TABLE 3.1 Features of Acute and Chronic Inflammation

Feature	Acute	Chronic
Onset	Fast: minutes or hours	Slow: days
Cellular infiltrate	Mainly neutrophils	Monocytes/macrophages and lymphocytes
Tissue injury, fibrosis	Usually mild and self-limited	May be severe and progressive
Local and systemic signs	Prominent	Less

TABLE 3.2 Disorders Caused by Inflammatory Reactions

Disorders	Cells and Molecules Involved in Injury
Acute	
Acute respiratory distress syndrome	Neutrophils
Asthma	Eosinophils; IgE antibodies
Glomerulonephritis	Antibodies and complement; neutrophils, monocytes
Septic shock	Cytokines
Chronic	
Arthritis	Lymphocytes, macrophages; antibodies?
Asthma	Eosinophils; IgE antibodies
Atherosclerosis	Macrophages; lymphocytes
Pulmonary fibrosis	Macrophages; fibroblasts

Listed are selected examples of diseases in which the inflammatory response plays a significant role in tissue injury. Some, such as asthma, can present with acute inflammation or a chronic illness with repeated bouts of acute exacerbation. These diseases and their pathogenesis are discussed in relevant chapters.

Causes of inflammation:

INFECTIONS	**Bacteria, fungi, viruses, parasites And their toxins**
NECROSIS	**Ischemia, trauma, physical and chemical injuries, burns, frostbite, irradiation**
FOREIGN BODIES	**Splinters, dirt, urate crystals (gout), Cholesterol crystals (atherosclerosis)**
IMMUNE REACTIONS	**Allergies and autoimmune diseases**

Transudate	Exudate
Low protein	High protein
Low cell content	Many cells & debris
Low specific gravity	Higher specific gravity
Caused by osmotic/hydrostatic pressure imbalance	Caused by increased vascular permeability and denotes inflammatory reaction

TABLE 3.3 Properties of Neutrophils and Macrophages

	Neutrophils	Macrophages
Origin	HSCs in bone marrow	• HSCs in bone marrow (in inflammatory reactions) • Many tissue-resident macrophages: stem cells in yolk sac or fetal liver (early in development)
Life span in tissues	1–2 days	Inflammatory macrophages: days or weeks Tissue-resident macrophages: years
Responses to activating stimuli	Rapid, short-lived, mostly degranulation and enzymatic activity	More prolonged, slower, often dependent on new gene transcription
• Reactive oxygen species	Rapidly induced by assembly of phagocyte oxidase (respiratory burst)	Less prominent
• Nitric oxide	Low levels or none	Induced following transcriptional activation of iNOS
• Degranulation	Major response; induced by cytoskeletal rearrangement	Not prominent
• Cytokine production	Low levels or none	Major functional activity, requires transcriptional activation of cytokine genes
• NET formation	Rapidly induced, by extrusion of nuclear contents	No
• Secretion of lysosomal enzymes	Prominent	Less

HSC, Hematopoietic stem cells; *iNOS*, inducible nitric oxide synthase; *NET*, neutrophil extracellular traps.

This table lists the major differences between neutrophils and macrophages. The reactions summarized above are described in the text. Note that the two cell types share many features, such as phagocytosis, ability to migrate through blood vessels into tissues, and chemotaxis.

CHEMOTAXIS:

- **WBCs moving to injury tissue site**
- **Due to CHEMOATTRACTANTS (exogenous and endogenous):**

Bacterial products	Peptides (N-…)
Cytokines	Chemokine family
Complement system	C5a
Lipoxygenase pathway AA	LTB4

WBCs infiltrate in tissue:

- **Depends on the age of inflammatory response and the type of stimulus**

Neutrophils (PMNs)	**6-24 hours, acute phase**
Macrophages and lymphocytes	**24-48 hours and then may stay**
Allergic reactions	**Eosinophils**

