Biology

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Cell Cycle and Cell division

- The cell cycle, or cell-division cycle, is the series of events that take place in a cell leading to its division and duplication of its DNA (DNA replication) to produce two daughter cells

- A cell divide through generations to create a population of cells called clone

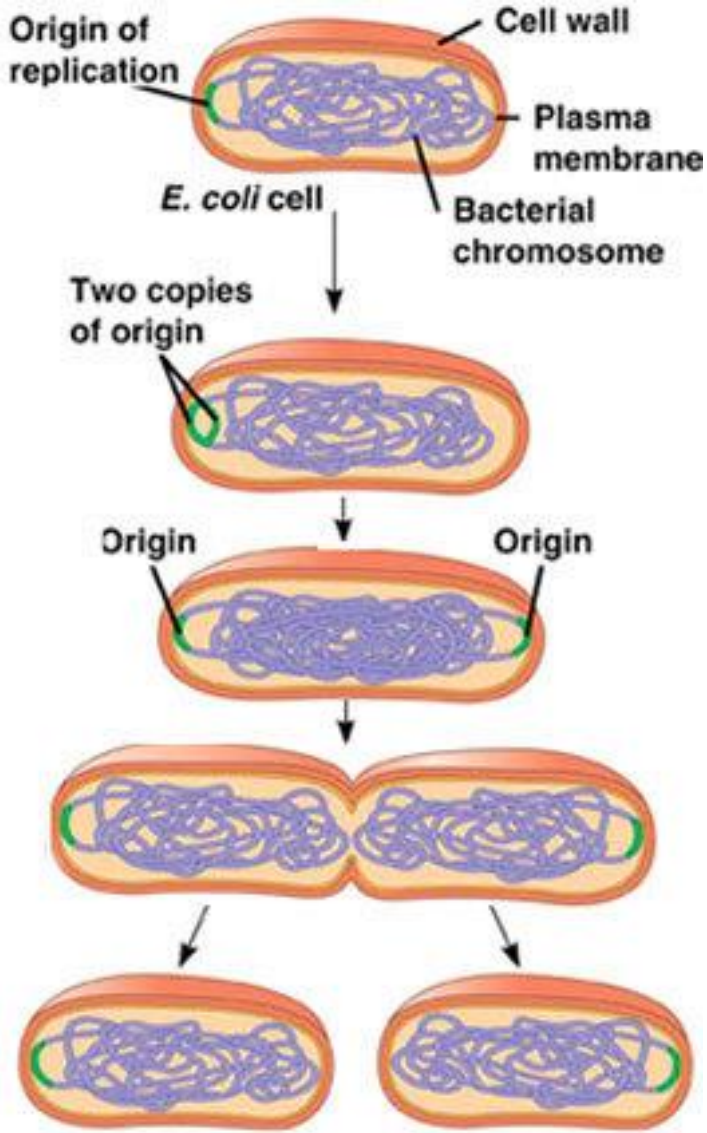
- A cell that is about to divide is called mother cell and product of division is called Daughter cells

- Prokaryotes - Binary fission
- Eukaryotes – Mitosis and Meiosis

Prokaryotic reproduction - Binary fission

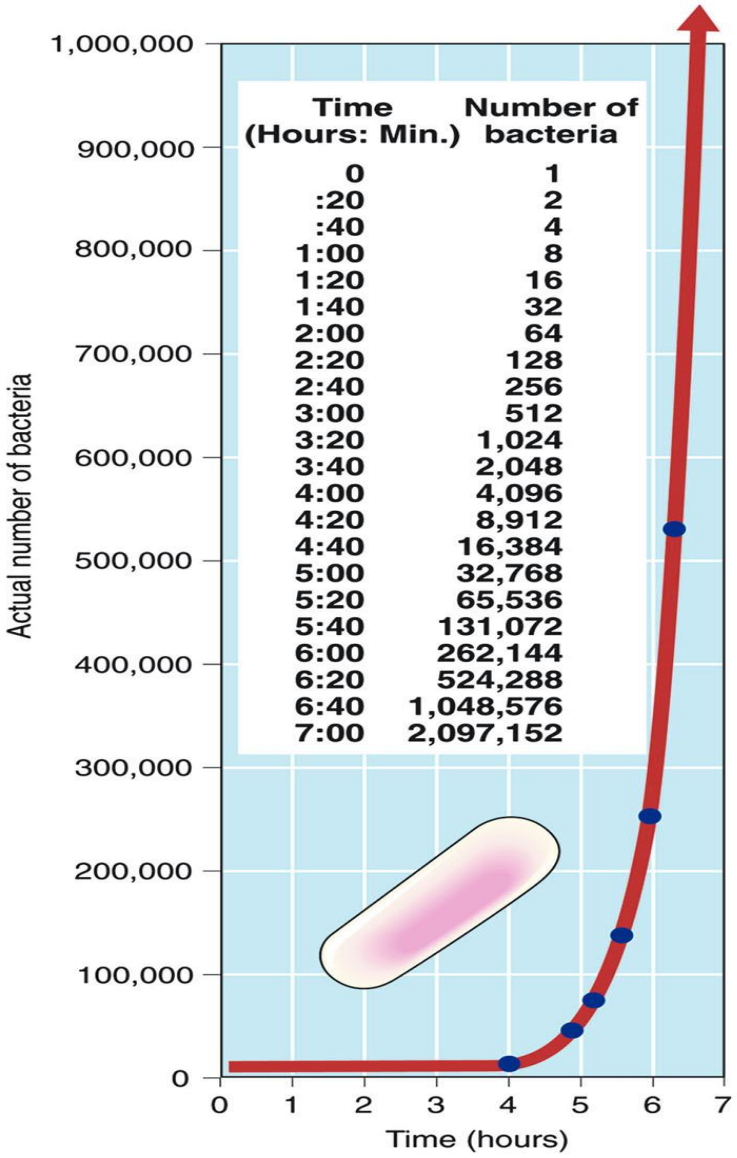
- Asexual reproduction and cell division used by all prokaryotes (bacteria and archaebacteria), and some organelles within eukaryotic organisms (e.g., mitochondria)
- This process results in the reproduction of a living prokaryotic cell (or organelle) by division into two parts that each have the potential to grow to the size of the original cell (or organelle)
- This type of division takes place without the formation of spindles
- The single DNA molecule first replicates, then each copy attaches to a different part of the cell membrane
- When the cell begins to pull apart, the replicated and original DNA molecules are separated
- The consequence of this asexual method of reproduction is that all the cells are genetically identical, meaning that they have the same genetic material

1. Chromosome replication begins. Soon thereafter, one copy of the origin moves rapidly toward the other end of the cell.
2. Replication continues. One copy of the origin is now at each end of the cell.
3. Replication finishes. The plasma membrane grows inward, and new cell wall is deposited.
4. Two daughter cells result.



