



Regulated Cell Death Modalities Beyond Apoptosis: Molecular Mechanisms and Biological Implications

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Abstract: The aim of this review was to contrast distinct ways of regulating cell death, by highlighting their morphology, biochemical pathways and functional outcomes. Thus, the following processes were studied and described: necroptosis, pyroptosis, ferroptosis and autophagy, starting from the definition, key molecular regulators, triggering signals, morphological features and physiological and pathological roles.

• Introduction

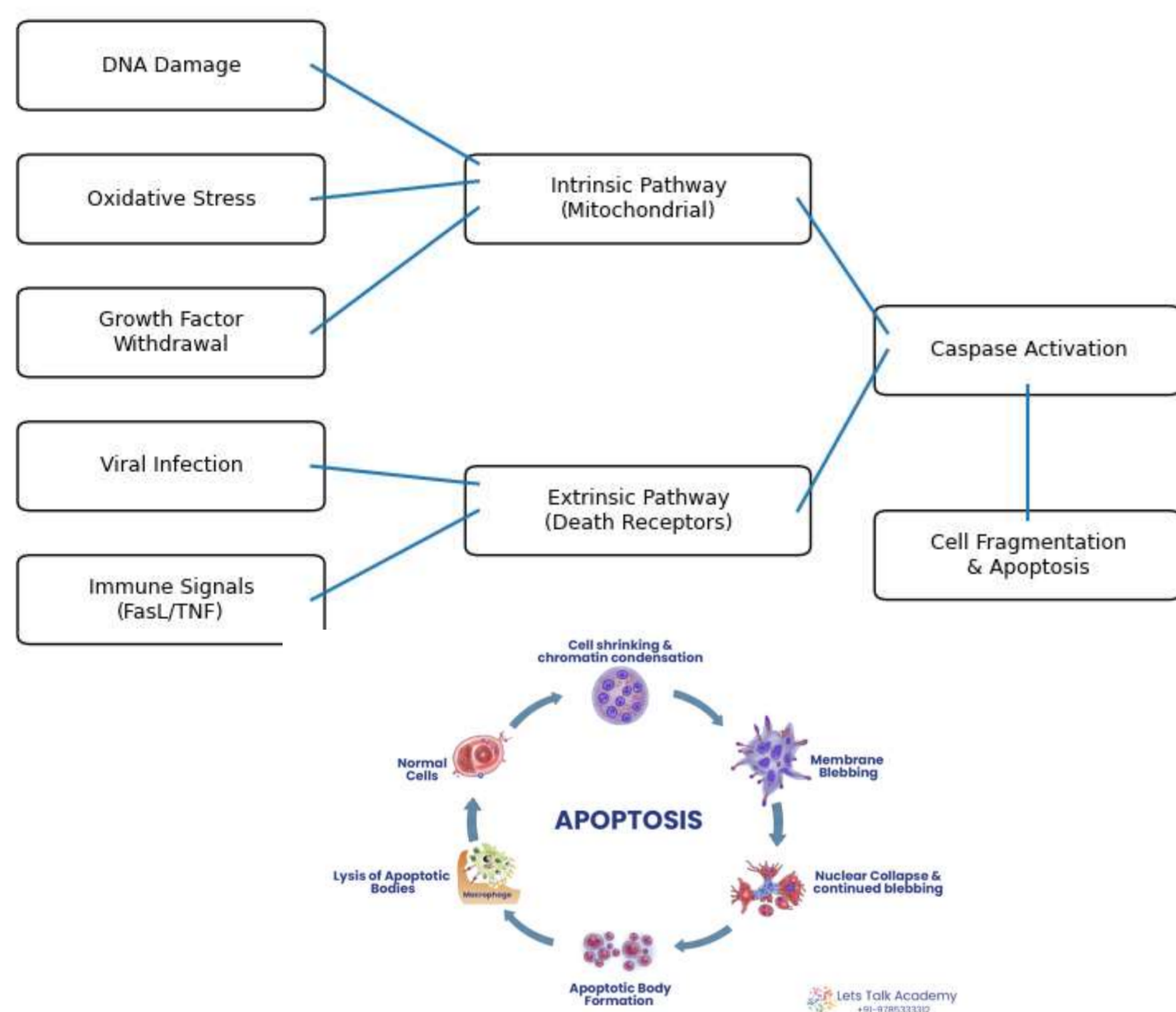
Apoptosis, also known as programmed cell death, is a fundamental biological process that plays a crucial role in maintaining the health and balance in the multicellular organisms. Unlike necrosis, which occurs as a result of injury and often causes inflammation, apoptosis is a highly regulated and controlled mechanism through which damaged, unnecessary, or potentially harmful cells are eliminated without affecting surrounding tissues.