TERMINATION OF ACUTE IR

Mediators are produced in rapid bursts

Release is stimulus dependent

Short half-lives

Degradation after release

PMNs short life (apoptosis)

Stop signals production (TGF-ß, IL-10)

Neural inhibitors (cholinergic): inhibits TNF

MEDIATORS OF A. INFLAMMATION:

Tissue macrophages, dendritic cells & mast cells

Vasoactive amines	**Histamine, serotonin**
Lipid products	**PGs and LTs**
Cytokines	**IL, TNF and chemokines**
Complement activation	**C1-9**

TABLE 3.5 Principal Mediators of Inflammation

Mediator	Source	Action
Histamine	Mast cells, basophils, platelets	Vasodilation, increased vascular permeability, endothelial activation
Prostaglandins	Mast cells, leukocytes	Vasodilation, pain, fever
Leukotrienes	Mast cells, leukocytes	Increased vascular permeability, chemotaxis, leukocyte adhesion, and activation
Cytokines (TNF, IL-1, IL-6)	Macrophages, endothelial cells, mast cells	Local: endothelial activation (expression of adhesion molecules). Systemic: fever, metabolic abnormalities, hypotension (shock)
Chemokines	Leukocytes, activated macrophages	Chemotaxis, leukocyte activation
Platelet-activating factor	Leukocytes, mast cells	Vasodilation, increased vascular permeability, leukocyte adhesion, chemotaxis, degranulation, oxidative burst
Complement	Plasma (produced in liver)	Leukocyte chemotaxis and activation, direct target killing (membrane attack complex), vasodilation (mast cell stimulation)
Kinins	Plasma (produced in liver)	Increased vascular permeability, smooth muscle contraction, vasodilation, pain

TABLE 3.6 Principal Actions of Arachidonic Acid Metabolites in Inflammation

Action	Eicosanoid
Vasodilation	Prostaglandins PGI_2 (prostacyclin), PGE_1, PGE_2, PGD_2
Vasoconstriction	Thromboxane A_2, leukotrienes C_4, D_4, E_4
Increased vascular permeability	Leukotrienes C_4, D_4, E_4
Chemotaxis, leukocyte adhesion	Leukotriene B_4
Smooth muscle contraction	Prostaglandins PGC4, PGD4, PGE4

TABLE 3.7 Cytokines in Inflammation

Cytokine	Principal Sources	Principal Actions in Inflammation
In Acute Inflammation		
TNF	Macrophages, mast cells, T lymphocytes	Stimulates expression of endothelial adhesion molecules and secretion of other cytokines; systemic effects
IL-1	Macrophages, endothelial cells, some epithelial cells	Similar to TNF; greater role in fever
IL-6	Macrophages, other cells	Systemic effects (acute phase response)
Chemokines	Macrophages, endothelial cells, T lymphocytes, mast cells, other cell types	Recruitment of leukocytes to sites of inflammation; migration of cells in normal tissues
IL-17	T lymphocytes	Recruitment of neutrophils and monocytes
In Chronic Inflammation		
IL-12	Dendritic cells, macrophages	Increased production of IFN-γ
IFN-γ	T lymphocytes, NK cells	Activation of macrophages (increased ability to kill microbes and tumor cells)
IL-17	T lymphocytes	Recruitment of neutrophils and monocytes

The most important cytokines involved in inflammatory reactions are listed. Many other cytokines may play lesser roles in inflammation. There is also considerable overlap between the cytokines involved in acute and chronic inflammation. Specifically, all the cytokines listed under acute inflammation may also contribute to chronic inflammatory reactions.

IFN-γ, Interferon-γ; *IL-1*, interleukin-1; *NK*, natural killer; *TNF*, tumor necrosis factor.