Prokaryotic reproduction - Binary fission

- Bacteria reproduce by binary fission
  - $1 \rightarrow 2 \rightarrow 2^2 \rightarrow 2^3 \rightarrow 2^4 \rightarrow 2^n$ (n=Number of generation)
  - Each succeeding generation, assuming no cell death, doubles the population
- Exponential growth rate
- Total population after certain time $N_t = N_0 \times 2^n$



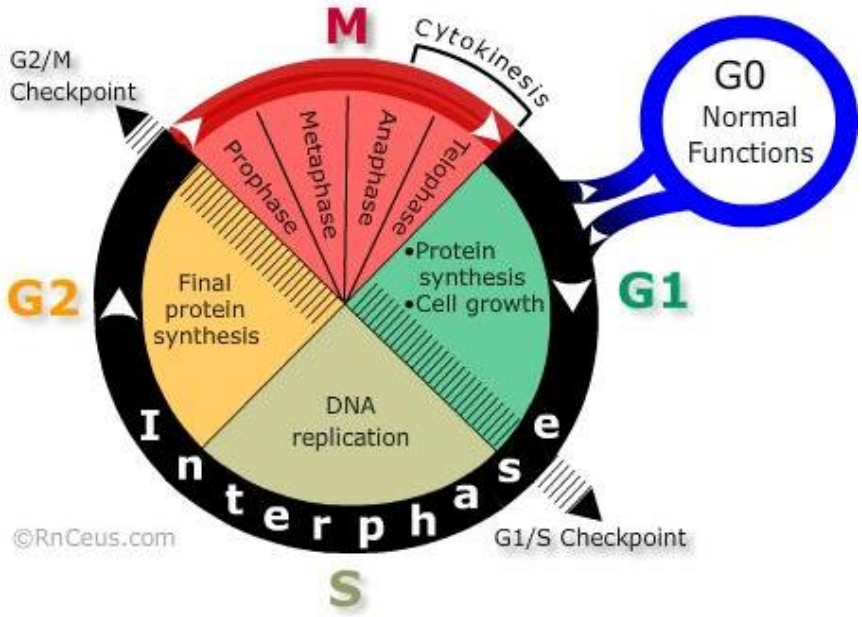
Prokaryotic reproduction - Binary fission

- *E. coli* has a generation time of 20 minutes. If you start with 1 *E. coli* cell how many do you have after 2 hours?
- **$Nt = N_0 \text{ X } 2^n$**
- $64 = 1 \text{ x } \mathbf{2^6}$

- If it is 2 hours, then 6 generations
- 120 minutes/20 minutes = 6

Eukaryotic cell division

- Three different phase
- Resting phase
- Interphase – Growth of cells (between two M phase)
- Mitotic phase – Division occurs

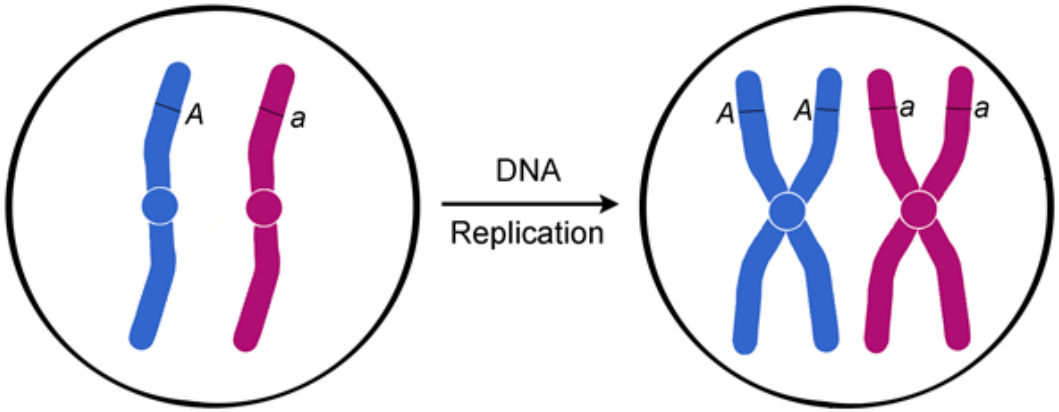


Cell cycle – G1 phase

- Post Mitotic phase
- Cells accumulate energy and prepares themselves for next phase
- Active synthesis of RNA and protein takes place
- That are required for DNA synthesis
- Features – unreplicated DNA is present, Cell increase in size, Chromosome remain uncondensed

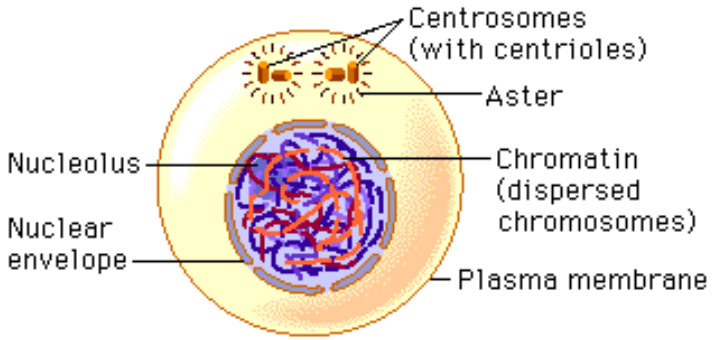
Cell cycle – S phase

- Duplication of DNA, copy number of DNA is doubled
- Duplication of centrioles
- Loose bundle of chromatin
- Sister chromatids are joined by centromere



Cell Cycle – G2 Phase

- Preparation of cells to undergo cell division
- Formation of macromolecules required for spindle formation
- So, RNA and protein are actively produced and organelles are also multiplied



Cell Cycle – M Phase

- Where the division of cell occurs through mitosis or meiosis phase
- Mitosis (**The process that distributes duplicated chromosomes exactly and equally to the daughter cells)** and cytokinesis (**The process that physically separates two daughter cells from each other)**:
  - Prophase
  - Metaphase
  - Anaphase
  - Telophase

