MULTICELLULARITY

Evolution and the Natural World

Lecture 12

12/10/2021

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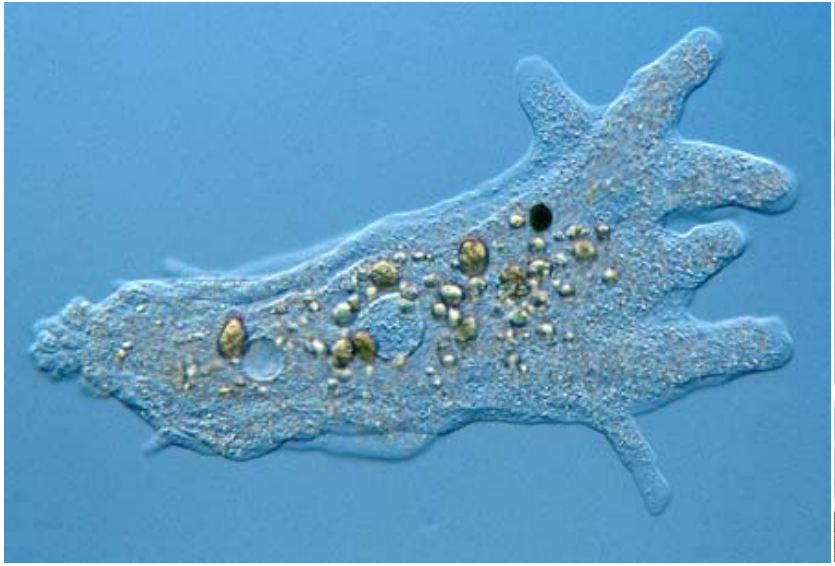
What is multicellularity (MC)?



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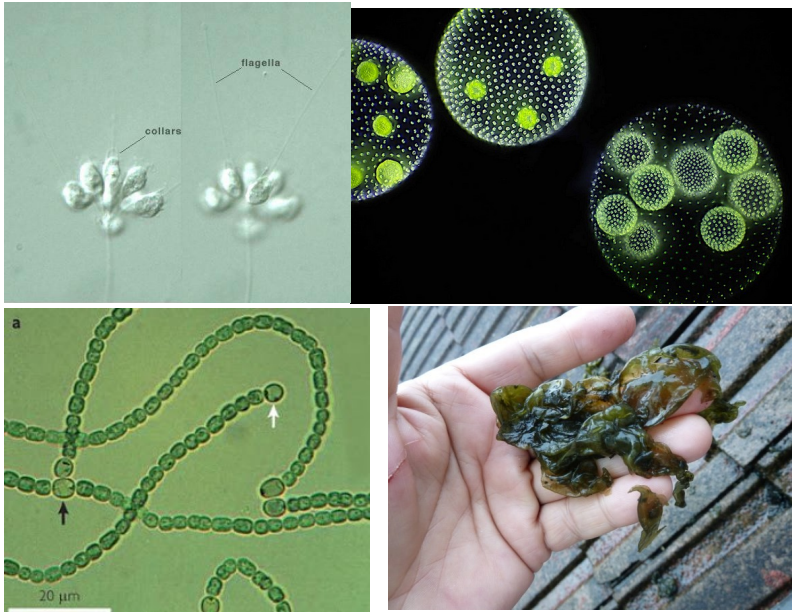
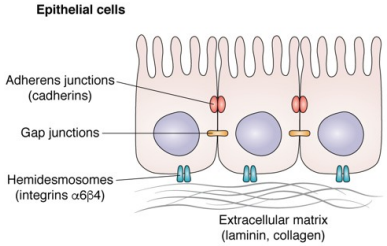
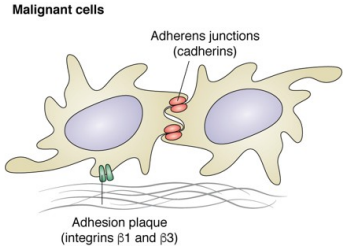


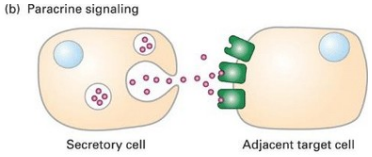
There are many cases which are hard to classify like colonies with various degree of cell differentiation

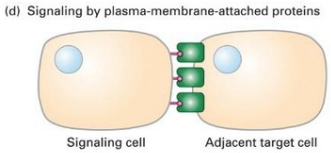
This is even observed in some species of bacteria (cyanobacteria)

