Advanced Level Biology:

CANCER BIOLOGY

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Learning outcome:

- analyse the structural and functional significance of nucleic acids in meiosis and mitosis, their role in cellular functions, and **how mutations in nucleotide sequences can contribute to disease (cancer).**

Study activities;

In groups

a) search and discuss:

i) mitosis

ii) cancer causes risk factors, prevention, and management.

b) Make a write-up that includes a mind map showing the relationship between cell division and cancer.

BS Pg 523

INTRODUCTION:

Define the following terms;

a) Oncogenes
b) Tumor
c) Metastasis
d) Malignant
e) Benign
f) Tumor suppressor genes
g) DNA repair genes
h) Carcinogens

BS Pg 523;

- **Tumor:** An abnormal mass of tissue that forms when cells grow and divide more than they should, or do not die when they should. Tumors can be non-cancerous or cancerous.
- **Benign:** A term used to describe a tumor or growth that is non-cancerous. Benign tumors do not usually spread to nearby tissues or other parts of the body.
- **Malignant:** A tumor that is cancerous. Malignant tumors can invade and destroy nearby tissue and spread to other parts of the body.
- **Metastasis:** The process by which cancer cells break away from the original tumor, move through the blood or lymphatic system, and form new tumors in other parts of the body.

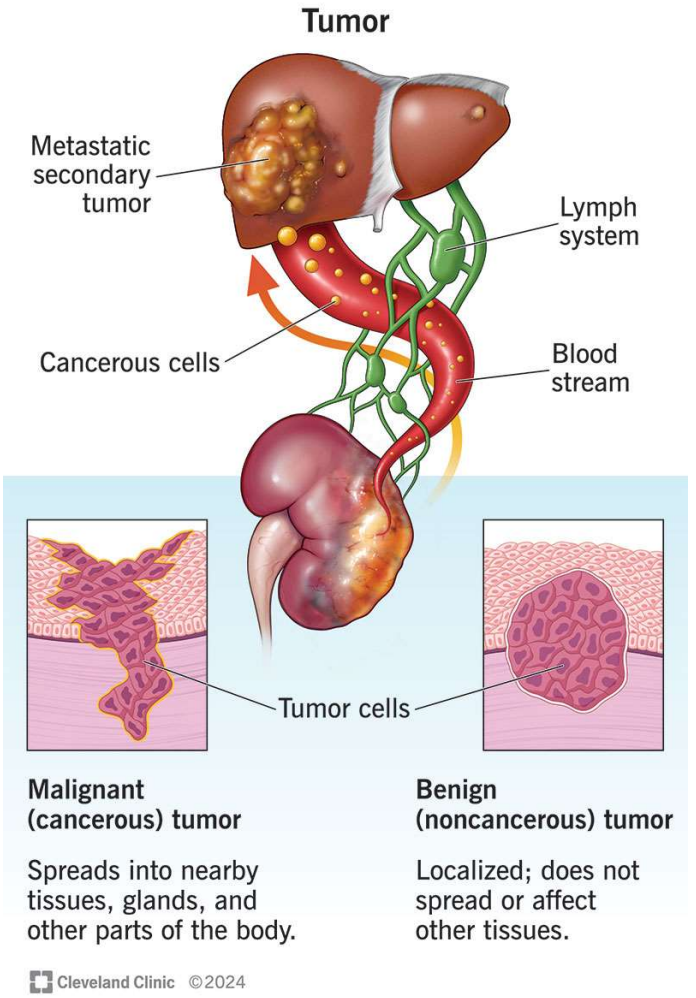
- **Oncogenes:** Mutated genes (previously inform proto-oncogenes) that cause cells to grow and divide uncontrollably, contributing to cancer development.
- **Tumor suppressor genes:** Normal genes that slow down cell division, repair DNA mistakes, When these genes mutate or lose function, cells can grow out of control. or tell cells when to die.
- **DNA repair genes:** Genes that code for proteins responsible for fixing damaged DNA. If these genes are damaged or mutated, genetic mistakes pile up, which can lead to cancer.
- **Carcinogens:** Any substance, radionuclide, or radiation that promotes the formation of cancer or increases its incidence by directly damaging DNA or disrupting cellular processes.

Cancer;

- A group of diseases characterized by uncontrolled, abnormal cell division that may invade nearby tissues and spread (metastasize) to other parts of the body.
- Unlike normal cells, cancer cells escape growth regulation mechanisms and continue dividing uncontrollably .