Cell Cycle – M Phase

- During mitosis chromosomes shorten and condense out of the chromatin network and easily recognizable
- After mitosis chromosomes de-condense and chromatin network is reformed
- Microtubules composed of protein tubulin distributes the chromosome equally to daughter cells
- These microtubules assemble into complex array called the spindle
- The formation of spindle is associated with microtubule organizing centres (MTOCs) found near nucleus in cytoplasm of eukaryotic cells
- In animal cells, MTOCs are differentiated into small organelles called centrosomes
- Each centrosome contains two barrel-shaped centrioles aligned at right angles to each other
- The single centrosome that exist in animal cell is duplicated during interphase

Cell Cycle – M Phase

- **As the cell enters mitosis, microtubules develop around each of the daughter centrosomes to form a sunburst pattern called aster**
- **These centrosomes then move to the opposite direction in the cell where they establish the axis of the upcoming mitotic division**
- **Mitosis consist of different phases i:e Prophase, Metaphase, Anaphase and Telophase**
- **The length of cell cycle varies between different cell types**
- **In embryos where growth is rapid it takes approx. 30 min.**
- **In slow growing adult tissues it takes several months**
- **Some cells in nerve and muscle tissue cease to divide**

Cell Cycle – M Phase – Prophase

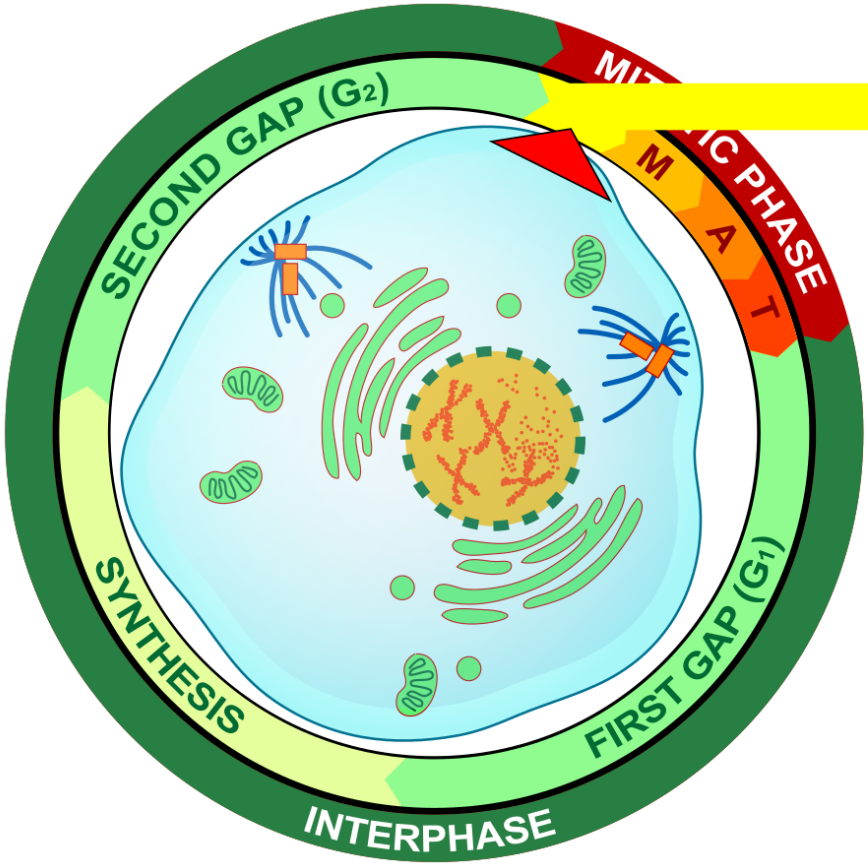
1. Chromatin in the nucleus begins to condense and becomes visible in the light microscope as chromosomes

2. The nucleolus disappears and Centrioles begin moving to opposite ends of the cell and fibres extend from the centromeres (aster)

3. Formation of spindle is accompanied by fragmentation of many intracellular organelles like ER and Golgi complex

4. Nuclear membrane breaks up into many small vesicles

Cell Cycle – M Phase – Prophase



*Nucleolus disappears

*Chromatin condenses into chromosomes

*Separation of centrosomes

*Formation of the mitotic spindle

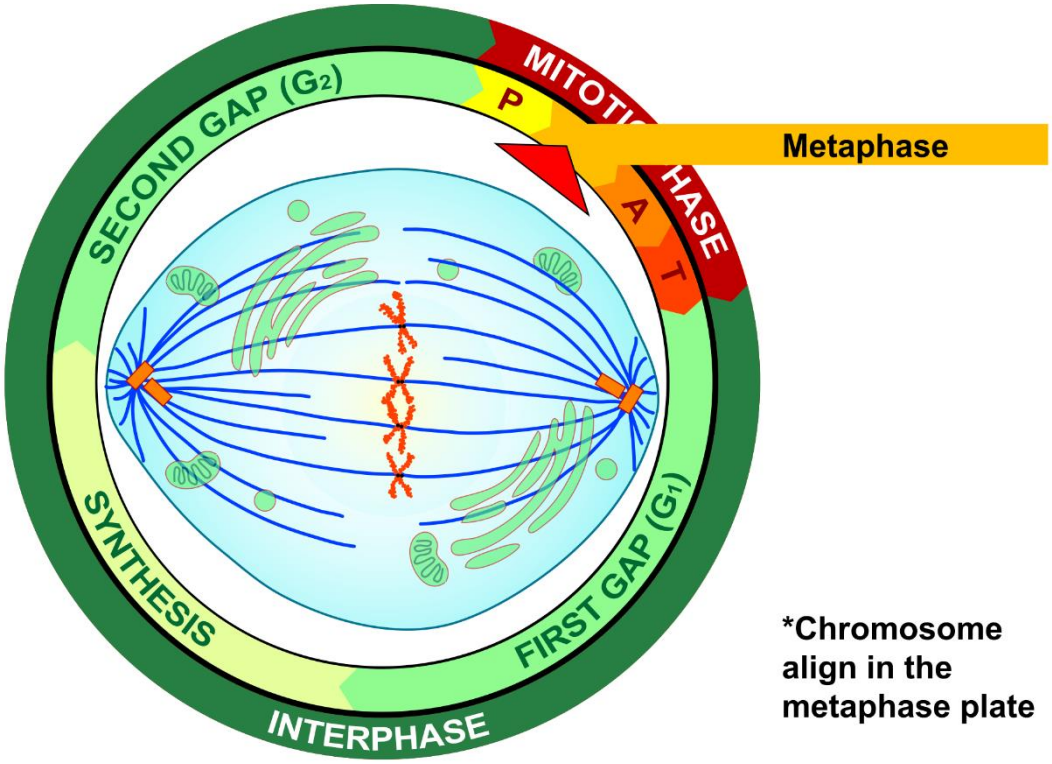
Cell Cycle – M Phase – Metaphase

1. Chromosomes are shortened and thickened

2. Proteins attach to the centromeres create the kinetochores

3. Microtubules attach at the kinetochores and the chromosomes begin moving towards centre of the cell until all the centromeres lie on a plane of the equator of the mitotic apparatus called metaphase plate