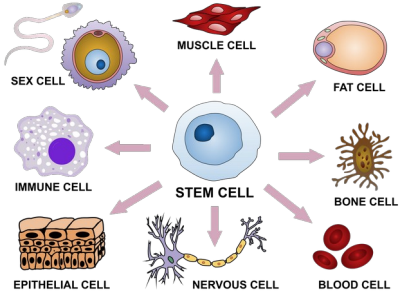
Requirements for MC











A. Stable cell adhesion (attachment)
B. Cell-cell communication and cell division control
C. Differentiation (different cells doing different jobs)

Specific proteins are involved in A and B

Differential genes expression is the key to C

https://www.scripps.edu/izard/
https://www.researchgate.net/figure/Cell-communication-type-a-endocrine-signaling-b-paracrine-signaling-c-autocrine_fig2_299402847
https://en.wikipedia.org/wiki/Cellular_differentiation#/media/File:Final_stem_cell_differentiation_(1).svg

Multicellularity evolved multiple times

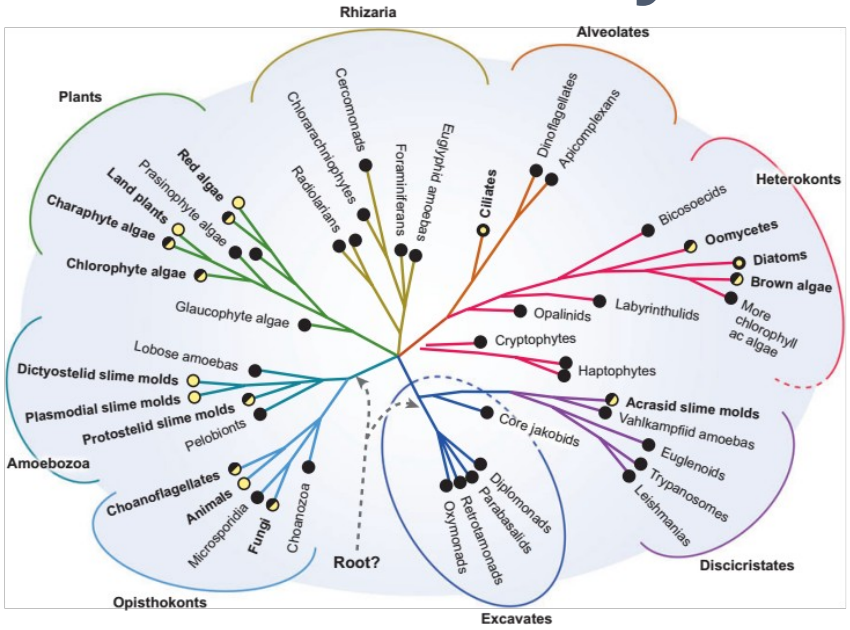


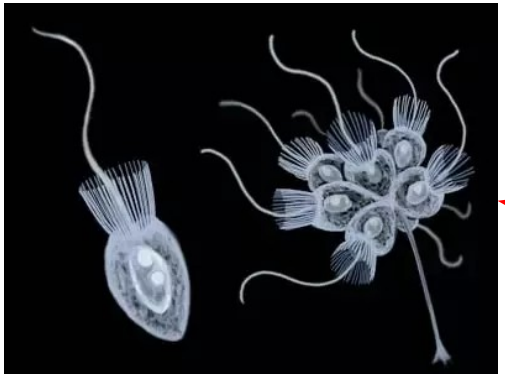
Figure 1

The phylogenetic distribution of multicellularity among eukaryotes. Multicellularity also arose multiply in prokaryotes. Taxa in boldface include at least some multicellular representatives. (After King 2004, from Baldauf 2003). Figure adapted with permission from Baldauf 2003.

Different degree of multicellularity has evolved multiple times among different eukaryotic lineages

This suggests it is relatively „easy“ and beneficial

Adhesion and communication are “easy“



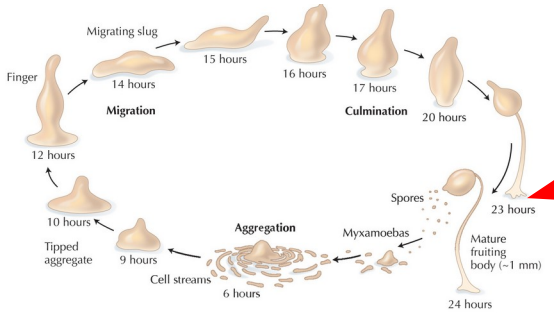


FIGURE 9.4. *Dictyostelium* sexual reproduction. Cues such as the lack of food cause the amoebas to aggregate together to form a crawling slug. Cell differentiation then occurs within the slug and results in part of the slug forming a stalk while the remaining cells form spores that disperse.