TABLE 3.8 Role of Mediators in Different Reactions of Inflammation

Reaction of Inflammation	Principal Mediators
Vasodilation	Histamine
	Prostaglandins
Increased vascular permeability	Histamine
	C3a and C5a (by liberating vasoactive amines from mast cells, other cells)
	Leukotrienes C_4, D_4, E_4
Chemotaxis, leukocyte recruitment and activation	TNF, IL-1
	Chemokines
	C3a, C5a
	Leukotriene B_4
Fever	IL-1, TNF
	Prostaglandins
Pain	Prostaglandins
	Bradykinin
Tissue damage	Lysosomal enzymes of leukocytes
	Reactive oxygen species

MORPHOLOGY OF ACUTE INFLAMMATION

- **The critical issue is blood vessel dilatation and accumulation of WBCs and fluids in the extravascular tissue.**

Edema	**Fluid and proteins in interstitium**
Redness	***rubor***
Warmth	***calor***
Swelling	***tumor***
Loss of function	***Functio laesa***
Pain	***dolor***

CAUSES OF CHRONIC

INFLAMMATION:

Persistent infections	**Mycobacteria (TB), viruses, fungi, parasites. Delayed hypersensitivity reaction. Granulomatous inflammation.**
Hypersensitivity diseases	**RA, asthma, MS. May end in fibrosis of end organs**
Prolonged exposure to toxic agents (exogenous or endogenous)	**Silica (silicosis) Atherosclerosis (cholesterol)**
Other associated diseases	**Alzheimer's, Metabolic syndrome of DM**

TH1	**INF-ʎ, activates Macs in classic pathway**
TH2	**IL-4, IL-5 & IL-13; activates eosinophils and Macs alternative pathway**
TH17	**IL-17 , induce chemokines secretion and recruits PMNs**

TABLE 3.9 Examples of Diseases With Granulomatous Inflammation

Disease	Cause	Tissue Reaction
Tuberculosis	*Mycobacterium tuberculosis*	Caseating granuloma (tubercle): focus of activated macrophages (epithelioid cells), rimmed by fibroblasts, lymphocytes, histiocytes, occasional Langhans giant cells; central necrosis with amorphous granular debris; acid-fast bacilli
Leprosy	*Mycobacterium leprae*	Acid-fast bacilli in macrophages; noncaseating granulomas
Syphilis	*Treponema pallidum*	Gumma: microscopic to grossly visible lesion, enclosing wall of macrophages; plasma cell infiltrate; central cells are necrotic without loss of cellular outline; organisms difficult to identify in tissue
Cat-scratch disease	Gram-negative bacillus	Rounded or stellate granuloma containing central granular debris and recognizable neutrophils; giant cells uncommon
Sarcoidosis	Unknown etiology	Noncaseating granulomas with abundant activated macrophages
Crohn disease (inflammatory bowel disease)	Immune reaction against undefined gut microbes and, possibly, self antigens	Occasional noncaseating granulomas in the wall of the intestine, with dense chronic inflammatory infiltrate

SYSTEMIC EFFECTS OF INFLAMMATION:

- **Any inflammation can be associated with systemic effects due to cytokines release**

  " ACUTE PHASE RESPONSE"

- **TNF, IL-1, IL-6, & type 1 interferons**

Fever (1-4 C) elevation	**Exogenous pyrogens (LPS) & endogenous pyrogens (IL-1 & TNF). All induce PGE2 secretion**
Acute phase proteins	**CRP, SAA, ESR, Hepcidin**
Leukocytosis (increase WBC)	**15-20 K if more than 40 (leukemoid reaction), left shift**
Others	**Tachycardia, Increase BP, Chills, Rigors, decreased sweating, anorexia, somnolence, and malaise**

TISSUE REGENERATION:

- **Regeneration requires growth factors and interactions between cells and matrix (ECM)**
- **Tissue types**

Labile tissue	**Continuous regeneration : epithelia of mucosal surfaces**
Stable tissue	**Normally in G_0, but can be stimulated to regenerate when injured (liver, Kidney, pancreas)**
Permanent tissue	**Terminally differentiated, non proliferative (neurons and cardiac muscle, skeletal muscle)**