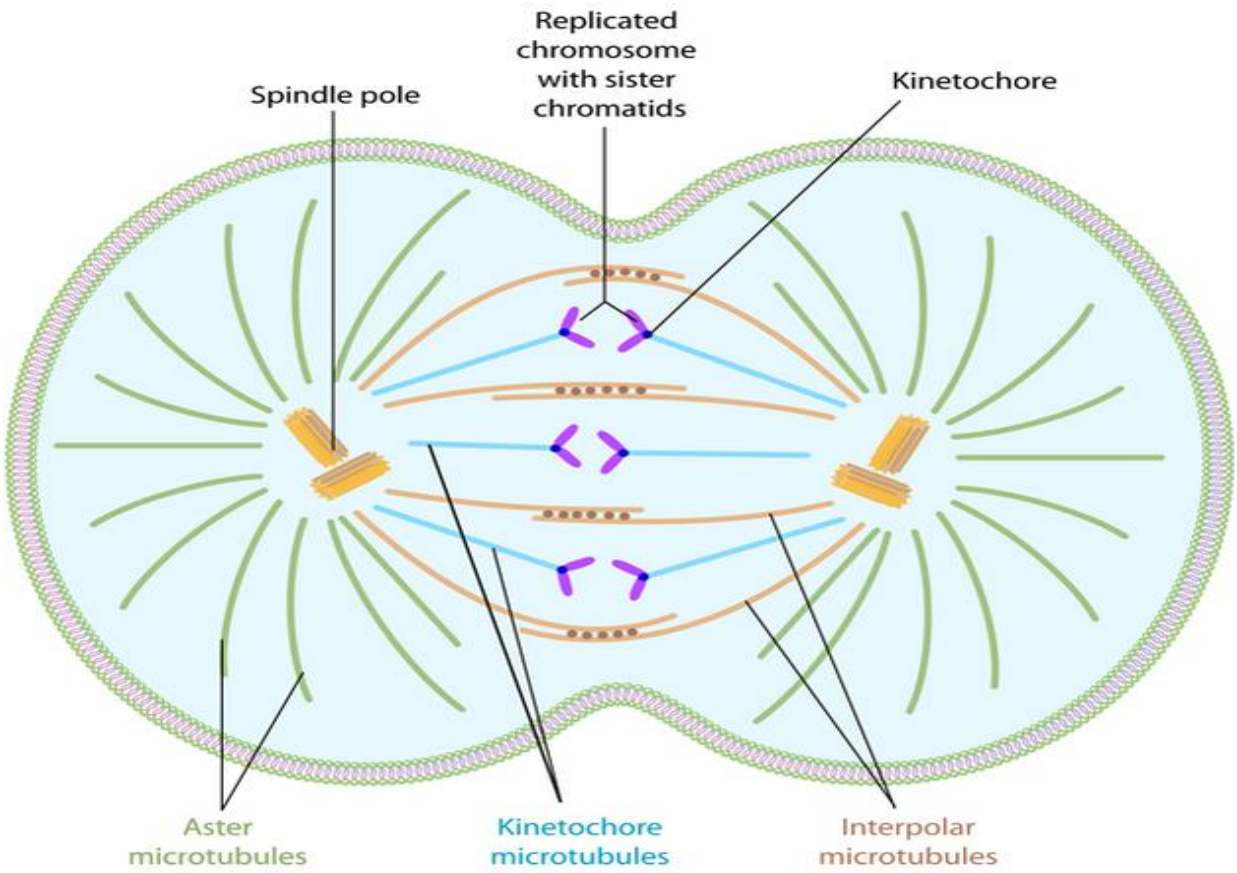
Cell Cycle – M Phase – Metaphase



Cell Cycle – M Phase – Anaphase

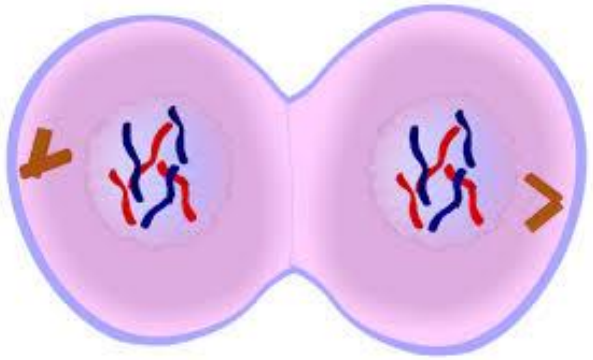
1. Centromere divides
2. Two sister chromatids move towards the opposite poles of the spindle fibre and become single chromosome
3. The position of metacentric chromosome look like V-shaped, sub-metacentric like J-shaped and telocentric like rod shaped
4. Process of cell cleavage begins which in animal cells begin like a furrow from periphery to inward and in the plant cell from inside to outside
5. The set of organelles that were lost, re-form
6. Set of chromosomes becomes enclosed in nuclear membrane

