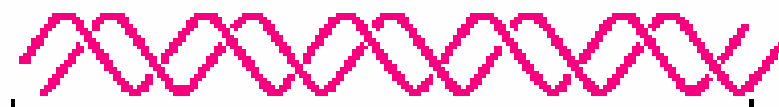
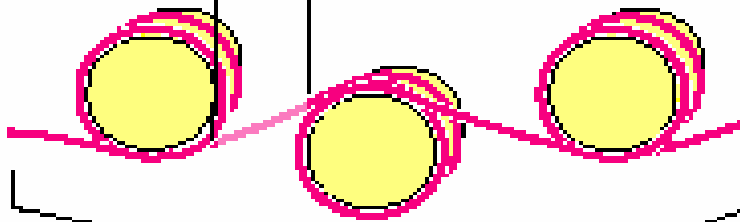


short region of DNA double helix



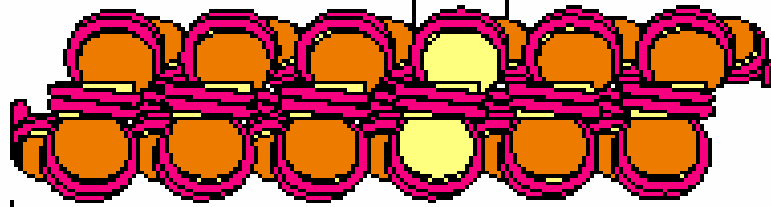
2 nm

"beads-on-a-string" form of chromatin



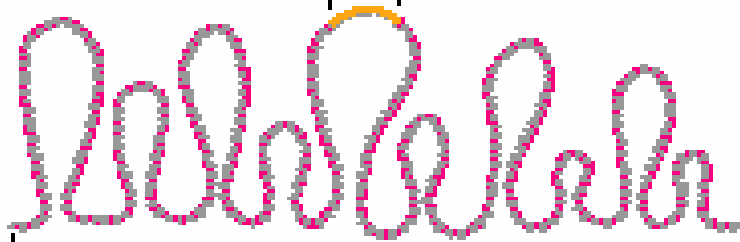
11 nm

30-nm chromatin fiber of packed nucleosomes



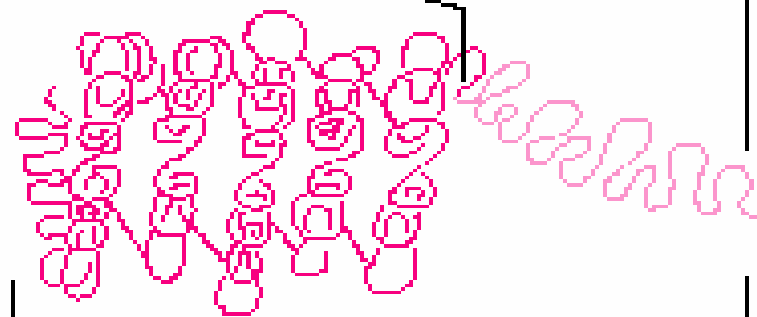
30 nm

section of chromosome in an extended form



300 nm

condensed section of chromosome



700 nm

entire mitotic chromosome



1400 nm

NET RESULT: EACH DNA MOLECULE HAS BEEN PACKAGED INTO A MITOTIC CHROMOSOME THAT IS 50,000x SHORTER THAN ITS EXTENDED LENGTH

Organization of DNA into Chromosomes allows for orderly process of nuclear functions such as

Molecular Level	{ DNA transcription DNA replication DNA repair etc.
Cellular Level	{ Nuclear vs. Cytoplasmic organization Chromosome duplication Chromosome separation Cell Division etc.
Organizmal Level	{ Reproduction Evolution Polyploidization etc.

Cell theory

Cell theory

Cells and their nuclei were the basic units of structure and function in living organisms

Lineage theory

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Cells are derived from pre-existing cells (i.e. all cells trace back to one original cell)

Mendel's Laws of Genetics

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Mendel's Laws of Genetics

1. Alleles are different forms of the same gene that segregate during gamete formation (Law of Segregation)
2. Alleles of different genes segregate independently (Law of independent assortment)

Chromosome theory of heredity

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Chromosome theory of heredity

Heredity characters are carried & passed on to generations in discrete units (Correlation between Mendelian inheritance and chromosome behavior)

Tools of Cytogenetics

Light microscope manipulating the path of light thru optics

Important factors

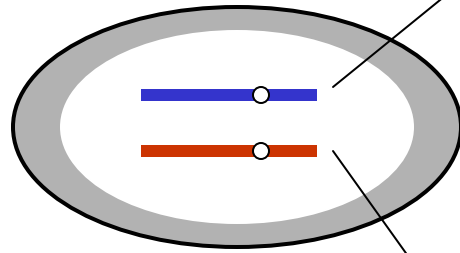
- optics
- wavelength of light
- liquid immersion
- phase contrast
- fluorescence
- computer enhancement

Transmitting electron, Scanning electron and Scanning tunneling microscopy have all increased the power of observation

The Somatic Cell Cycle



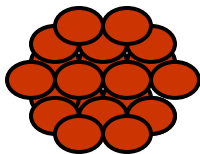
Diploid Zygote



Diploid Zygote



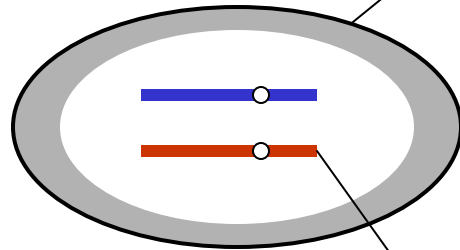
MITOSIS



Diploid organism



MITOSIS



Diploid organism

The Somatic Cell Cycle

Stages of the cell cycle:

➤ **M** Mitosis= period of cell division

➤ **G₁** Gap₁=period during cellular interphase from the end of one telophase to the beginning of DNA replication