- In many species daughter cell may remain attached after cell division
- Choanoflagellates have cadherin homologs – these are proteins involved in cell adhesion in animals
- In Dictyostelium (and some other cases) multicellular forms arise due to cell aggregation

Simple cell differentiation

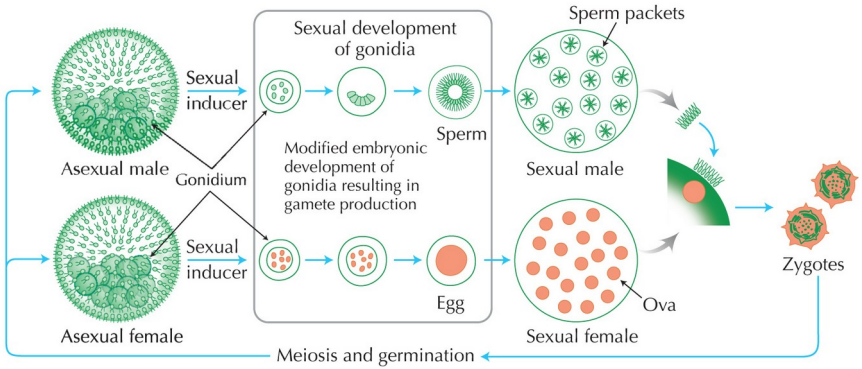
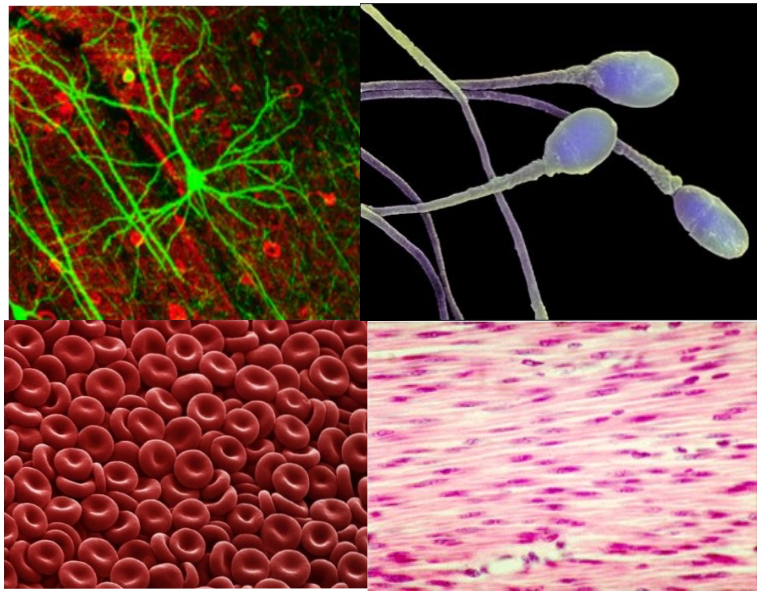


FIGURE 9.3. *Volvox carteri* sexual reproduction. Sexual inducer protein results in the development of gonidia into sperm in males and ova in females. The sperm then fertilize the ova of adult females, and the resulting zygotes (embryos) complete meiosis and development to produce adult asexual males and females.