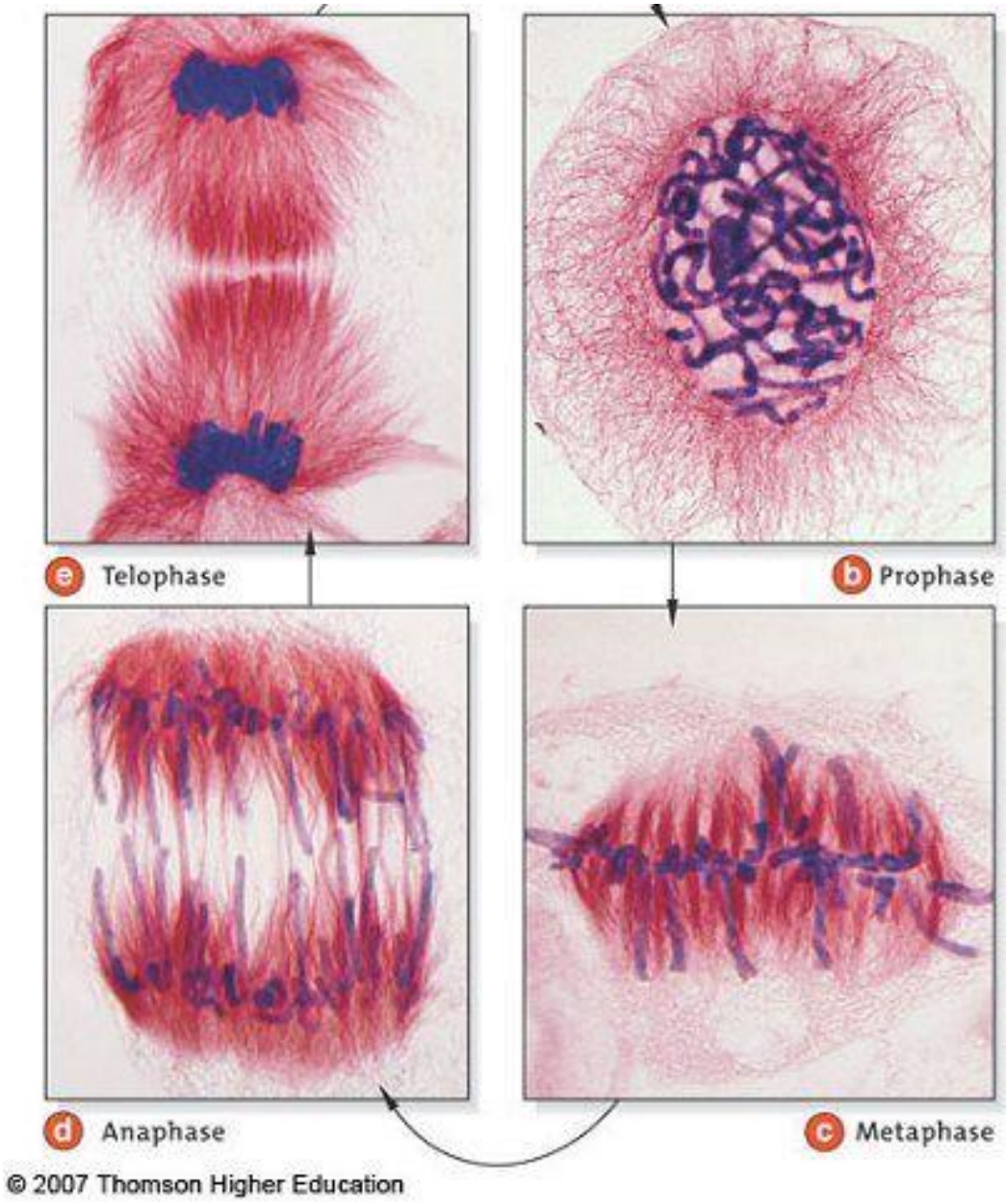
Cell Cycle – M Phase – Anaphase



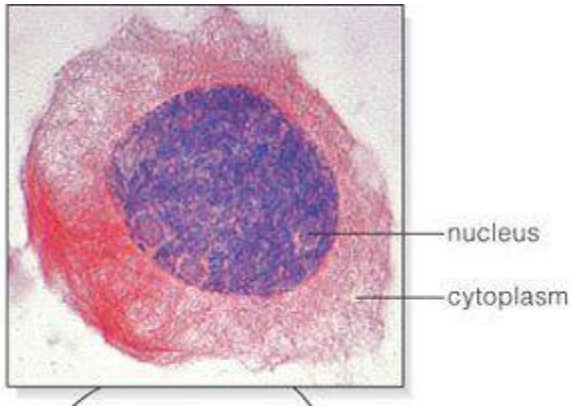
Cell Cycle – M Phase – Telophase

1. Sister chromosomes reach to opposite poles on their migration
2. Spindle fibres disappear
3. Cytokinesis starts
4. All the internal organelles are restored
5. Chromosomes become distant and invisible
6. Two nuclei slowly enter into interphase





a Cell at Interphase

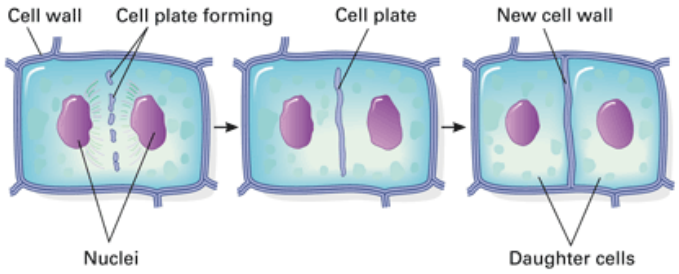


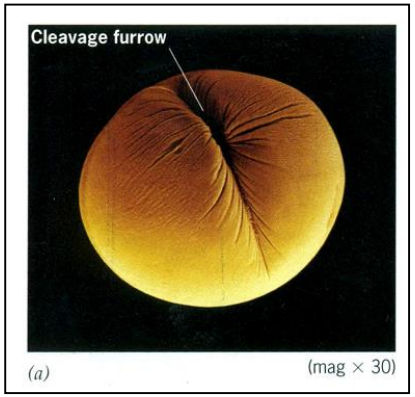
Cell Cycle – Cytokinesis

1. Initiates during anaphase and occurs during telophase

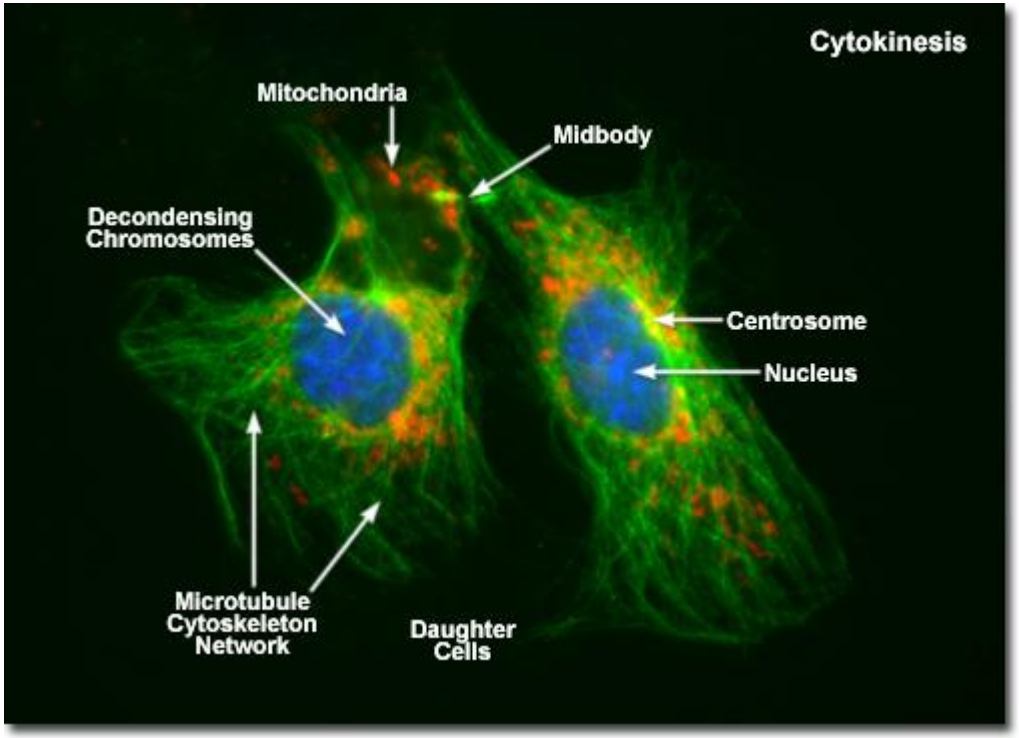
2. In higher plants, it occurs with the formation of cell plate in the mid-plane of the mitotic apparatus which is later converted to middle lamella with a new cross-wall between daughter cells