• Material and method

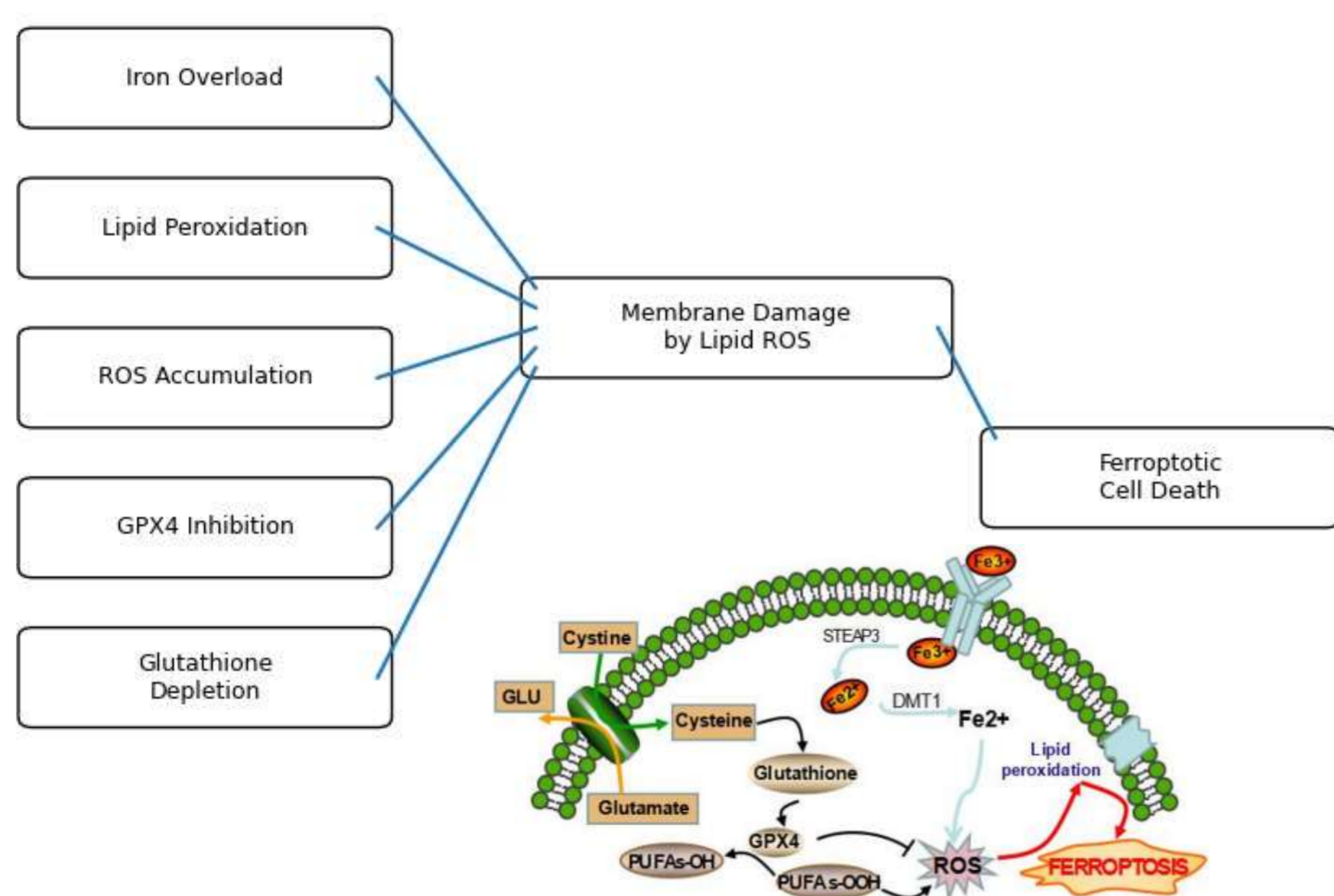
This systematic review conducted a literature review to determine keywords and subject headings. A systematic search was conducted, covering articles published between, 2010 and 2026, using the keywords as "apoptosis", "pyroptosis", "necroptosis", "ferroptosis", "autophagy" and "molecular regulators"