➤ **S** Synthesis=period of pre-mitotic interphase when DNA is replicated

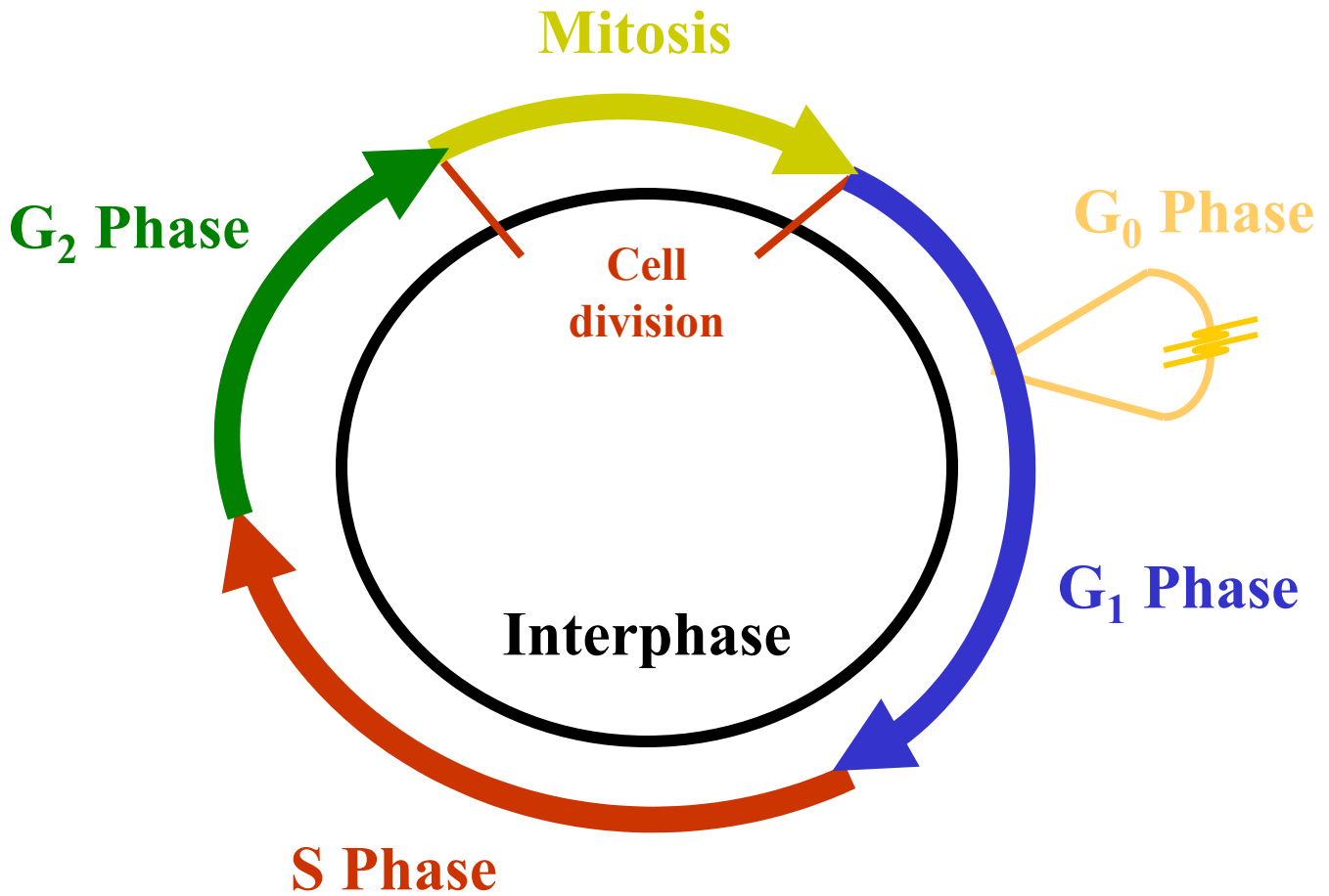
➤ **G₂** Gap₂=period during interphase after completion of DNA replication and before beginning of prophase

Interphase

G₁ and **G₂** are called gaps in the cell cycle when no DNA synthesis occurs

Cytological observations of the cell cycle are divided into two parts, interphase and mitosis

The Somatic Cell Cycle



The Mitotic cell cycle is essential to cell division and growth of an organism

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Gene Expression and Cell Division conflict:

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- Gene expression requires that chromosomal DNA be uncoiled to allow access to enzymes such as RNA polymerase

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Gene Expression and Cell Division conflict:

- Gene expression requires that chromosomal DNA be uncoiled to allow access to enzymes such as RNA polymerase
- Cell division requires that chromosomes be tightly coiled to allow orderly migration of chromosomes to daughter cells

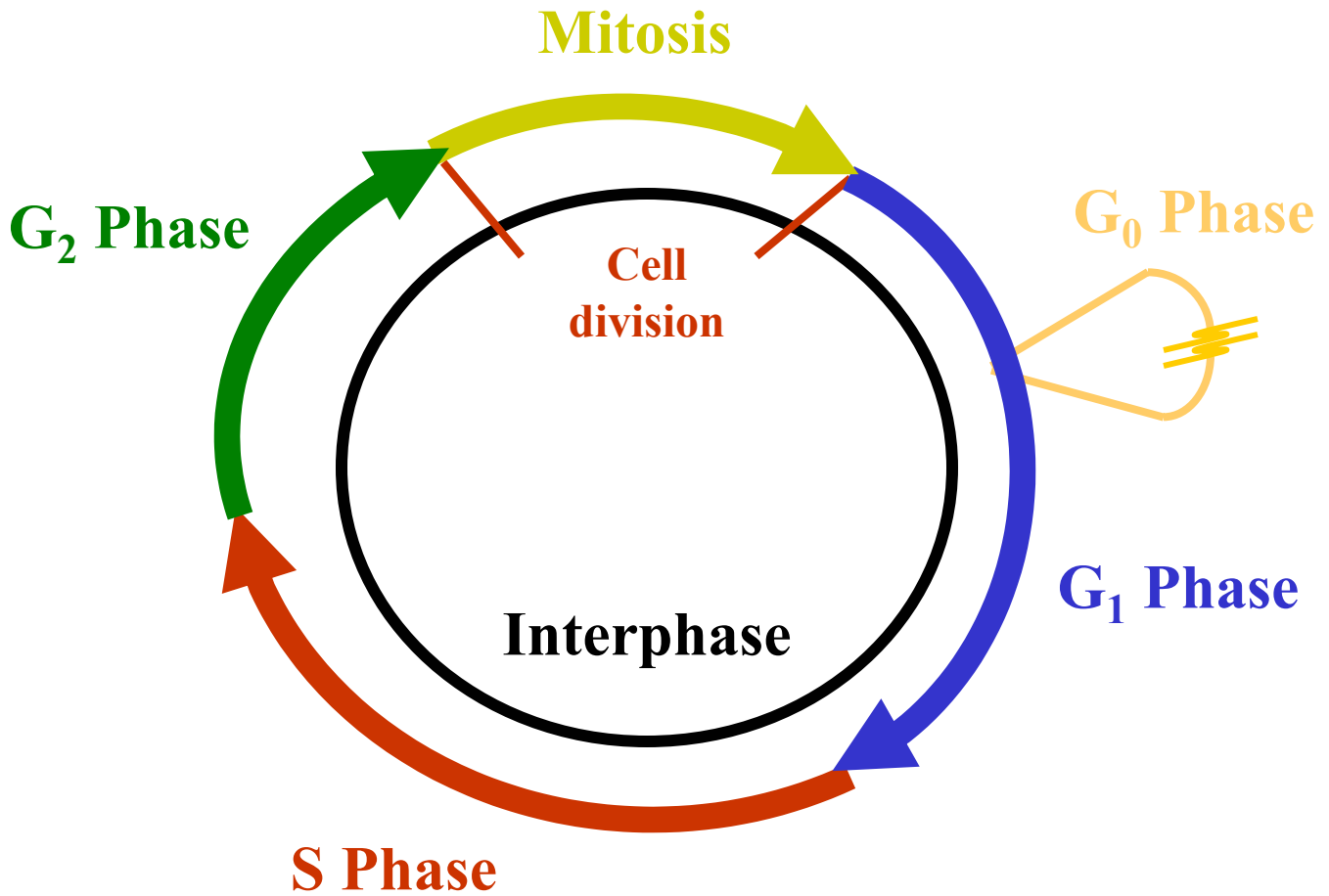
The Mitotic cell cycle is essential to cell division and growth of an organism