3. In animal cells, it starts with the cleavage formation as a furrowing process around the cell in the plane of metaphase plate





Cell Cycle – Cytokinesis



Mitosis in Rat Kangaroo Epithelial Kidney Cells

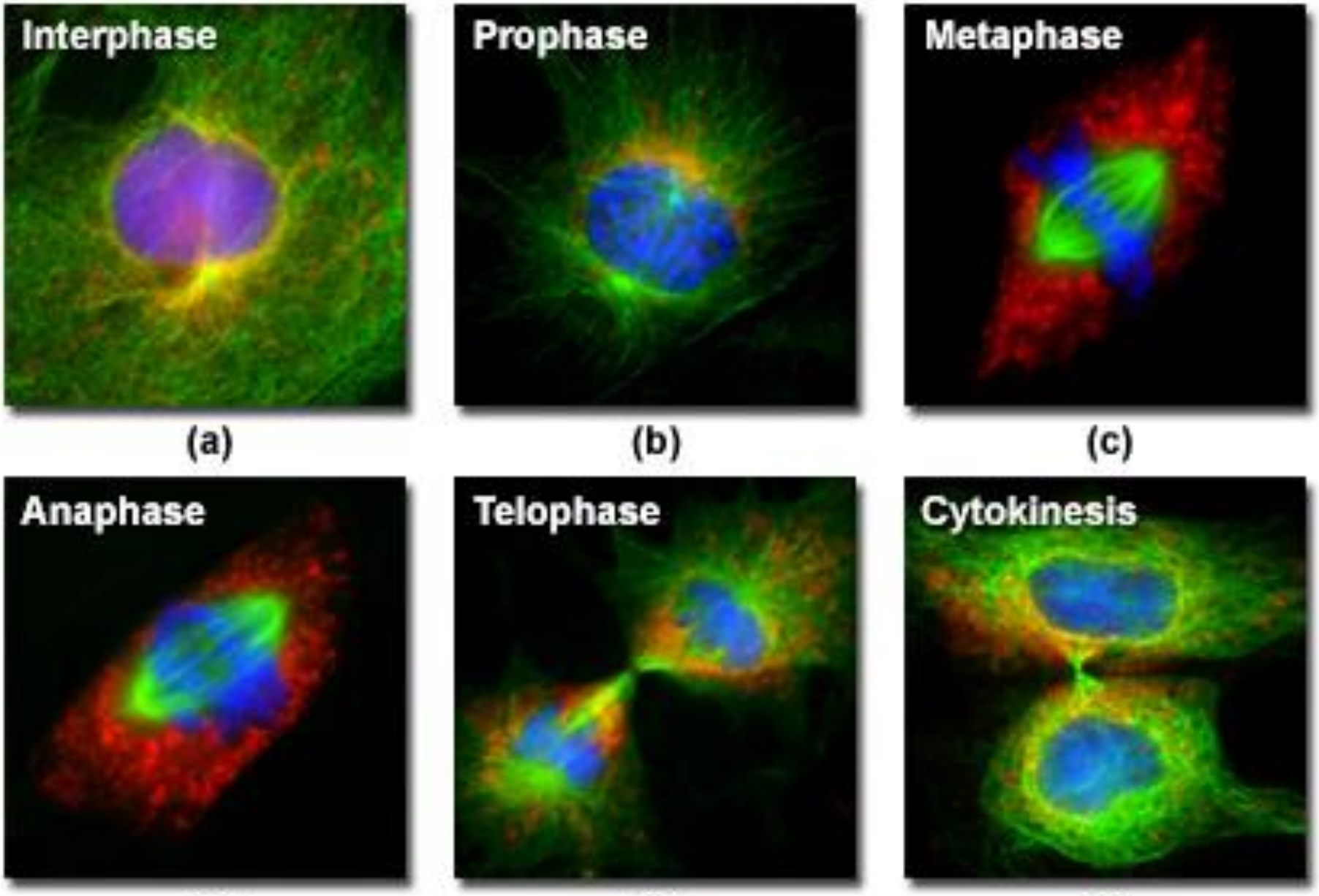
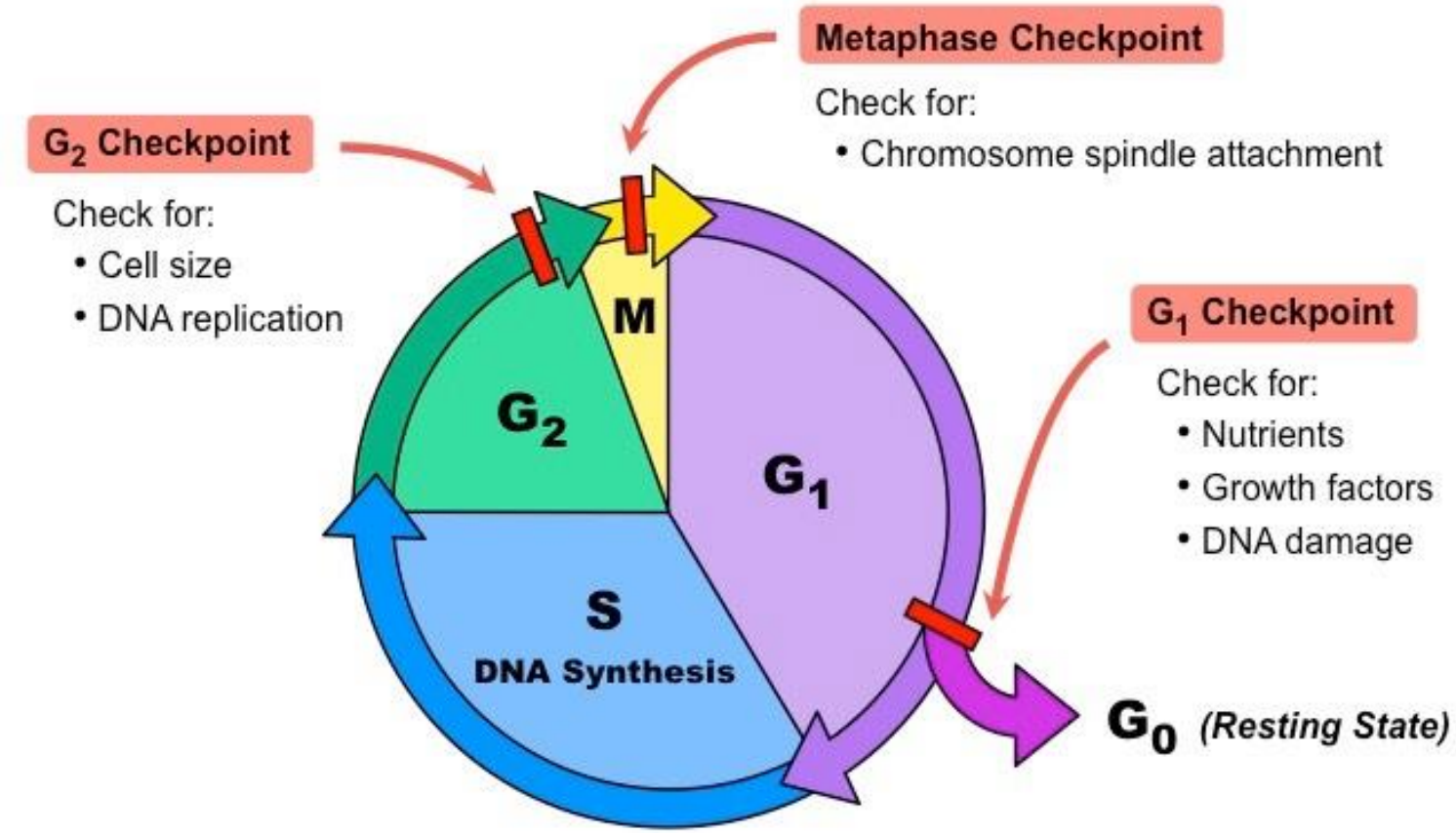