9.3, source unknown

Volvox has differentiation into somatic cells and gonidia that produce gamets

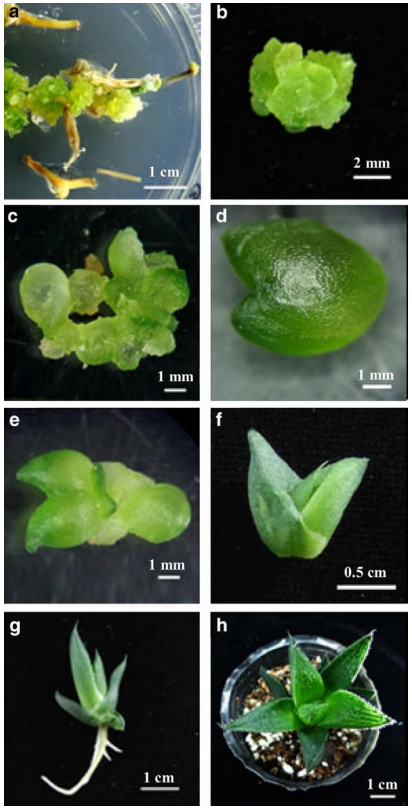
Cell differentiation

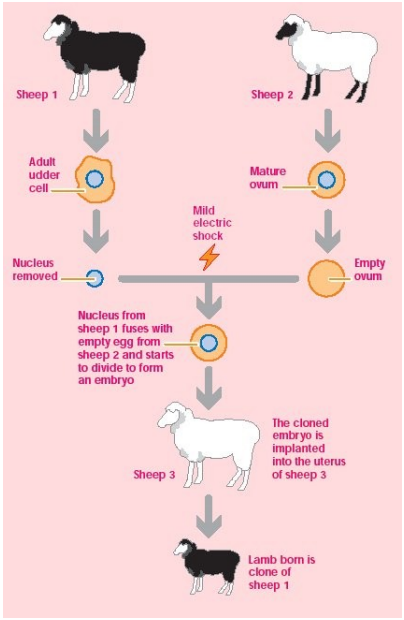


Cell differentiation in animals and plants is much more prominent

Nevertheless all cells of one organism have (nearly) identical DNA

Same DNA in all cells of the body





Cloning — growing an organism from a single somatic cell

Somatic cells have all genetic info to make a whole organism

https://as-botanicalstudies.springeropen.com/articles/10.1186/s40529-019-0257-y
https://www.csus.edu/indiv/g/gaskilld/ethics/cloninglect.htm

Basis of cell differentiation

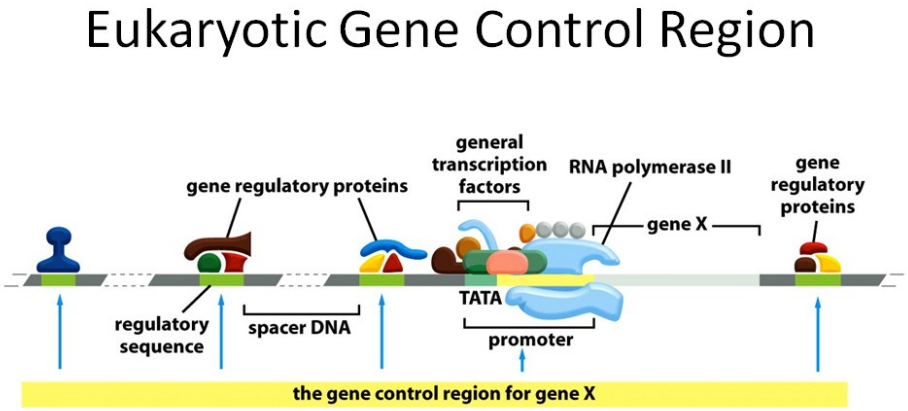
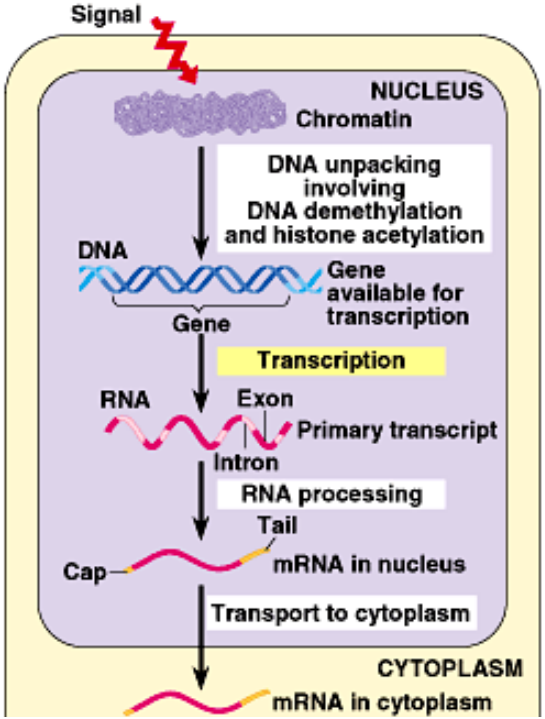
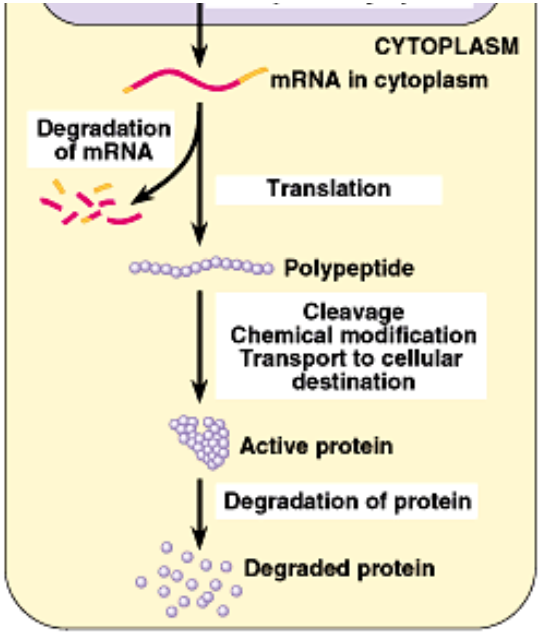