Gene Expression and Cell Division conflict:

- Gene expression requires that chromosomal DNA be uncoiled to allow access to enzymes such as RNA polymerase
- Cell division requires that chromosomes be tightly coiled to allow orderly migration of chromosomes to daughter cells

Gene Expression and Cell Division are separated into different stages

The Somatic Cell Cycle



Interphase

G_1

1. Period of gene expression
2. Daughter cells retain the diploid set of chromosomes and DNA content is $2c$
3. More variable in length than S, G_2 or M
4. Some event during G_1 is the focus of regulation of cell reproduction in tissues
5. Differentiated cells that cease to reproduce usually contain G_1 amount of DNA ($2c$) whether cessation is reversible or irreversible (G_0)

Interphase

G_1

6. In cells that continue to reproduce, the reproductive rate is governed by the average length of time that cells are retained in the G_1
7. Measurement of DNA content in dormant plant embryos indicate cells are arrested in G_1
8. G_1 may be absent in rapidly proliferating cells of higher organisms, particularly during embryogenesis
9. Once cells progress from G_1 to S, they are committed to proceed through mitosis

Interphase

S

1. Period of DNA synthesis (DNA content goes from $2c$ to $4c$)
2. Autoradiography shows that DNA synthesis is confined to a relatively short period
3. DNA replication is initiated by factors in the cytoplasm
 - a) when two or more nuclei share the same cytoplasm, they are nearly always synchronized

Interphase

S

4. DNA replication is initiated by factors in the cytoplasm
 - b) Gurdon (1973) observed that DNA synthesis was initiated when nuclei from various tissue of *Xenopus* were implanted into an unfertilized egg
 - c) Nuclei from adult liver, brain, and blood cells injected into mature eggs of *Xenopus* initiated DNA synthesis within 90 minutes of injection
 - d) Inhibition of protein synthesis in G_1 will inhibit or delay on set of the S phase

Interphase

G₂

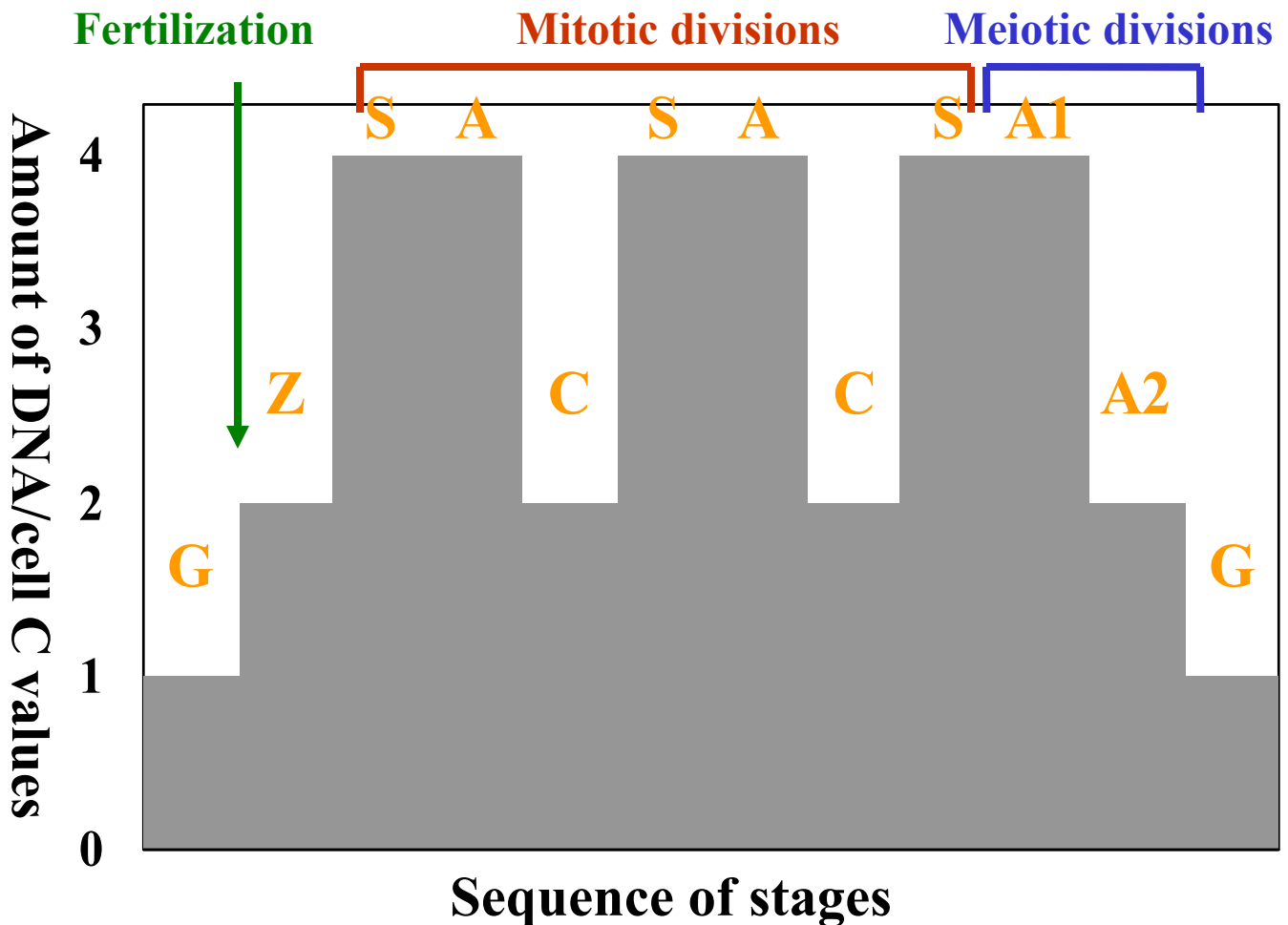
1. The nucleus contains two diploid sets of chromatids (DNA content is 4c)
2. Period required for cells to synthesize elements necessary for chromosome condensation and the construction and operation of the mitotic apparatus
3. Protein synthesis is necessary for cells to complete most of the G₂ period, but protein synthesis required for mitosis is completed prior to prophase
4. G₂ lasts until mitosis begins