• Results and discussions

Apoptosis Pathways and Triggers

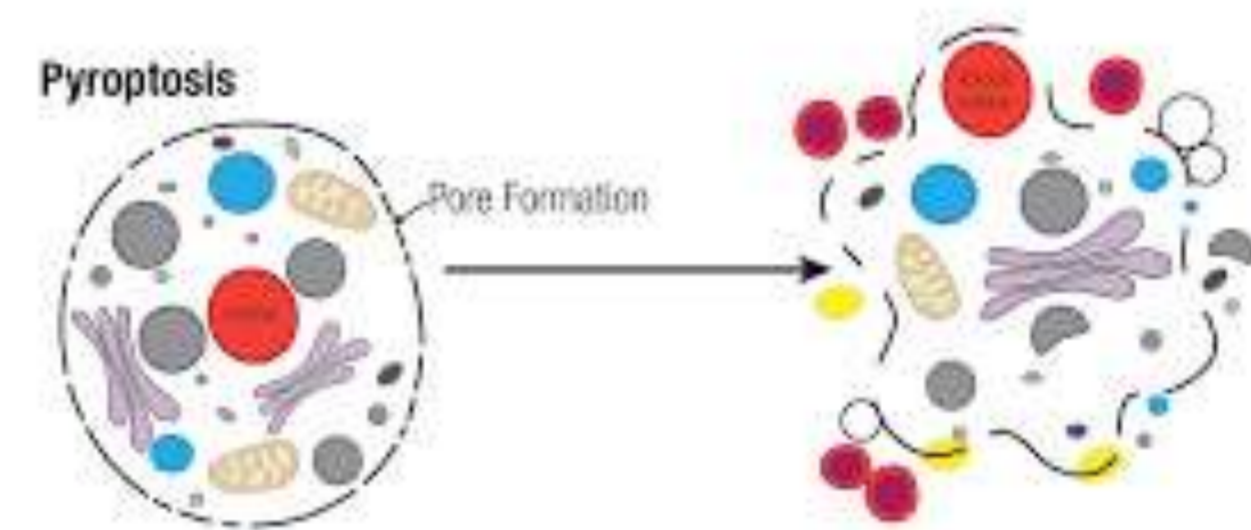
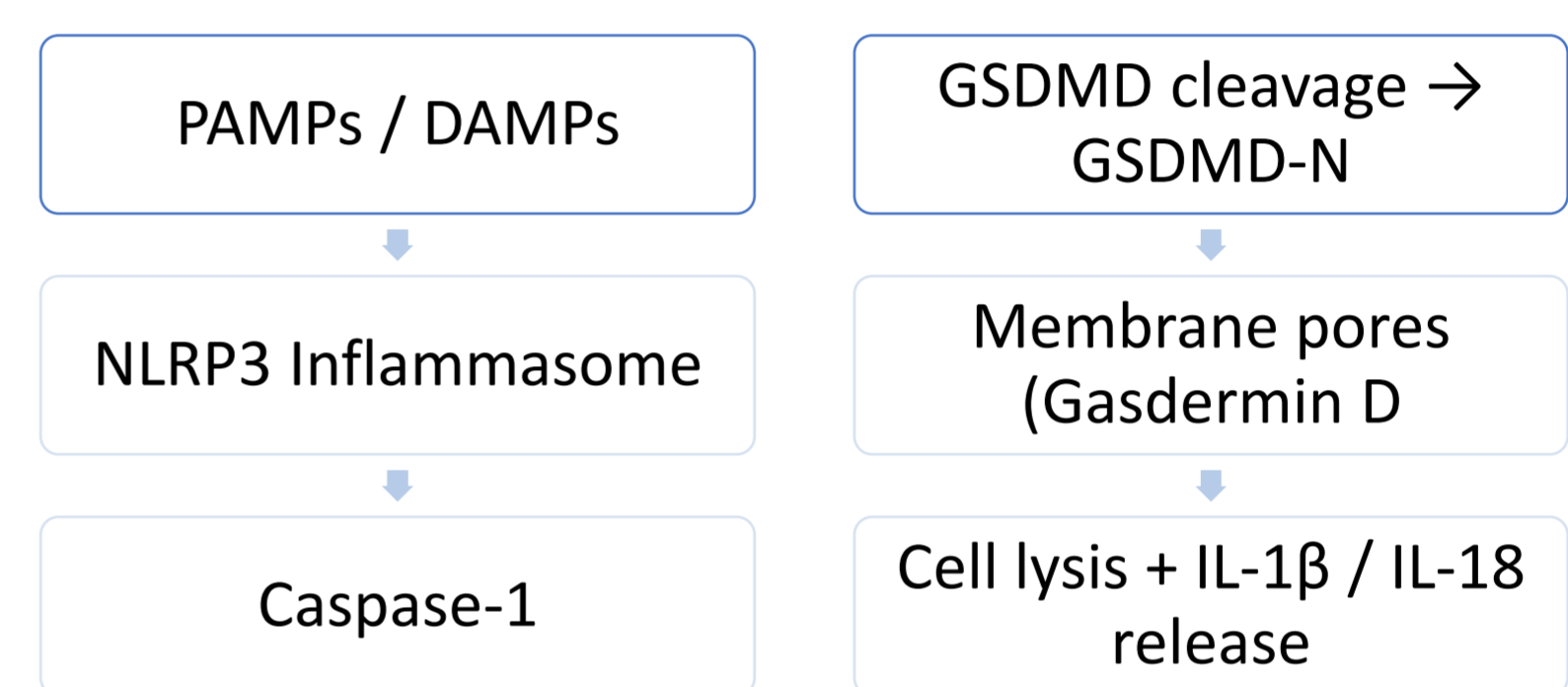