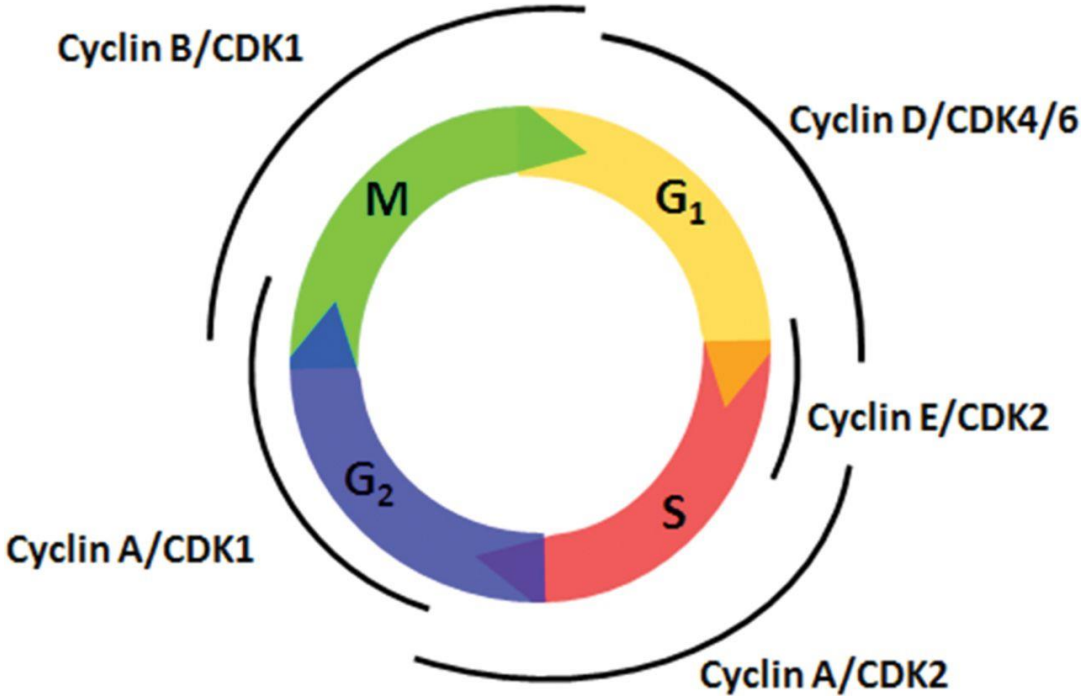
Figure 1

Check points



Check points

- Cyclin – small protein
- Cyclin dependent kinase (Cdk)