Interphase

G₂

5. The fusion of a mitotic HeLa cell with an interphase cell results in condensation of interphase chromosomes (Rao and Johnson, 1970)
 - a) Chromosomes do not have to be replicated to respond to the condensation signal
 - b) The condensation factor is effective across phylogenetic lines (Bull sperm, chicken erythrocytes, and mosquito were condensed by the HeLa factor)

Life cycle of a sexually reproducing organism correlated with the amount of DNA per cell



G= Gamete, **Z**=Zygote, **S**=Period of DNA synthesis,
A=Mitotic Anaphase, **C**=Somatic Cells, **A1**=First meiotic
anaphase, **A2**= Second meiotic anaphase

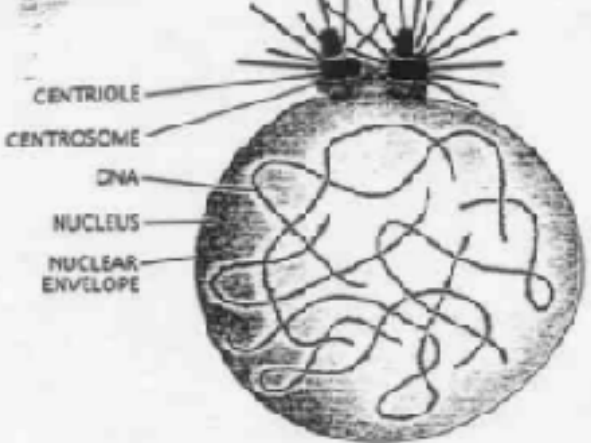
Mitosis

A mechanism by which replicated chromosomes are evenly distributed to two daughter cells. Each of the daughter cells will have the same number and kind of chromosomes as the parent.

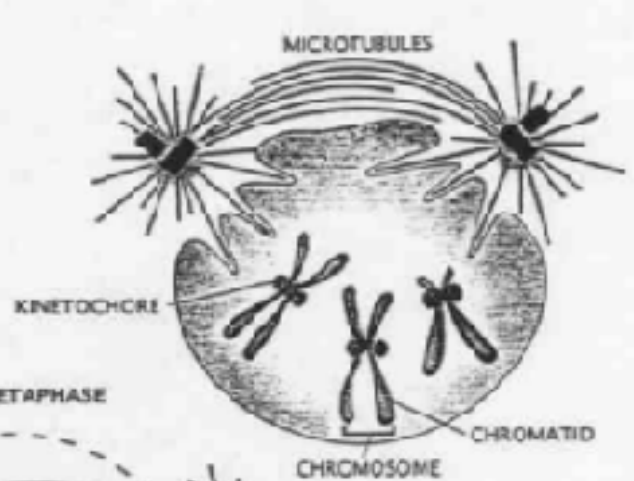
Stages of mitosis:

- **Interphase**
- **Prophase**
- **Prometaphase**
- **Metaphase**
- **Anaphase**
- **Telophase**
- **Cytokinesis**