Figure 7-44 *Molecular Biology of the Cell* (© Garland Science 2008)

Despite have the same DNA different cell types have different proteins because of differential gene expression

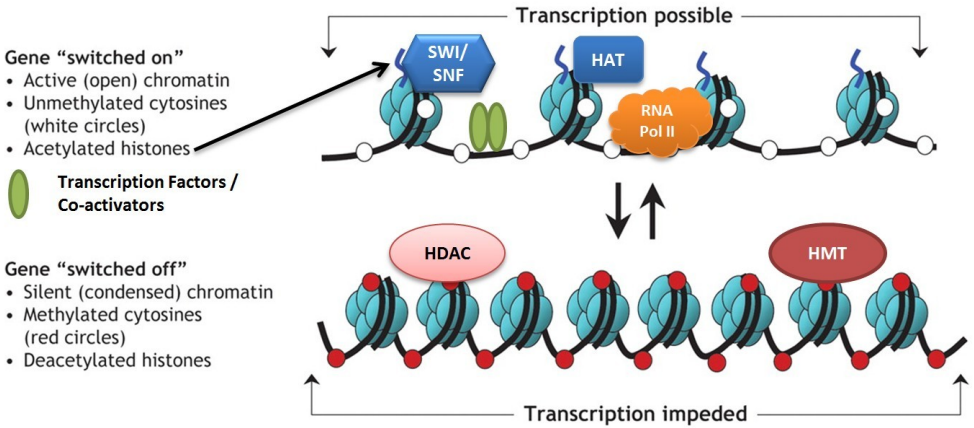
Gene expression control





http://www.bio.utexas.edu/faculty/sjasper/bio212/eukaryotes.html

Chromatin modification



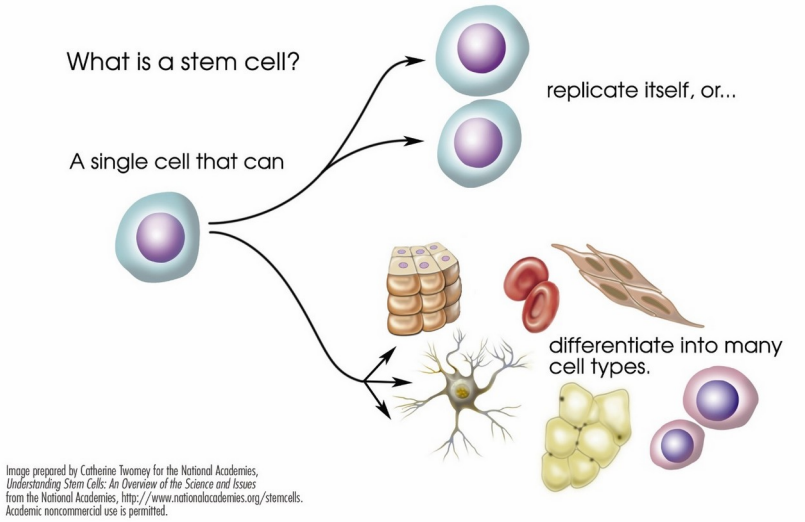
Chemichal modification to DNA (cytosin methylation) and histones (acytilation) can make chromatin opened or closed

https://en.wikipedia.org/wiki/Chromatin_remodeling

Epigenetics

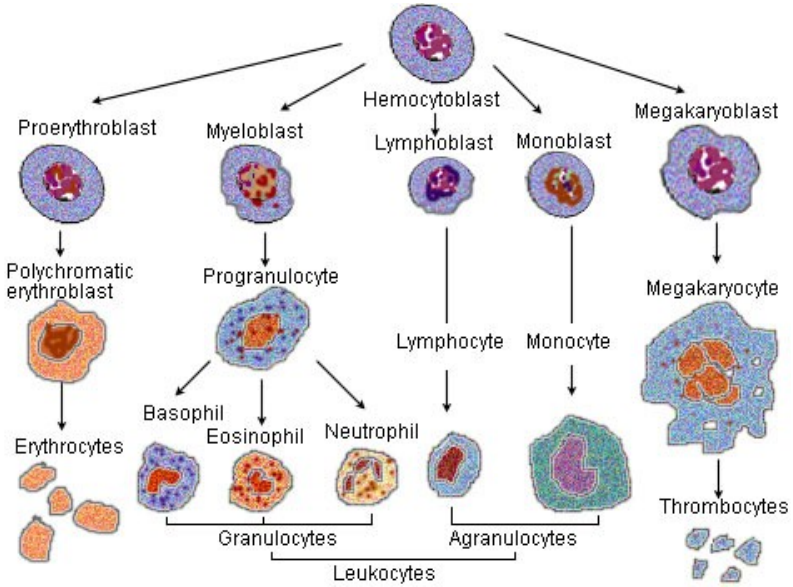
- Chromatin modification as well as the presence of certain proteins in the nucleus or mRNAs in the cytoplasm can be inherited during cell division
- Such „epigenetic“ inheritance can ensure that cell type is inherited along cell generations

