Brain Tumor Biology

Definition

Brain tumor biology refers to the **molecular, cellular, and physiological mechanisms** underlying the development, progression, and behavior of primary and metastatic brain tumors. It encompasses genetic mutations, signaling pathways, tumor microenvironment interactions, and immune evasion strategies.

Tumor Types

- **Primary brain tumors** – originate in the brain (e.g., glioblastoma, astrocytoma, meningioma)
- **Metastatic brain tumors (BrM)** – arise from cancers elsewhere (e.g., lung, breast, melanoma)

Hallmarks of Brain Tumor Biology

- **Uncontrolled cell proliferation** – due to mutations in genes like EGFR, IDH1, TP53
- **Invasion of surrounding brain tissue** – limits surgical resection and contributes to recurrence
- **Angiogenesis** – formation of abnormal blood vessels (e.g., via VEGF)
- **Hypoxia and necrosis** – common in aggressive tumors like glioblastoma
- **Immune evasion** – through upregulation of PD-L1, recruitment of regulatory cells
- **Resistance to therapy** – intrinsic or acquired resistance to chemotherapy, radiotherapy, and targeted agents

Tumor Microenvironment

- Includes **astrocytes**, **microglia**, **immune cells**, **endothelial cells**, and **extracellular matrix**
- Influences tumor growth, invasion, and response to therapy
- Can be immunosuppressive, especially in high-grade gliomas and BrM

Molecular Classification

- Based on **mutational profiles**, **gene expression**, and **epigenetics**
- Example: WHO CNS tumor classification includes IDH status, 1p/19q co-deletion, MGMT methylation
- Emerging classification includes **single-cell RNA-seq** and **spatial transcriptomics**

Clinical Relevance

- Understanding tumor biology helps guide **diagnosis, prognosis**, and **treatment decisions**
- Molecular profiling enables **precision medicine** and **targeted therapy**
- Insights into the biology of brain tumors inform the development of **immunotherapies** and

novel agents

Example Insight

Glioblastoma exhibits a highly invasive growth pattern, driven by mesenchymal transition and hypoxic signaling, making it resistant to conventional therapies and highlighting the need for combination approaches targeting both tumor cells and the microenvironment.