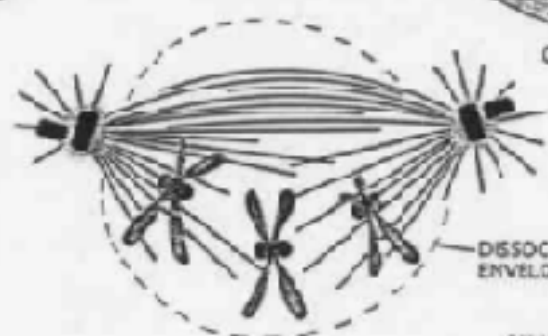
INTERPHASE



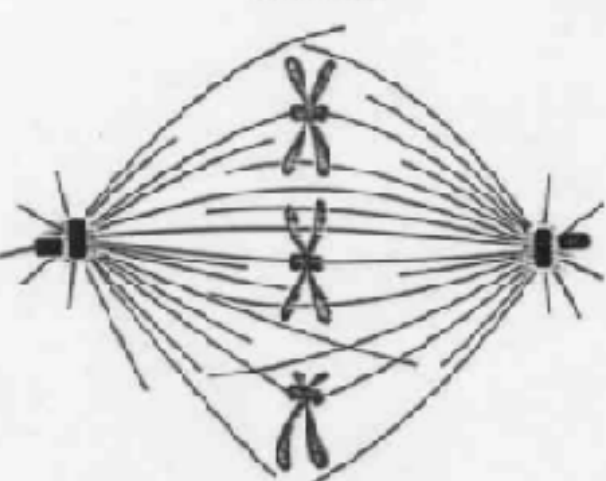
PROPHASE



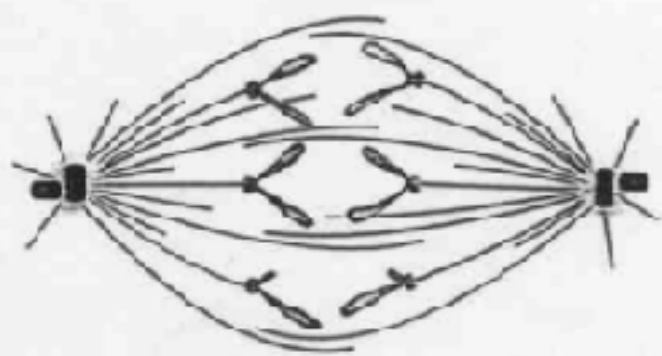
PROMETAPHASE



METAPHASE



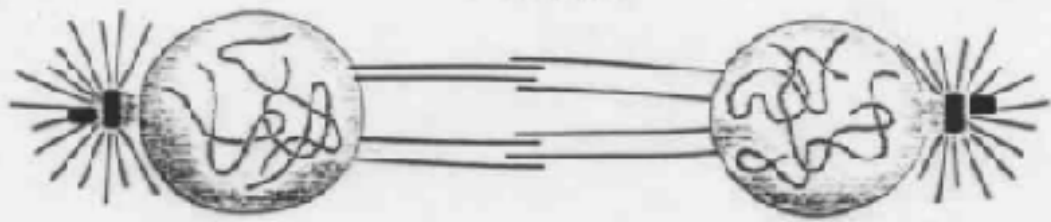
ANAPHASE A



ANAPHASE B



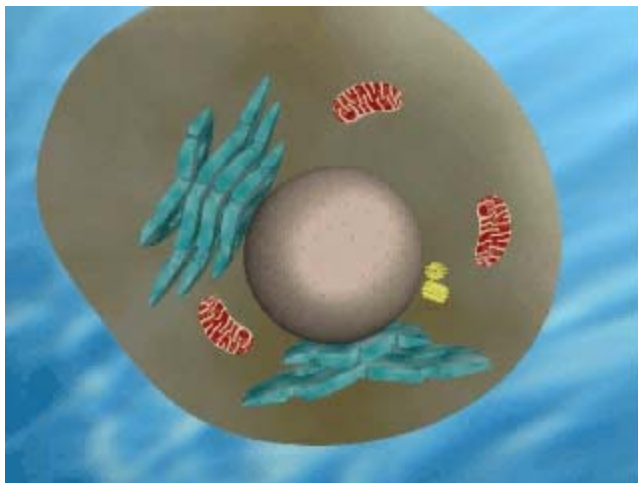
TELOPHASE



Stages of Mitosis

➤ Interphase:

- ✓ Chromosomes are fine diffuse strands and are difficult to see with light microscopy
- ✓ Chromosomes are duplicated
- ✓ The nuclear envelope is intact



Interphase

Stages of Mitosis

➤ **Interphase:**

- ✓ Chromosomes are fine diffuse strands and are difficult to see with light microscopy
- ✓ Chromosomes are duplicated
- ✓ The nuclear envelope is intact

➤ **Prophase**

- ✓ Chromosomes condense into distinct structures
- ✓ Chromosomes become visible with light microscopy



Prophase

Stages of Mitosis

➤ **Interphase:**

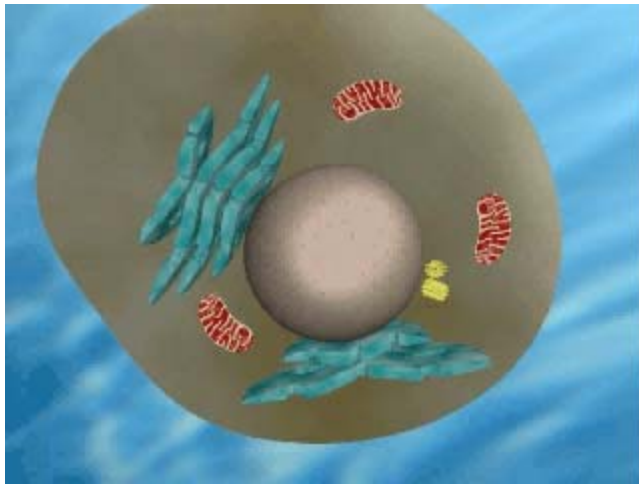
- ✓ Chromosomes are fine diffuse strands and are difficult to see with light microscopy
- ✓ Chromosomes are duplicated
- ✓ The nuclear envelope is intact

➤ **Prophase**

- ✓ Chromosomes condense into distinct structures
- ✓ Chromosomes become visible with light microscopy

➤ **Prometaphase**

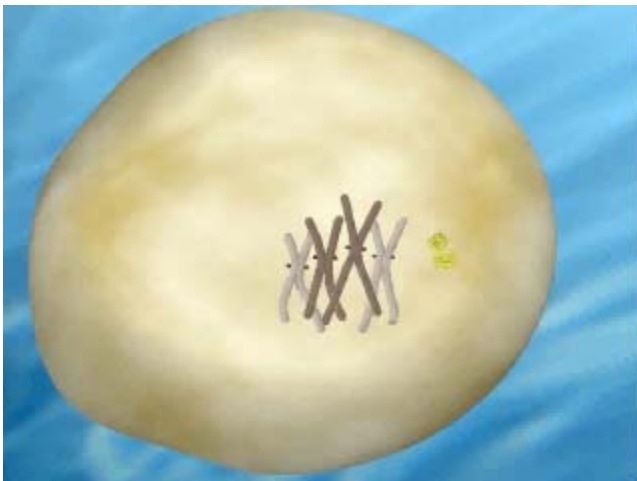
- ✓ Further chromosome condensation
- ✓ Nuclear envelope disintegrates
- ✓ Chromosomes become associated with spindle apparatus
- ✓ Sister chromatids remain attached at the centromere, but begin to separate at other regions