Stem cells



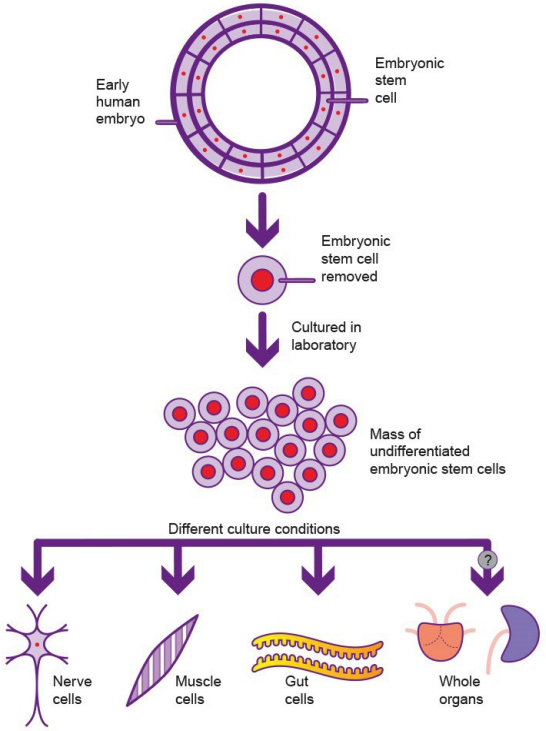
- Fully specialized cells do not divide
- Stem cells can both divide and differentiate

Types of stem cells



- **Totipotent** – able to differentiate into all types of cells of an organism (the zygote and cells of the early embryo)
- **Pluripotent** – able to differentiate into several cell types
- **Unipotent** – able to differentiate into one cell type

Using stem cells

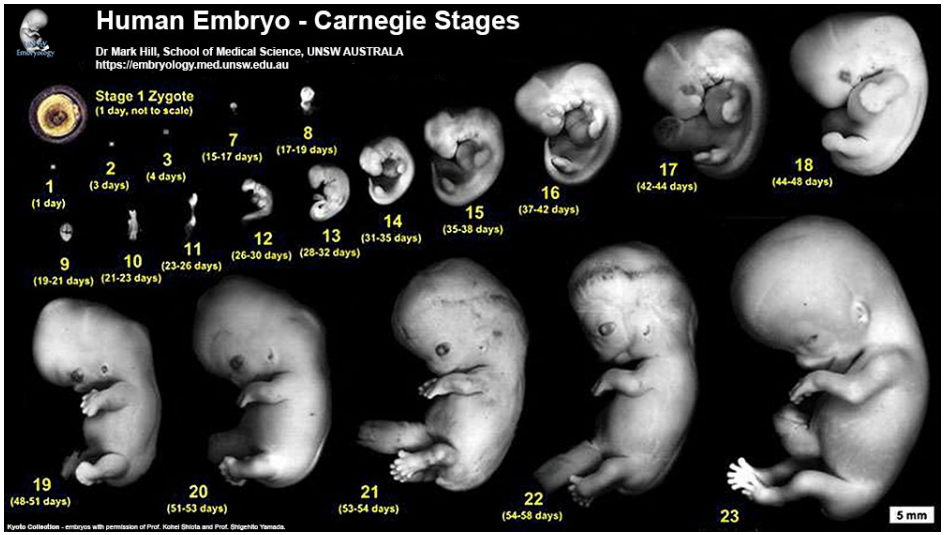


- Stem cells can be used to treat lesions, synthesize certain proteins in the body (like insulin) and grow organs *ex vivo* for transplantation
- Mostly people used embryonic stem cells
- Nobel prize 2012 was awarded for developing a method of de-differentiating somatic cells into pluripotent cells – induced pluripotent stem cells (iPSC)