Cancer in 3D
Malignant tumor in the liver
(Metastasis)





Causes of cancer (BS Pg 524)

Genetic mutations

- Changes in DNA sequences of proto-oncogenes, tumor suppressor genes, or DNA repair genes can trigger cancer. For example: Mutation in the **p53 tumor suppressor gene** leads to loss of cell cycle control.
- **Carcinogens;**

Substances that can cause cancer by damaging DNA. Examples: tobacco smoke, asbestos, benzene, aflatoxins, radiation (UV & X-rays).

Viruses and microorganisms

- Certain viruses integrate their genetic material into host DNA, leading to uncontrolled cell proliferation. Examples: Human Papillomavirus (HPV_cervical cancer), Hepatitis B and C viruses (liver cancer), and Epstein-Barr virus (Burkitt's lymphoma).

Hormonal factors

- Prolonged exposure to certain hormones can stimulate excessive cell division. For example: estrogen linked to breast and endometrial cancers.

Chronic inflammation & immune Suppression

- Persistent inflammation damages tissues and increases mutation rates. Immunocompromised individuals have a reduced ability to destroy abnormal cells.

Cancer risk factors

The chances of developing cancer are influenced by certain risk factors—conditions, behaviors, or exposures that increase the likelihood of cancer development. They can be categorized into two major groups:

Modifiable Risk Factors

(Controllable)

These factors can be changed, avoided, or controlled.

(a) Lifestyle factors: Tobacco smoking, excessive alcohol consumption, unhealthy/poor diet (high-fat, low-fiber), obesity, and physical inactivity.

(b) Environmental exposure: Exposure to radiation, industrial chemicals like asbestos, benzene, heavy metals, or pollutants like pesticides.

(c) Biological factors: Viral infections (HPV → cervical cancer; Hepatitis B & C → liver cancer; HIV → Kaposi sarcoma) and long-term use of hormone replacement therapy (HRT) or birth control pills.

Non-Modifiable Risk Factors

(Uncontrollable)

These factors cannot be changed.

(a) **Age:** Cancer risk increases with age due to accumulation of genetic mutations over time.

(b) **Family history/genetics:** Inherited mutations increase risks (e.g., BRCA1 & BRCA2 increase breast/ovarian cancer risk).

(c) **Sex:** Specific cancers occur in one sex (prostate in men, cervical in women) or show varied prevalence due to hormonal differences.

(d) **Ethnicity/race:** Certain cancers are more common in particular ethnic groups due to genetic differences and lifestyle patterns.

Preventive measures for cancer (BS 525)

Cancer prevention aims to minimize risk factors and detect the disease early for effective management. Measures are categorized into three levels:

1. Primary preventive measures

(Reducing risk factors)

- Avoid tobacco and limit alcohol intake.
- Eat a healthy diet (fruits, vegetables, fiber-rich foods; reduced processed/red meat).
- Maintain regular physical activity and a healthy body weight.
- Get vaccinated (e.g., HPV vaccine, Hepatitis B vaccine).
- Limit exposure to radiation and carcinogenic chemicals.
- Practice safe sex to reduce cancer-linked viral infections.

2. Secondary preventive measures

(Early detection & screening)

- Regular medical screening tests (e.g., Pap smears for cervical cancer, mammograms for breast cancer, colonoscopy for colorectal cancer).
- Genetic testing for hereditary cancer risk.

Tertiary preventive measures

(Managing disease & preventing recurrence)

- Post-treatment surveillance: Regular/timely treatment and follow-up to prevent recurrence or progression.
- Rehabilitation: Offering physical, psychological, and social support.
- Lifestyle adjustments: Observing healthy practices to reduce relapse risk.

3. Cancer treatment and management strategies

Treatment choices depend on the cancer type, stage, and overall patient health. Approaches may be curative, palliative, or supportive:

1. **Surgery:** Surgical removal of the primary tumor mass and nearby affected tissues. Most effective when the cancer is localized.

2. **Radiotherapy:** Uses high-energy ionizing radiation rays to destroy cancer cell DNA or shrink tumors.

3. **Chemotherapy: involves use of** cytotoxic drugs to target and kill rapidly dividing cells. May cause systemic side effects like hair loss, nausea, and immune suppression.

4. Targeted therapy: Uses drugs designed to attack specific molecular targets or block cancer cell growth pathways (e.g., HER2 inhibitors in breast cancer).

5. Immunotherapy: Enhances or restores the body's immune response to identify and destroy cancer cells (e.g., checkpoint inhibitors, CAR-T cell therapy).