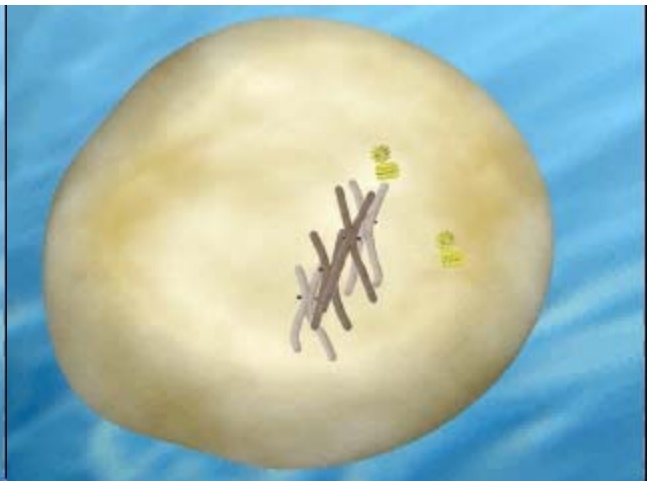
Interphase



Prophase



Prometaphase

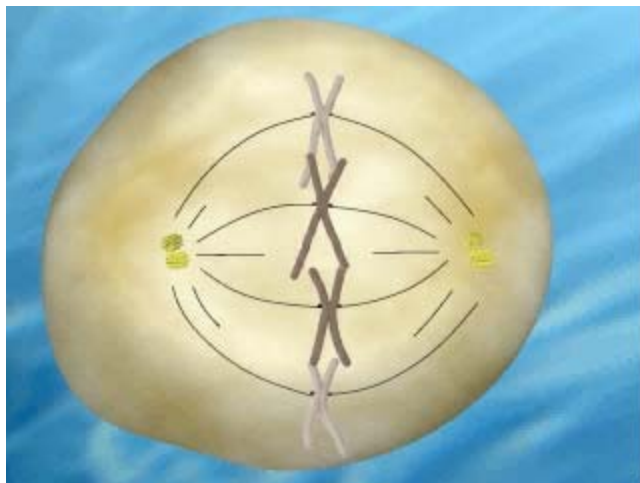


Prometaphase

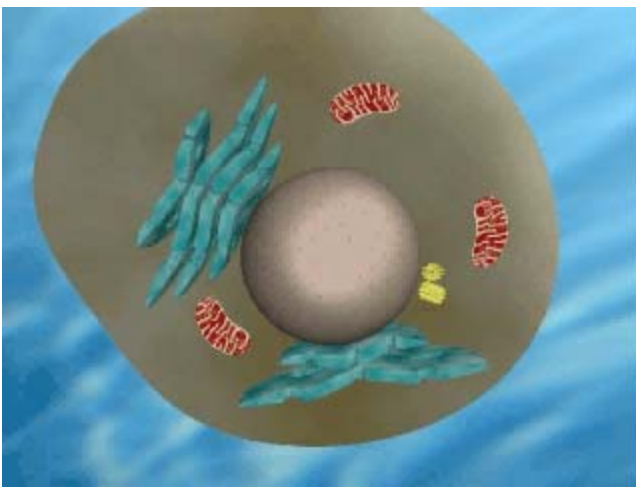
Stages of Mitosis

➤ Metaphase

- ✓ Sister chromatid pairs are aligned near the spindle with centromeres still associated
- ✓ The centromeres orient toward opposite poles and are lined up on the metaphase plate



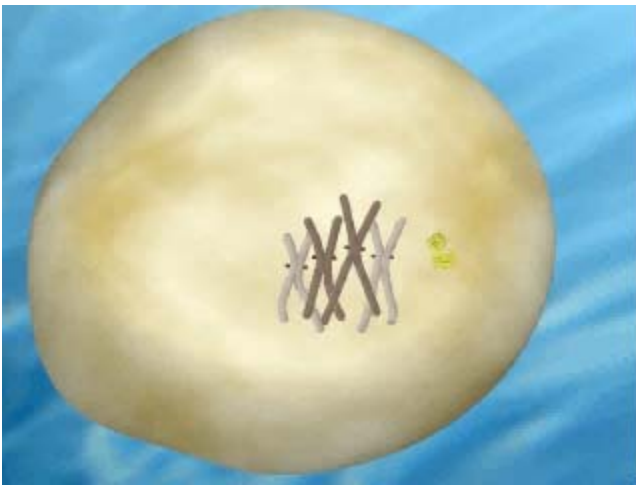
Metaphase



Interphase



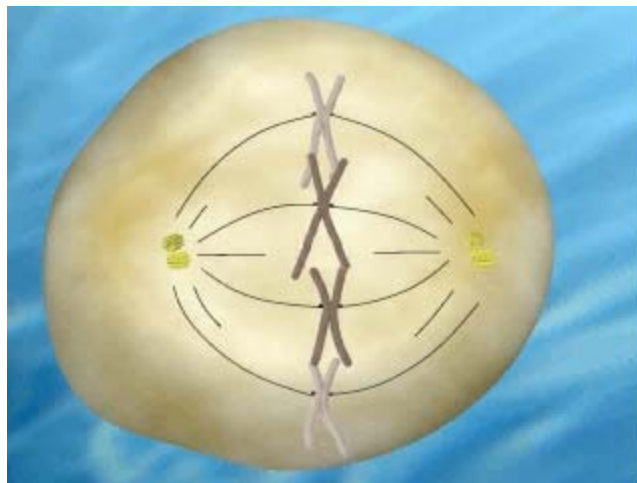
Prophase



Prometaphase



Prometaphase



Metaphase

Stages of Mitosis

➤ Metaphase

- ✓ Sister chromatid pairs are aligned near the spindle with centromeres still associated
- ✓ The centromeres orient toward opposite poles and are lined up on the metaphase plate

➤ Anaphase

- ✓ Sister chromatid pairs separate with one member of each pair moving toward the poles



Anaphase

Anaphase

Stages of Mitosis

➤ **Metaphase**

- ✓ Sister chromatid pairs are aligned near the spindle with centromeres still associated
- ✓ The centromeres orient toward opposite poles and are lined up on the metaphase plate

➤ **Anaphase**

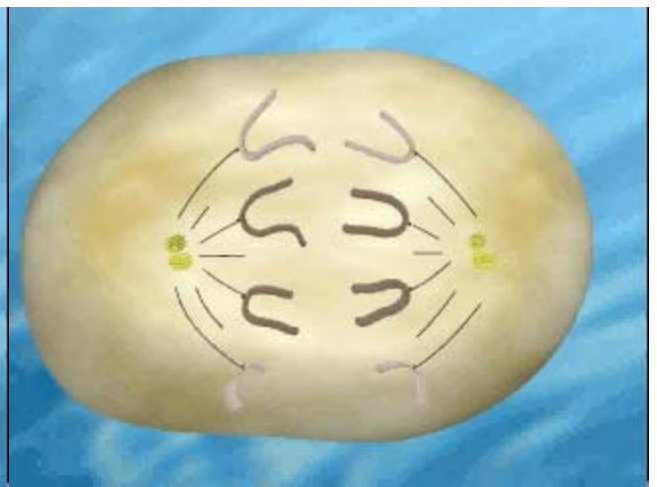
- ✓ Sister chromatid pairs separate with one member of each pair moving toward the poles

➤ **Telophase**

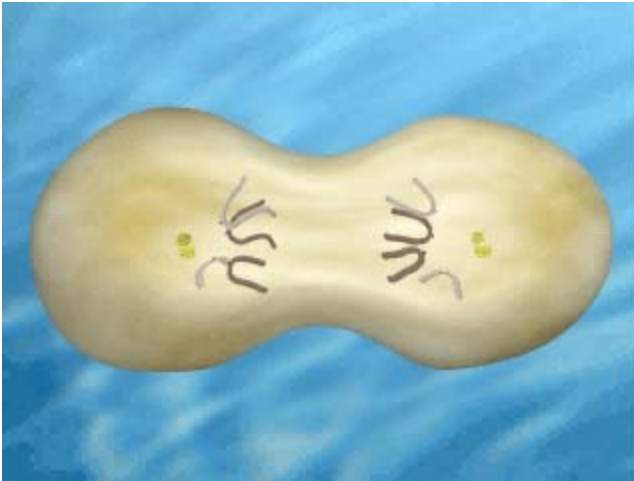
- ✓ Chromatids reach opposite poles and poleward movement ceases
- ✓ New nuclear envelope is formed around each diploid chromosome set
- ✓ Chromosomes begin to decondense