Cell de-differentiation leads to cancer

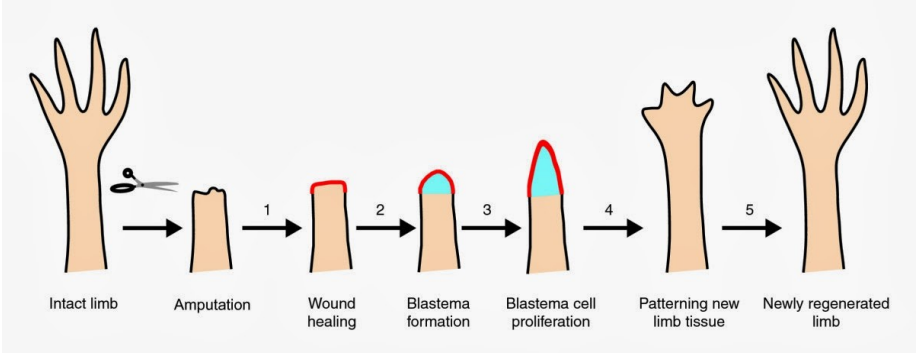
- Stem cells and cancer cells are similar: they can divide potentially an unlimited number of times
- Cancer cells may have a different degree of differentiation – the less differentiated the worse because undifferentiated cells move around – metastases
- The key difference is that division and differentiation of stem cells is controlled by the organism (hormones and other secreted factors) while cancer cells behave as unicellular organism
- Often normal cell turn into cancer cells because of mutations in genes controlling the cell cycle

Body plan



- The body plan is formed during embryonic development as a result of cell division
- Cell differentiation should depend on the position of a cell in the body
- This is achieved due to gradients of various compounds

Body plan

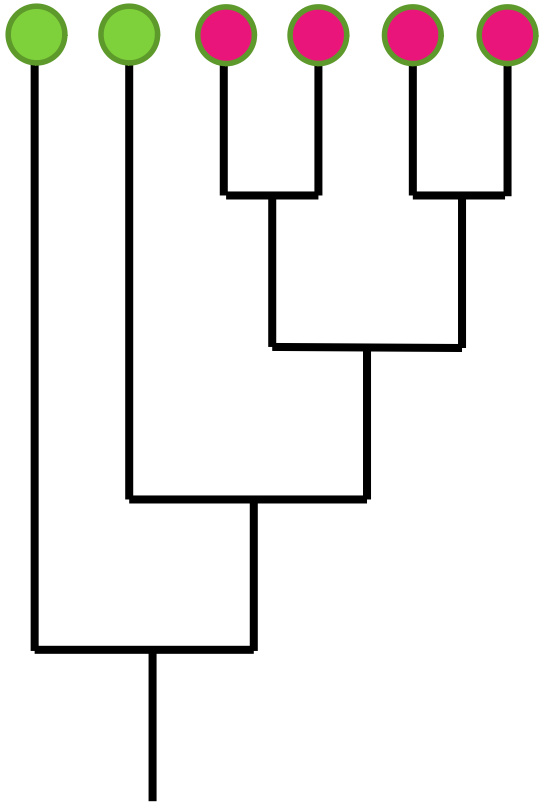


- Cells carry the information about organs' structure which is the basis of regeneration

Summary

- Multicellularity evolved several times – there is something beneficial about it
- Multicellulary requires cell adhesion, communication and differentiation into different cell types
- Differentiation is achieved by differential gene expression which is controlled by chromatin modification and presence of tissue-specific proteins; such cell differences can be inherited during cell division
- Undifferentiated cells (stem cells in animals) can divide and produce other cell types; this is the bases growth and regeneration
- If cells loose normal cell division control this results in cancer

