Asexual Reproduction in Eukaryotes: Mitosis

The Argentine band

The real thing going on inside their cells

Mitosis in various stages: (a) prophase; (b) metaphase; (c) anaphase; (d) telophase (all magnified about 2700 times).
## Nuclear Genomes and Chromosomes

Genome size in bp (or kbp or Mbp or Gbp) = C value

<table>
<thead>
<tr>
<th></th>
<th>S. cerevisiae</th>
<th>Homo sapiens</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>12.5 Mbp</td>
<td>3.3 Gbp</td>
</tr>
<tr>
<td>Number genes</td>
<td>5,770</td>
<td>20,000 - 25,000 (or even 65,000?)</td>
</tr>
</tbody>
</table>

Number of chromosomes in a haploid set = N  Diploids have 2N chromosomes

<table>
<thead>
<tr>
<th></th>
<th>Number</th>
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<tbody>
<tr>
<td>Drosophila</td>
<td>4</td>
</tr>
<tr>
<td>Yeast</td>
<td>16</td>
</tr>
<tr>
<td>Humans</td>
<td>23</td>
</tr>
<tr>
<td>Dogs</td>
<td>39</td>
</tr>
</tbody>
</table>

Human chromosome size ranges 49 Mbp - 246 Mbp  ≈ 1.6 - 8.2 cm  Smallest is longer than entire cell.  Total  ≈ 1 m

Go to [http://www.ncbi.nlm.nih.gov/mapview/map_search.cgi](http://www.ncbi.nlm.nih.gov/mapview/map_search.cgi)  Click on the number below any chromosome; 22 might be best because it is smallest.
Chromosome Structure and Karyotypes

Basic chromosome structure

Conventional diagram of metaphase chromosome with 2 chromatids. Centromere = DNA sequence where proteins bind to make a kinetochore = structure to which microtubules bind.

Left: human metaphase chromosomes squashed and stained to show landmarks

Right: diagram of human karyotype with G-bands. Short (p) and long (q) arms.
**Eukaryotic Cell Cycle**

Cell Cycle

- **G1**
- **S**
- **G2**

\[ \text{G1} + \text{S} + \text{G2} = \text{interphase} \]

Mitosis

Cytokinesis (cell division)

Variable lengths. Total time 15 minutes \(\rightarrow\) days

Animal cells in culture ca. 1 day

\[
\begin{align*}
\text{G1} & \quad \text{G2} \\
\text{Diploid cell} & \quad 2C \rightarrow 4C \quad C = \text{amount of DNA} \\
& \quad 2N \rightarrow 4N \\
\text{Haploid cell} & \quad C \rightarrow 2C \\
& \quad N \rightarrow 2N \\
\text{chromosomes} & \rightarrow \text{chromatids}
\end{align*}
\]

Each eukaryotic chromosome replicates once and only once in each cell cycle. Replication origins are caused to fire in S phase, then are prevented from re-initiating. Block to reinitiation is removed at mitosis.
Mitosis Diagrams 1

Karyotype: \( N = 2 \)
- 1 short acrocentric chromosome
- 1 long metacentric chromosome

Gene \( A \) is on metacentric, gene \( B \) is on acrocentric chromosome. Cell is heterozygous: \( A \ a, \ B \ b \)

Nuclear membrane may or may not break down, depending on the species.
In mitosis:
Sister kinetochores (centromeres) are attached to microtubules from opposite poles in metaphase, therefore sister kinetochores and sister chromatids segregate at anaphase, therefore daughter cells get one copy of each chromosome.
Mitosis
Images
Many organisms are haploid during part or all of their life cycle: e.g. ferns, many unicellular protists, fungi. These include important experimental organisms.

Mitosis works the same way in haploid as in diploid cells, except that there is only one set of chromosomes.
Eukaryotic Clones

Clone = all descendants of a single cell by mitosis.

Asexual reproduction.

Seen in:
(1) Unicellular organisms (e.g. yeast, Chlamydomonas): progeny of single cell. Handle like bacteria.
(2) Multicellular organisms (e.g. animal, plant):
   (a) all cells in one individual
   (b) monozygotic twins, etc.
   (c) progeny produced by fission (planaria) or budding (Hydra)
   (d) progeny produced by vegetative propagation of plants (aspen)
   (e) progeny produced by some kinds of parthenogenesis (some fish, lizards, Drosophila; many plants)

Parthenogenesis = egg develops into an adult without fertilization. Some forms of parthenogenesis produce diploid egg by mitotic division; others do it by meiotic division followed by restoration of diploidy by various means. All usually called asexual.
Some Asexual Eukaryotes

Many eukaryotes are asexual

Many parasites are asexual
Today much genetic analysis is done with cells or organisms reproducing asexually. Used for:

- Selecting mutants.
- Making custom-made mutants by transformation/transfection.
- Growing identical organisms that can be used to separate effects of genotype from environment, etc.
Modern genetic methods might allow one to use a clone for other purposes. So far, this one is impossible:

Verse by Isaac Asimov, meant to be sung to tune of "Home on the Range"

"O give me a clone
Of my own flesh and bone
With its Y chromosome changed to X.
And when it is grown
Then my own little clone
Will be of the opposite sex.

Clone, clone of my own,
With its Y chromosome changed to X.
And when I'm alone
With my own little clone
We'll both think of nothing but ---."
Summary

1. In the cell cycle, each chromosome = DNA molecule is replicated exactly once.

2. In anaphase of mitosis, sister centromeres (kinetochores), and hence sister chromatids, segregate. Thus each daughter cell gets one copy of each chromosome.

Consequence:
Daughter cells produced by mitosis have identical chromosomes.
Genes are identical, barring mutation.
Cells and organisms produced by mitosis constitute a clone.

Today much genetic analysis is done with cells or organisms reproducing asexually.
   - Bacteria
   - Yeast
   - Chlamydomonas
   - Animal (including human) and plant cells in culture

Used to:
   - Select and identify mutants.
   - Custom-made mutants:

Transform/transpose cells: get them to take up a piece of a gene with a mutation built into it.
That piece of DNA replaces the resident gene, which is now mutant.