Anaphase



Anaphase



Telophase

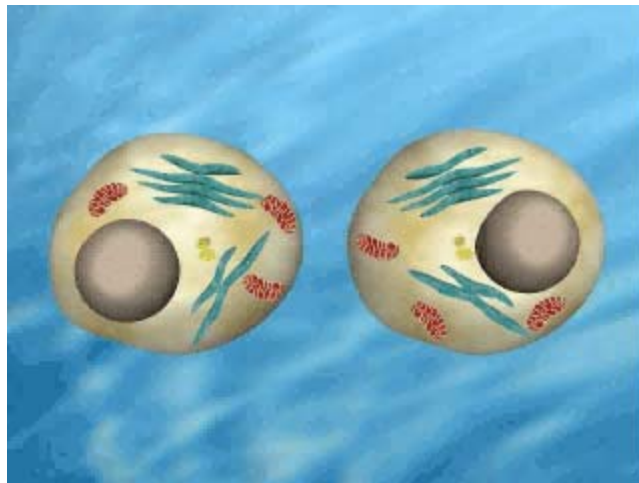


Telophase

Stages of Mitosis

➤ Cytokinesis

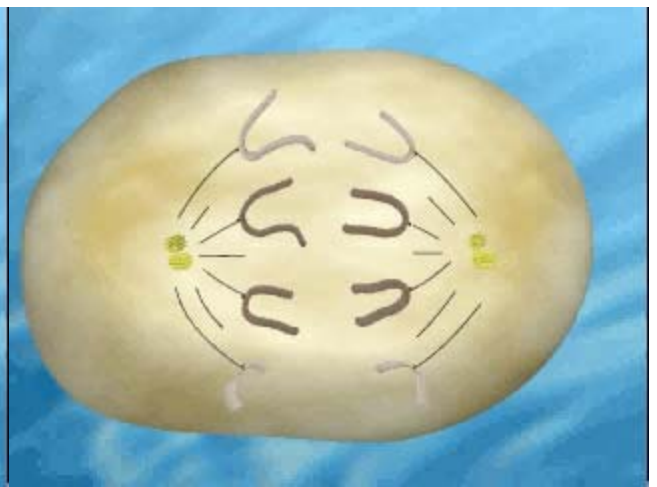
- ✓ During mitosis doubling of all the cytoplasmic organelles also occurs, they are distributed to daughter cells during this stage
- ✓ Central ring of myosin and actin fibers contract to separate the daughter cells
- ✓ In plants the cell plate is laid down in preparation for the rigid cell wall