Bonus: Phylogenetic reconstructions



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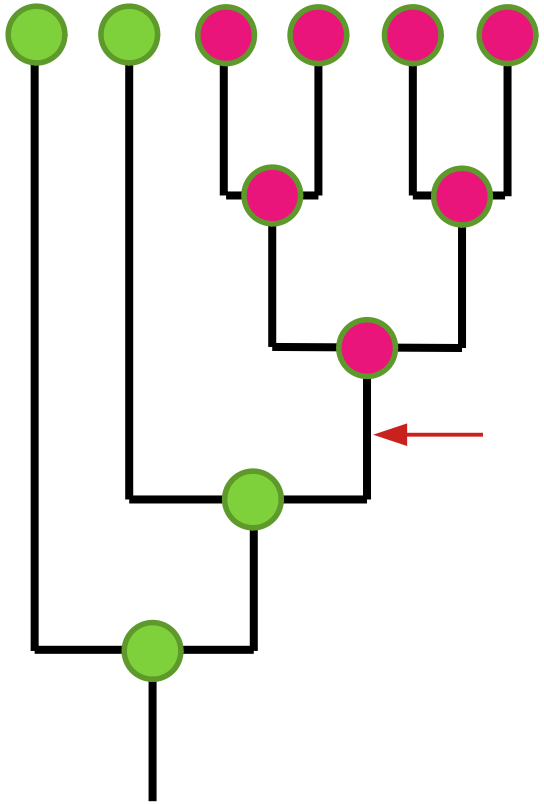
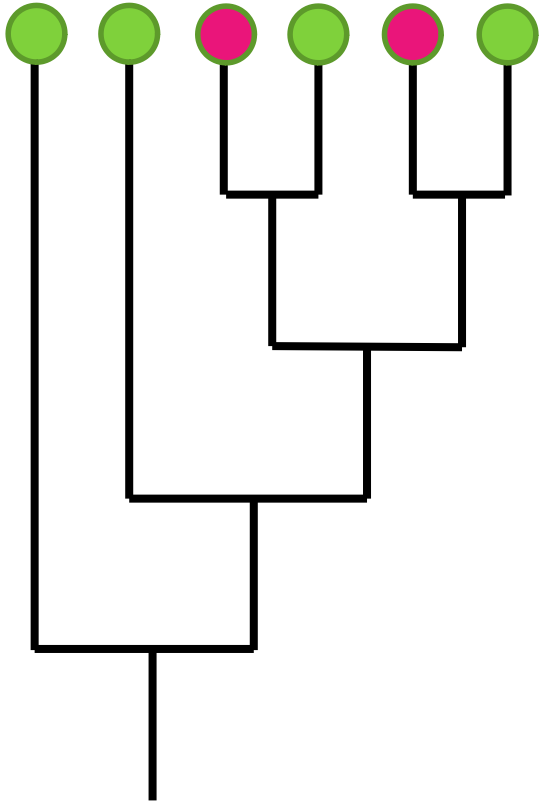


Change of the trait from green to red during evolution

Bonus: Phylogenetic reconstructions



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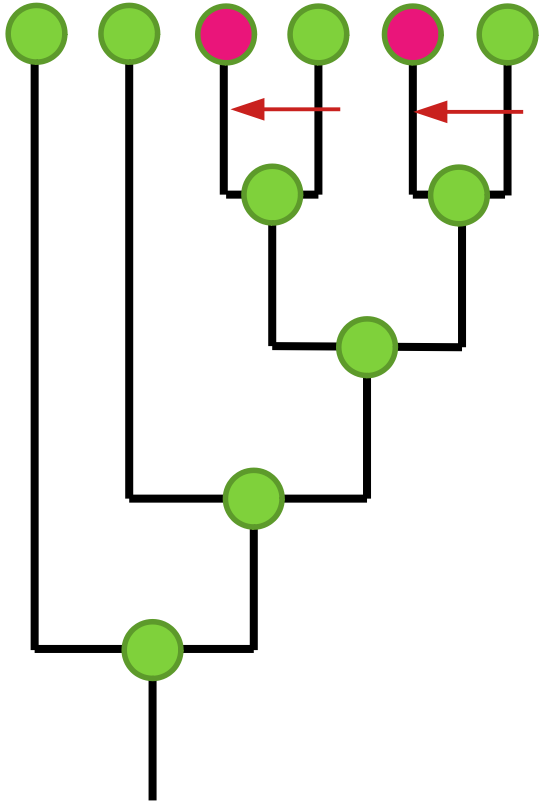

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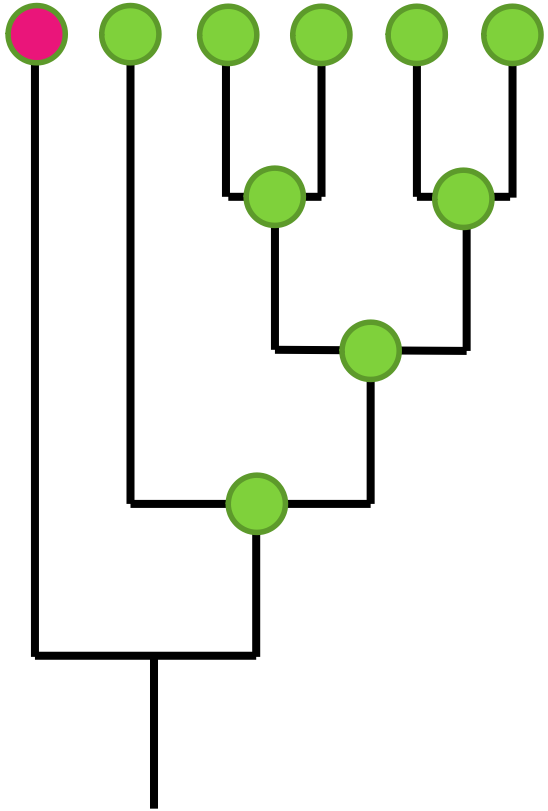

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