Check points

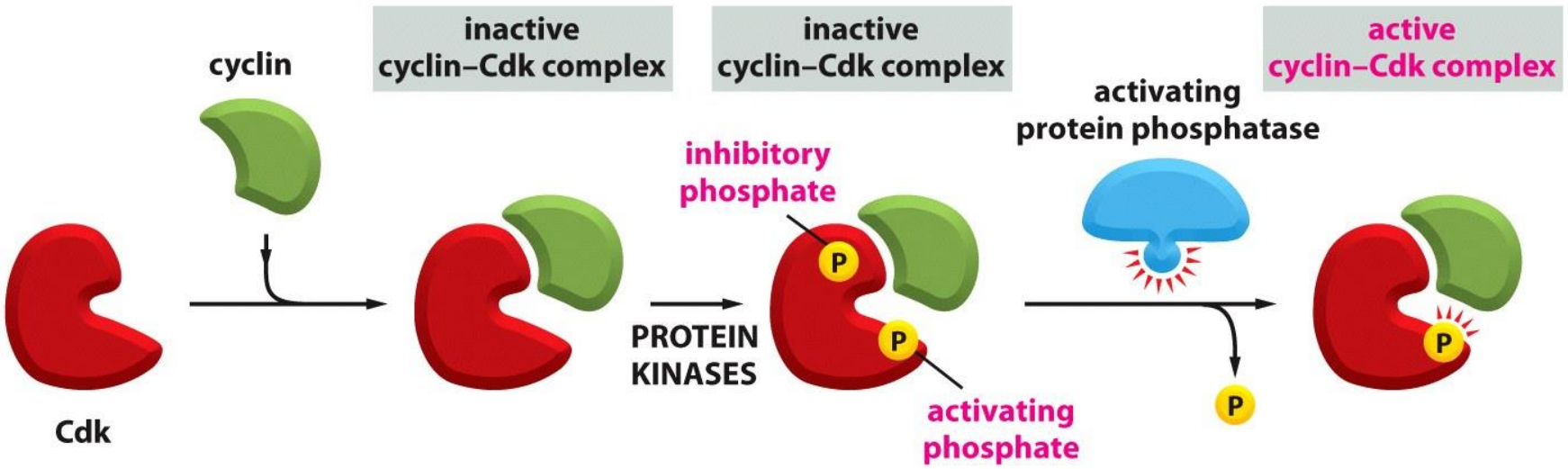
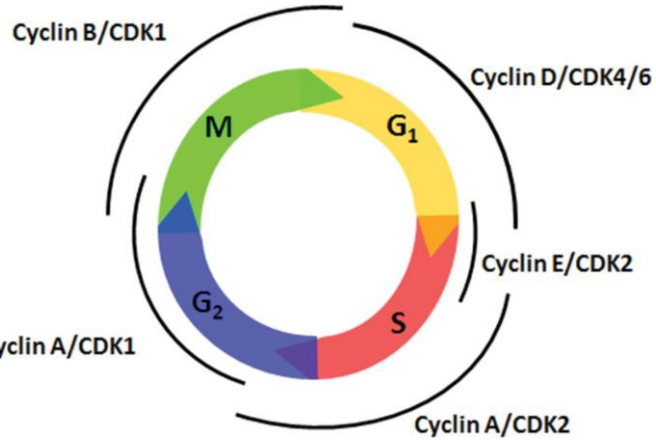
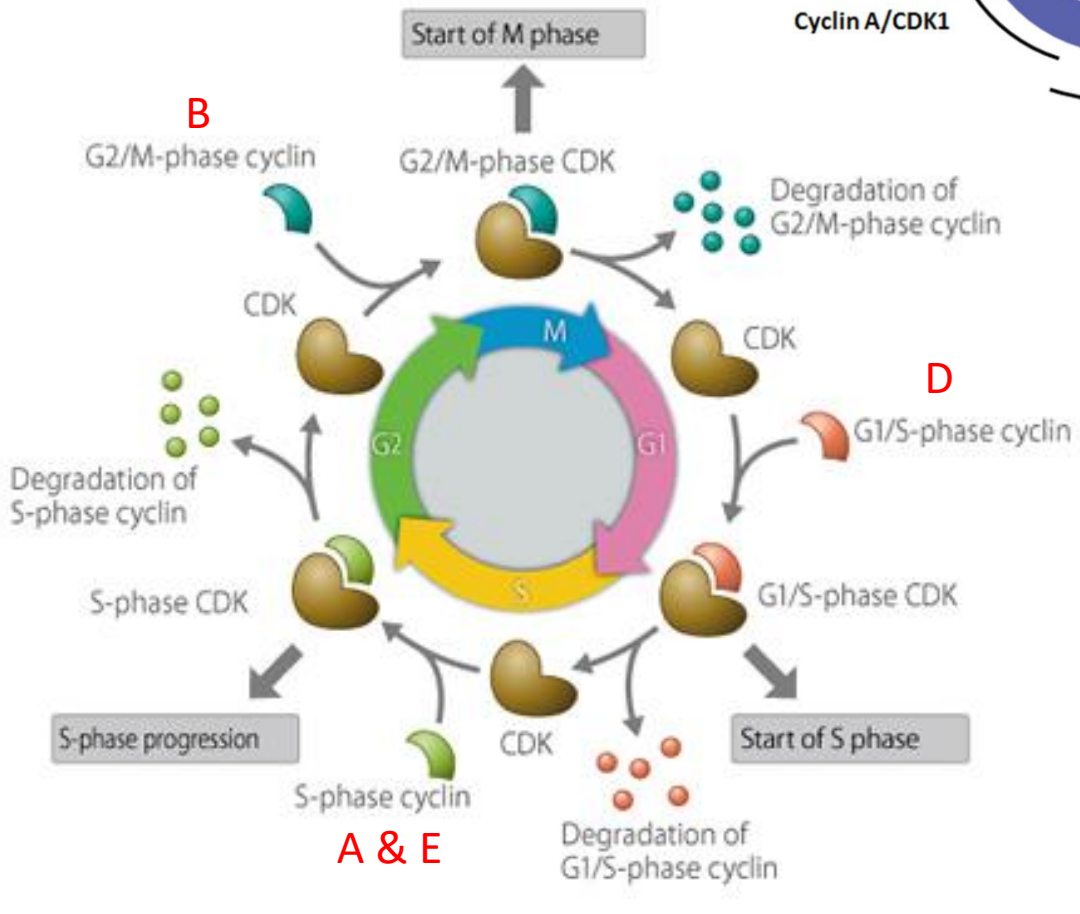


Figure 18-9 Essential Cell Biology 3/e (© Garland Science 2010)


Cyclin B/CDK1
Cyclin D/CDK4/6
M
G1
Cyclin E/CDK2
G2
S
Cyclin A/CDK1
Cyclin A/CDK2


Start of M phase
B
G2/M-phase cyclin
G2/M-phase CDK
Degradation of
G2/M-phase cyclin
CDK
CDK
M
D
G1/S-phase cyclin
G2
G1
Degradation of
S-phase cyclin
S-phase CDK
G1/S-phase CDK
S
S-phase progression
CDK
Start of S phase
S-phase cyclin
A & E
Degradation of
G1/S-phase cyclin
ZOOM

Check points

- **The passage of a cell through the cell cycle is controlled by proteins in the cytoplasm**
- **Among the main players in animal cells are:**
- **Cyclins**
  - **G_1 cyclins (D cyclins)**
  - **S-phase cyclins (cyclins E and A)**
  - **mitotic cyclins (B cyclins)**
- **Their levels in the cell rise and fall with the stages of the cell cycle.**
- **Cyclin-dependent kinases (Cdks)**
  - **a G_1 Cdk (Cdk4)**
  - **an S-phase Cdk (Cdk2)**
  - **an M-phase Cdk (Cdk1)**
- **Their levels in the cell remain fairly stable, but each must bind the appropriate**
- **cyclin (whose levels fluctuate) in order to be activated**