6. Hormone therapy: Blocks or removes hormones that promote cancer cell growth (e.g., tamoxifen in breast cancer, androgen deprivation in prostate cancer).

7. Palliative & supportive care: Symptom management and quality-of-life care for patients in advanced stages.

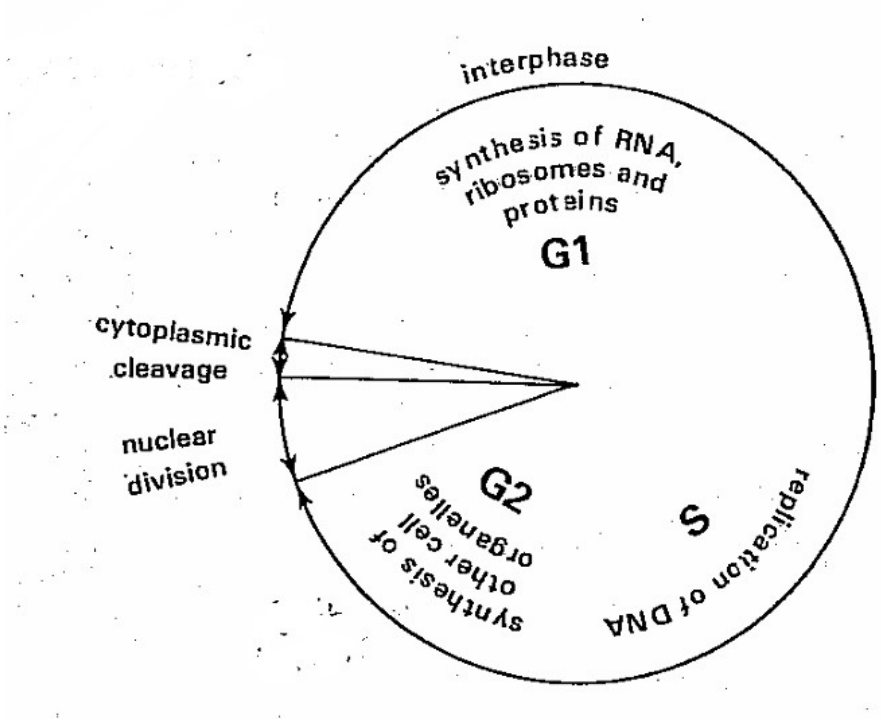
8. Stem cell & bone marrow transplantation: Restores healthy stem cells in patients with blood-related cancers like leukemia.

Relationship between cell division and cancer

Activity: Review the interphase stage of mitosis; and show how cancer cells arise…

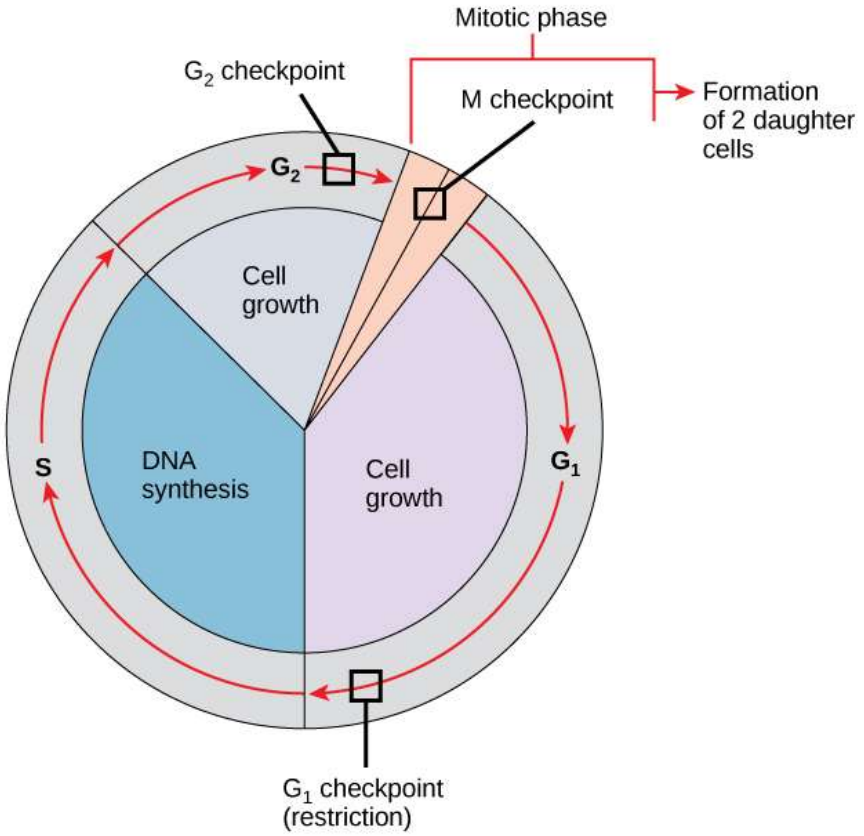
Normal cell division (mitosis) & checkpoints:

- In healthy tissue, division is tightly regulated by cell cycle checkpoints-quality control mechanisms ensuring each stage is accurately completed before advancing.
- Key regulatory genes include **tumor suppressor genes** (which halt uncontrolled division or induce repair/apoptosis) and proto-oncogenes (which stimulate normal growth).



Major cell cycle checkpoints

- G1 checkpoint (end of G1 phase): Ensures DNA is undamaged and cellular nutrients are sufficient before S phase DNA replication.
- G2 checkpoint (end of G2 phase): Confirms that DNA has been fully and accurately replicated prior to entering mitosis.
- M Checkpoint (metaphase): Verifies that all chromosomes are properly attached to spindle fibers before anaphase separation.



Checkpoint failure & malignant transformation:

Changes in nucleotide sequence may occur as a result of mutations esp through;

Point mutations: a single DNA nucleotide is swapped, added, or removed and

Chromosomal rearrangements: Large segments of DNA are deleted, copied, flipped, or moved to different chromosomes.

This results into malfunctioning of the regulatory genes causing;

- **Proto-oncogenes** to mutate into oncogenes; abnormally active forms that continuously drive cell proliferation.
- **Tumor suppressor genes** lose function, disabling division inhibition and error-repair mechanisms.
- **Apoptosis avoidance:** Normal damaged cells undergo programmed cell death (apoptosis), but cancer cells evade apoptosis, giving rise to a tumor (an abnormal tissue mass).

Biological hallmarks of cancer

1. Self-sufficiency in growth signals: Cancer cells synthesize their own growth signals independently of external body controls.

2. Evading growth suppressors: Insensitive to anti-growth signals that normally cease division.

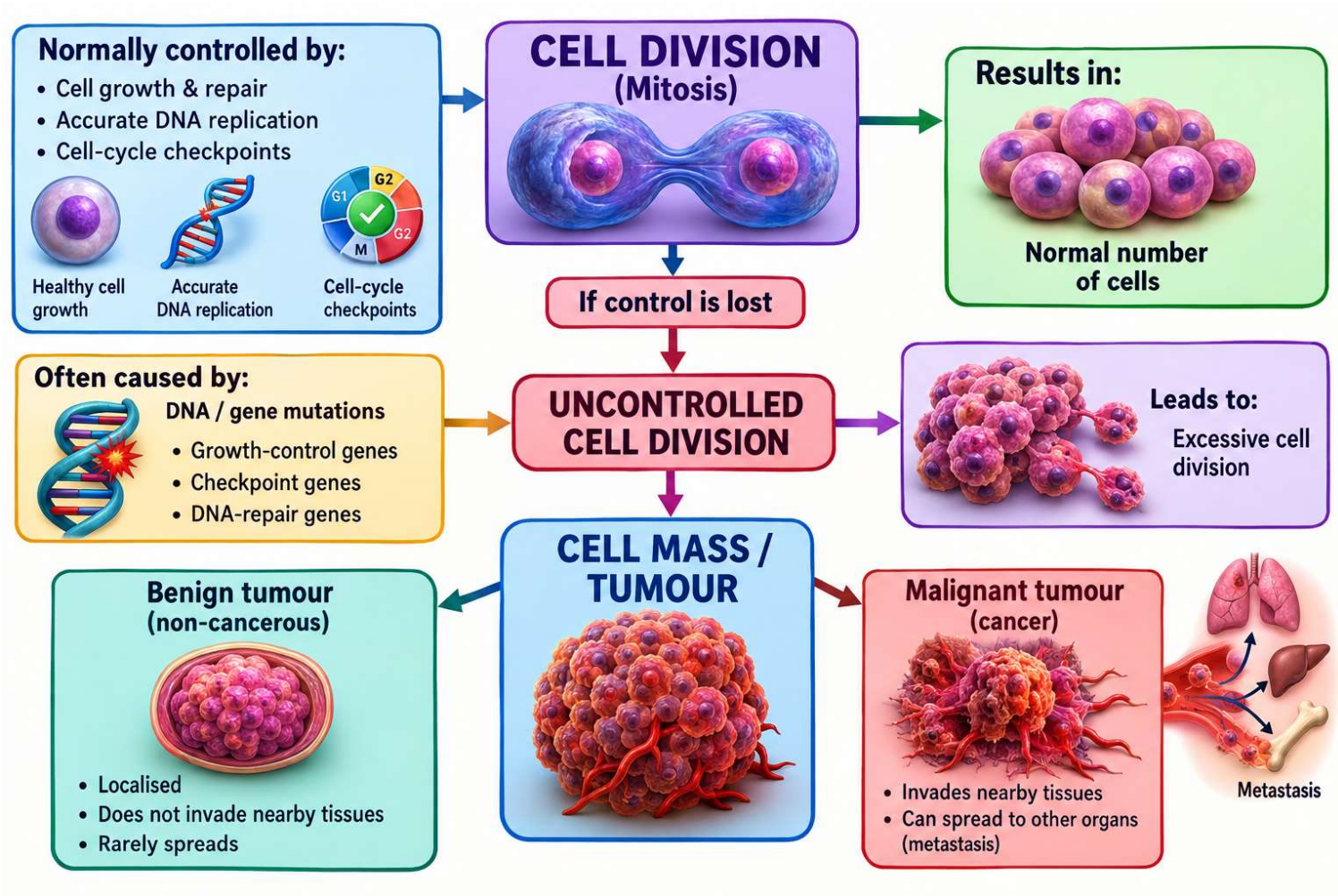
3. Evading apoptosis: Resistant to programmed cell death despite internal genetic damage.

