter) in the green algae. It grows in protective sites on coral reefs.

Question - Why are unicellular organisms constrained in their ability to develop large sizes?

Thiomargarita

Valonia

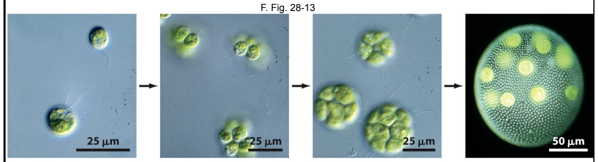
- Low surface area/volume ratio for gas exchange and nutrient uptake -
  - nutrient uptake correlates with surface area (~ diameter squared)
  - metabolic rate correlates with volume (~ diameter cubed)
- Less precise spatial control of cell activities like metabolite biosynthesis and macromolecular transport
- No internal support - very vulnerable to mechanical damage

"Multicellular life - the escape from the limitations of diffusion"

Question - What are the convergent design strategies operating in the evolution of multicellular eukaryotes?

Colony - a loose association of "independent" cells

F. Fig. 28-13

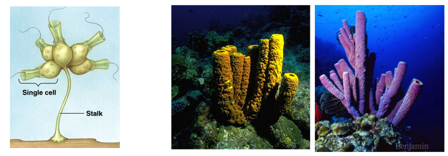


***Chlamydomonas* -** (unicellular) | ***Gonium* -** (small colony) | ***Pandorina* -** (large colony) | ***Volvox* -** (multicellular?)

Volvox - up to 60,000 *Chlamydomonas*-like cells
limited cell specialization but some organization
specialized cells are capable of regenerating the organism
cells can not live as independent unicells

Design strategies of multicellular eukaryotes

Colony - a loose association of "independent" cells

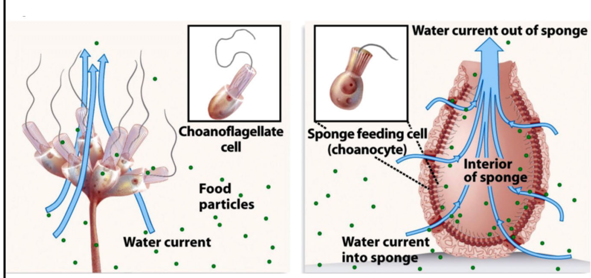


Choanoflagellates | **Sponges**

Choanoflagellates - closest living relatives of the animal lineage
adult cells as individual cells or a colony attached to substrate
phagocytosis of prokaryotes and food particles
individual cells undergo asexual reproduction

Sponges - multicellular sessile animals composed of several cell types
totipotency - an individual cell can often regenerate the entire organism
separated cells can reform the sponge

Choanoflagellates and sponges

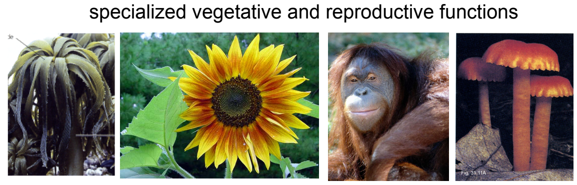


F. Fig. 31.11

Feeding cells (or choanocytes) of sponges are virtually identical to choanoflagellates

Design strategies of multicellular eukaryotes

Multicellularity - tight association of many cells carrying out specialized vegetative and reproductive functions

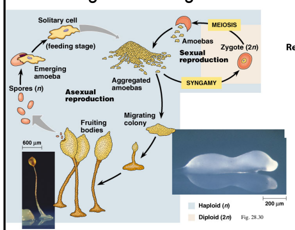


Independent evolution ---> unique molecular mechanisms for each lineage

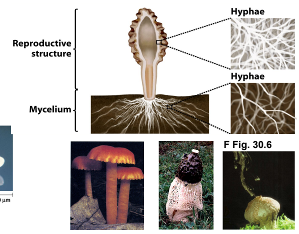
Several convergent designs of multicellular organisms related to their nutrition:

1. Multicellular photosynthetic organisms – convergent designs of flat "leaves", tubular "stems" and attaching "roots/holdfasts/etc."
2. Ingestive organisms (animals) – nervous, muscular, and digestive systems
3. Absorptive organisms - dispersed unicellular vegetative stages, then aggregated reproductive stages - e.g., cellular slime molds and fungi.

Some absorptive organisms have unicellular or filamentous vegetative stages and multicellular reproductive stages



Cellular slime mold *Dictyostelium*



Typical club fungi

1) Maximizes surface area and cellular distribution for nutrient uptake during vegetative growth
2) Enhances aerial dispersal of asexual spores

Design constraints on multicellular eukaryotes

- Major physiochemical constraints on large organisms – diffusion/transport, mechanical support, and scaling
- The survival of large organisms, especially animals, required the evolution of organ systems for carrying out: 1) transport (molecules, gases, fluids, food substances, waste products) and signaling (electrical, chemical) over long distances, and 2) neural/skeletal/muscular systems for organismal movement relative to the environment
- Animal form and function – diffusion rules transport processes at membrane and cellular levels, other mechanisms operate for long-distance activities.
- Different lineages evolved analogous biological solutions to the challenges of large size.