Ferroptosis Pathway and Triggers



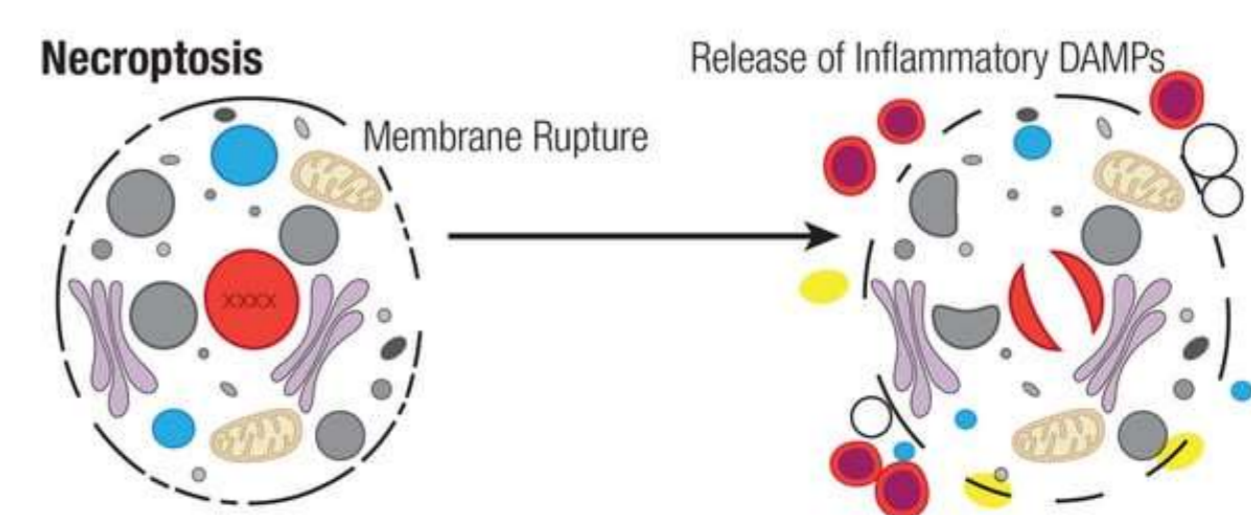
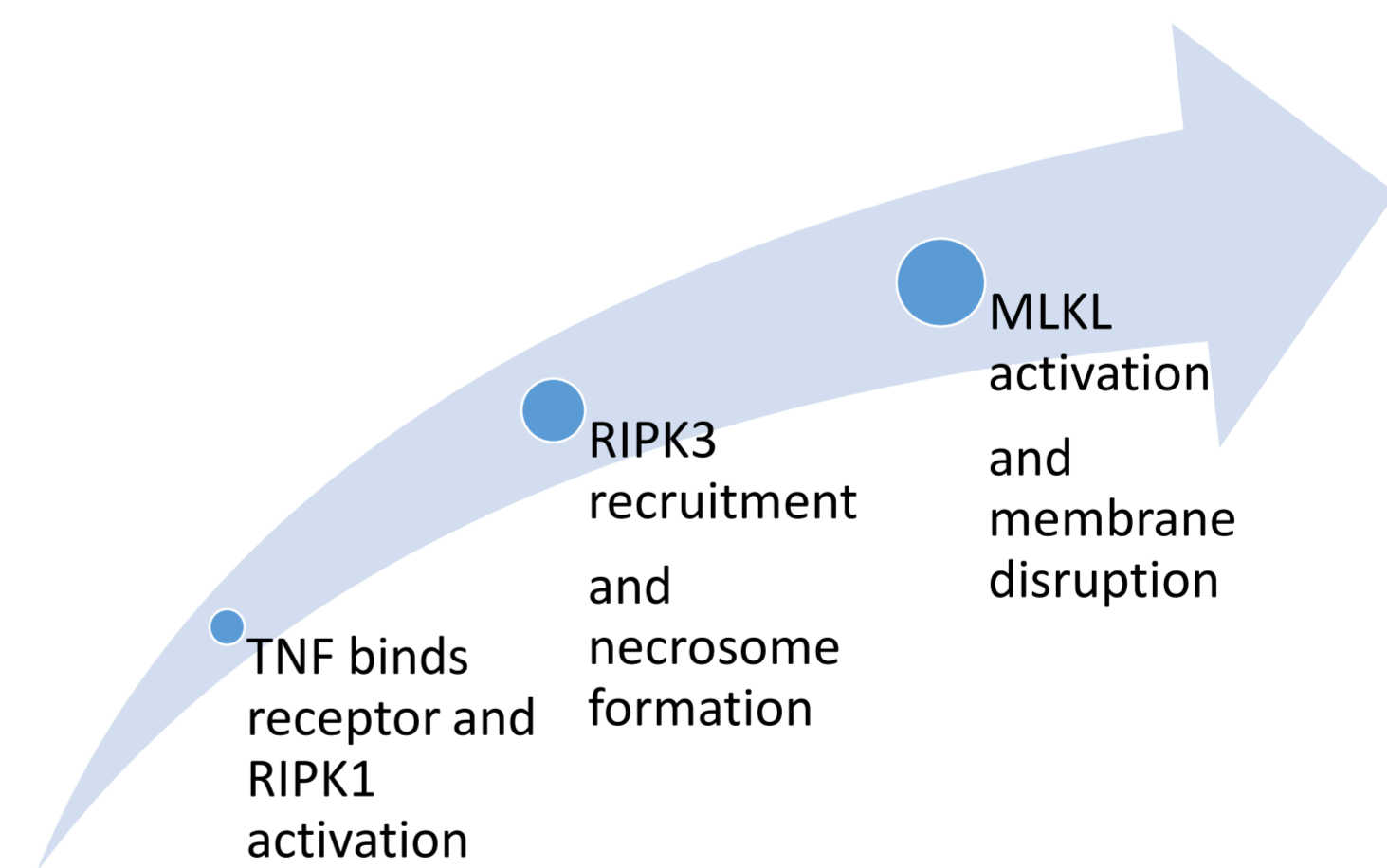
Ferroptosis has major biological and medical significance, by suppressing tumor growth in cancer, by contributing to neurodegenerative diseases, and by being involved in ischemia-reperfusion injury. Can represent a potential therapeutic target in medicine.

Pyroptosis Signaling Pathway



Pyroptosis is a programmed inflammatory cell death, with importance in immunity and diseases.

Necroptosis signaling pathways



Necroptosis is a programmed, caspase-independent cell death, which is triggered by TNF, TLRs, infections and occurs mainly when apoptosis is blocked