4. Limitless replicative potential: Divide indefinitely without cellular senescence.

5. Sustained angiogenesis: Stimulate new blood vessel formation to supply nutrients and oxygen.

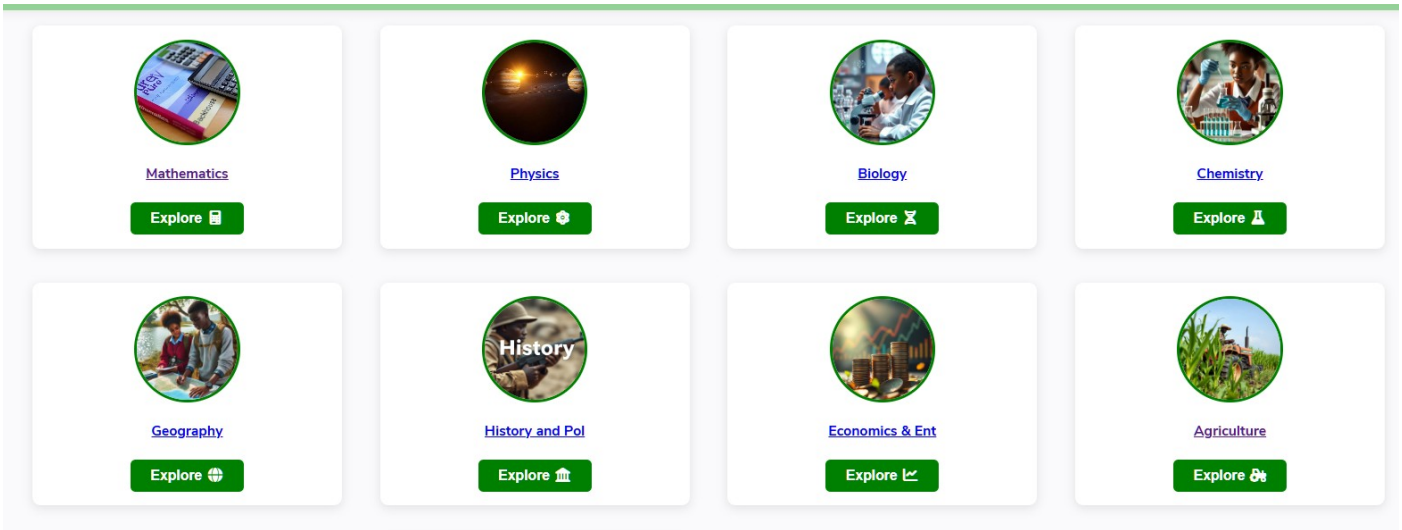
6. Tissue invasion and metastasis: Cells break away from the primary tumor, traverse blood/lymph vessels, and form secondary tumors (metastases) across distant organs.

Mind map showing the relationship between cell division and cancer. (Summary)



END

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