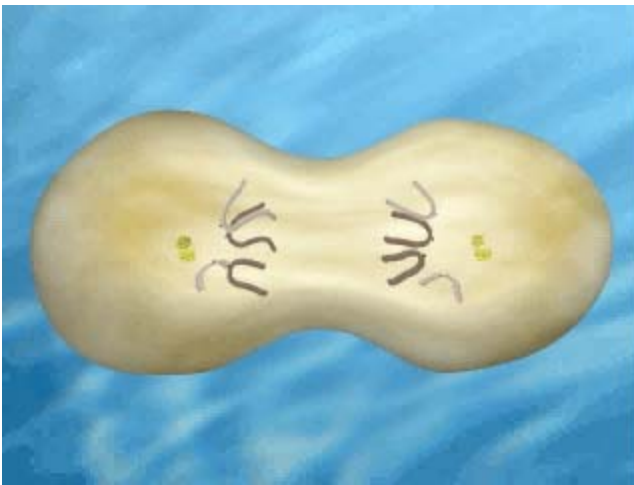
Cytokinesis



Anaphase



Anaphase



Telophase



Cytokinesis

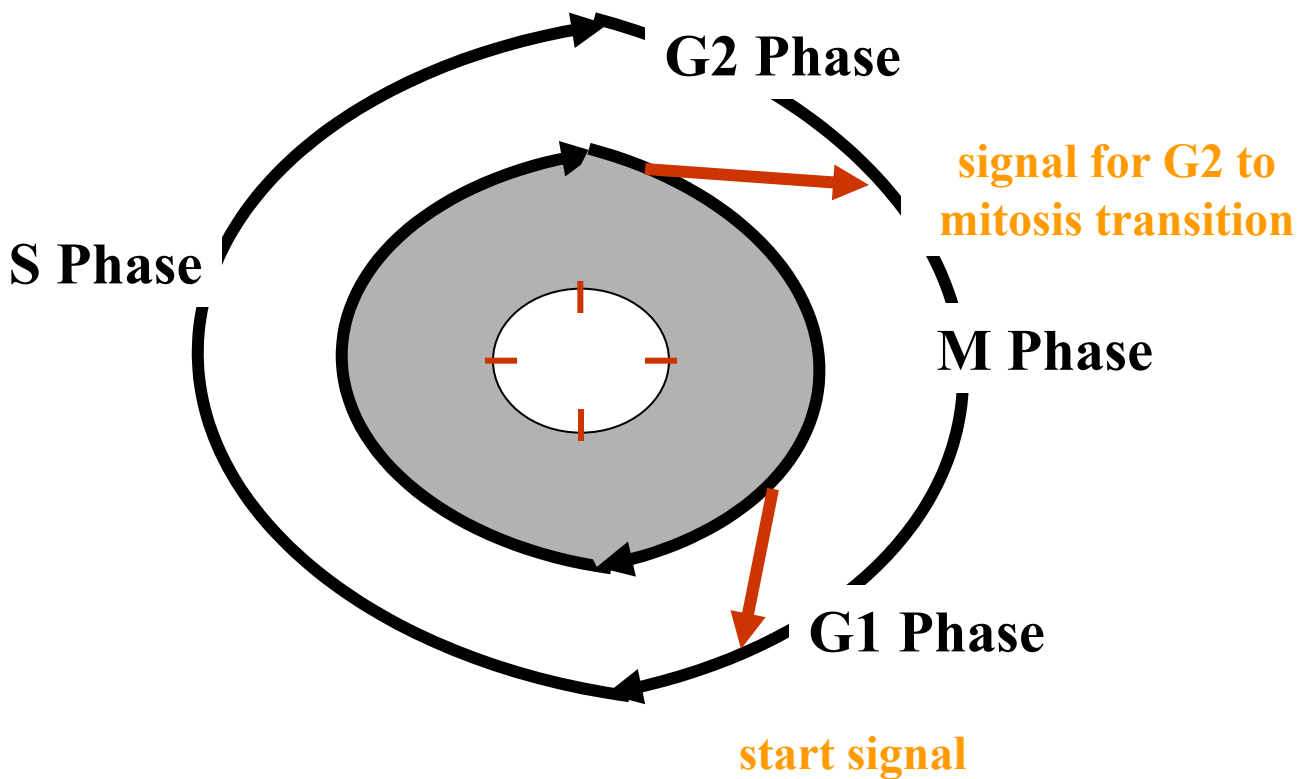


Cytokinesis

$$\text{Mitotic Index} = \frac{\text{\# of mitotic cells}}{\text{Total \# of cells}}$$

Mitotic cells = cells in stages from prophase to telophase

Control of Mitotic Cell Division



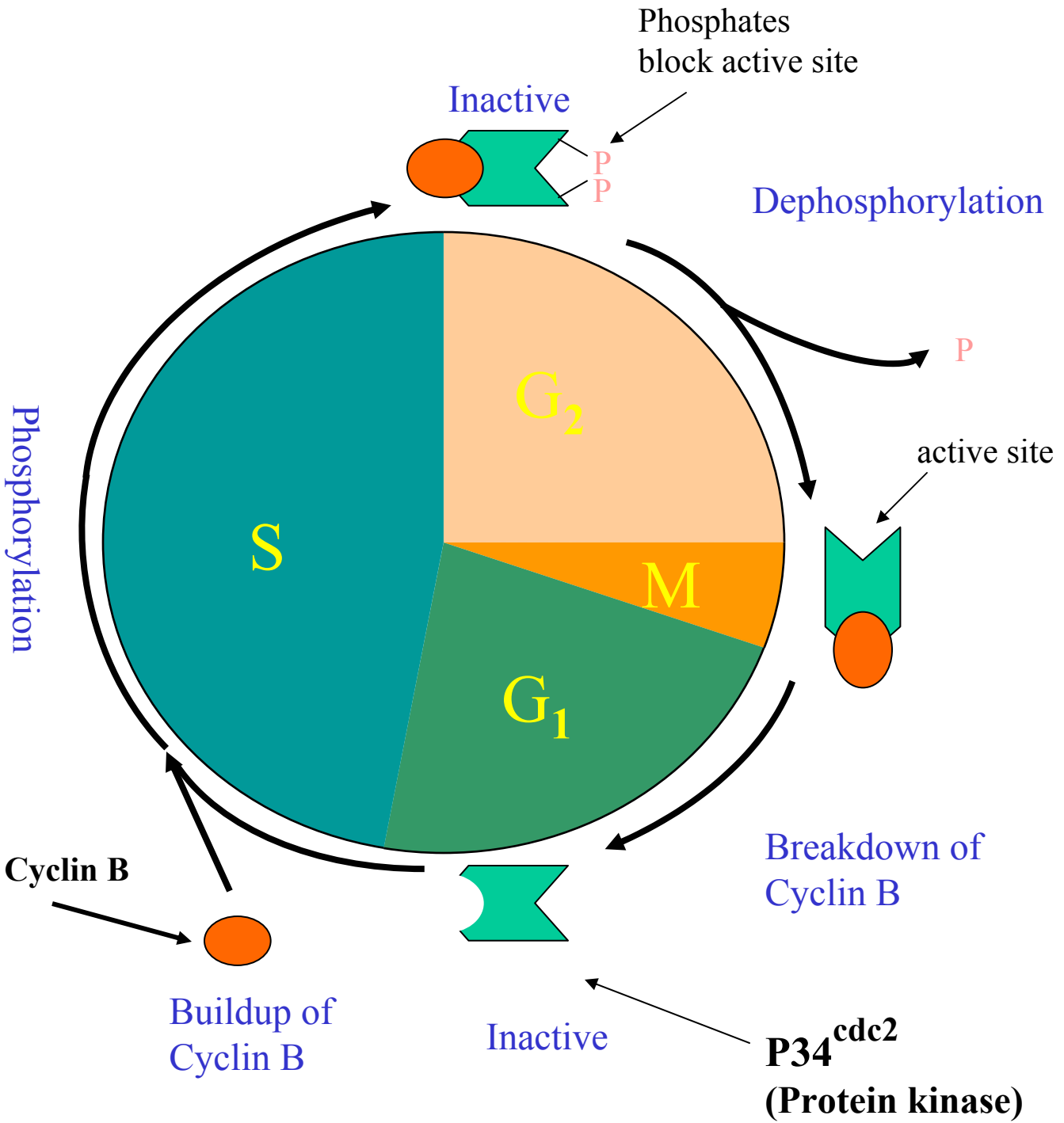
**Molecular
clock**

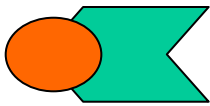
Control of Mitotic Cell Division

- a) The onset of mitosis is accompanied by the presence of an active maturation (or mitosis) promoting factor (MPF)

Control of Mitotic Cell Division

- The onset of mitosis is accompanied by the presence of an active maturation (or mitosis) promoting factor (MPF)
- MPF purified from frog eggs consists of two protein subunits (Lohka et al. 1988). These were recognized as the 34 kD Protein Kinase (P34^{cdc2}) and 45 kD B-type cyclin.
- Active MPF triggers the onset of mitosis, immediately afterward following events occur:
 - a) Cyclin activity is degraded
 - b) The nuclear membrane begins to break down
 - c) Chromosome condensation begins
 - d) The spindle apparatus is organized



 = MPF or maturation-promoting factor or mitosis promoting factor

Glossary of terms

The Somatic Cell Cycle= Events that occur from one cell division to the next

2C= DNA content of nucleus in the somatic cells of an organism

Chromatid= A single chromosomal strand; a metaphase chromosome is composed of two “sister” chromatids

Centromere=A region of chromosome from which kinetichore microtubules radiate during mitosis or meiosis

Kinetochores= A specialized region on the centromere that links each sister chromatid to the mitotic spindle

Heterochromatin= non-transcribed eukaryotic chromatin that is so highly compacted that it is visible with a light microscope during interphase

Euchromatin= The more open, unraveled form of eukaryotic chromatin, which is available for transcription