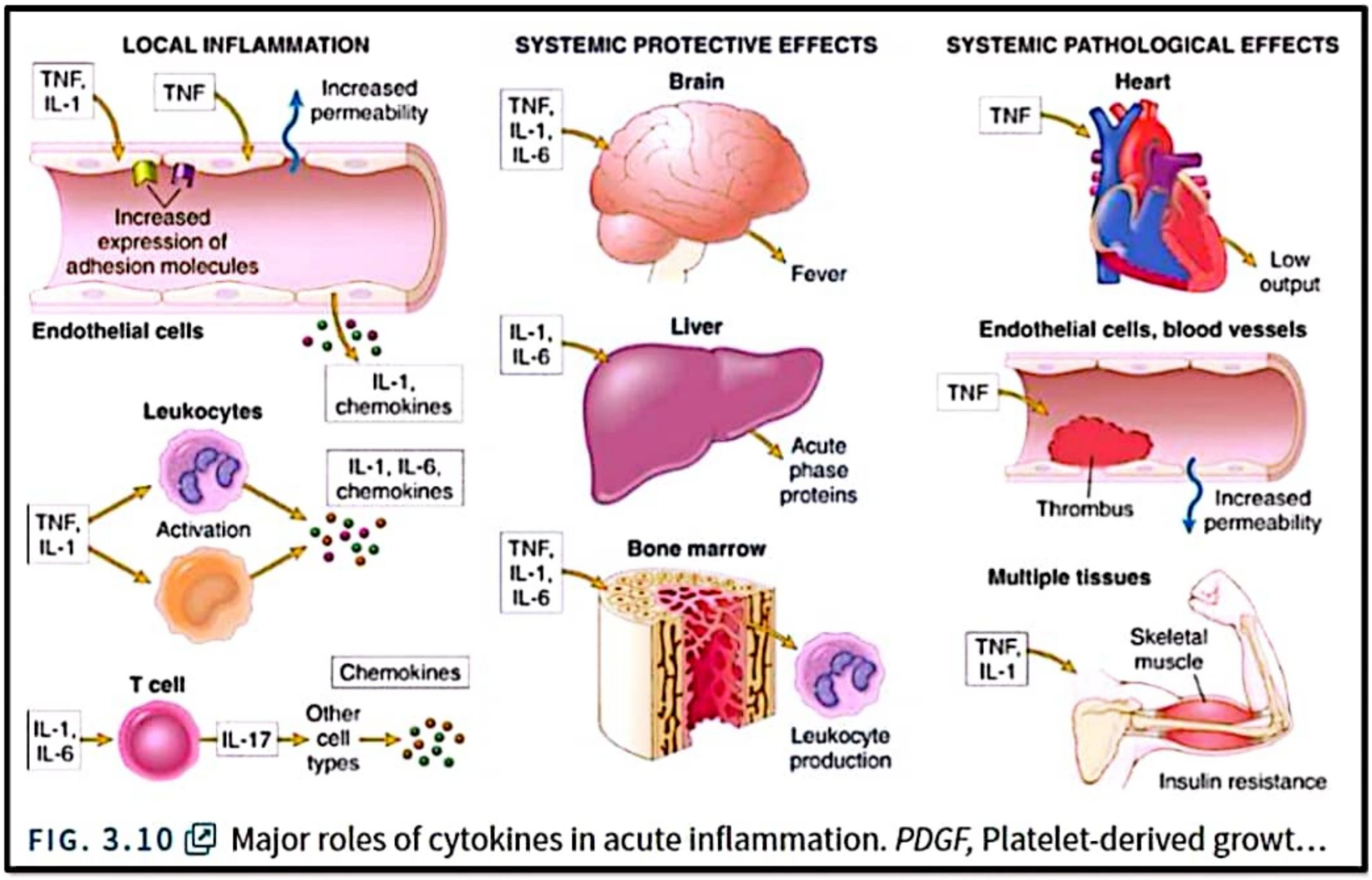
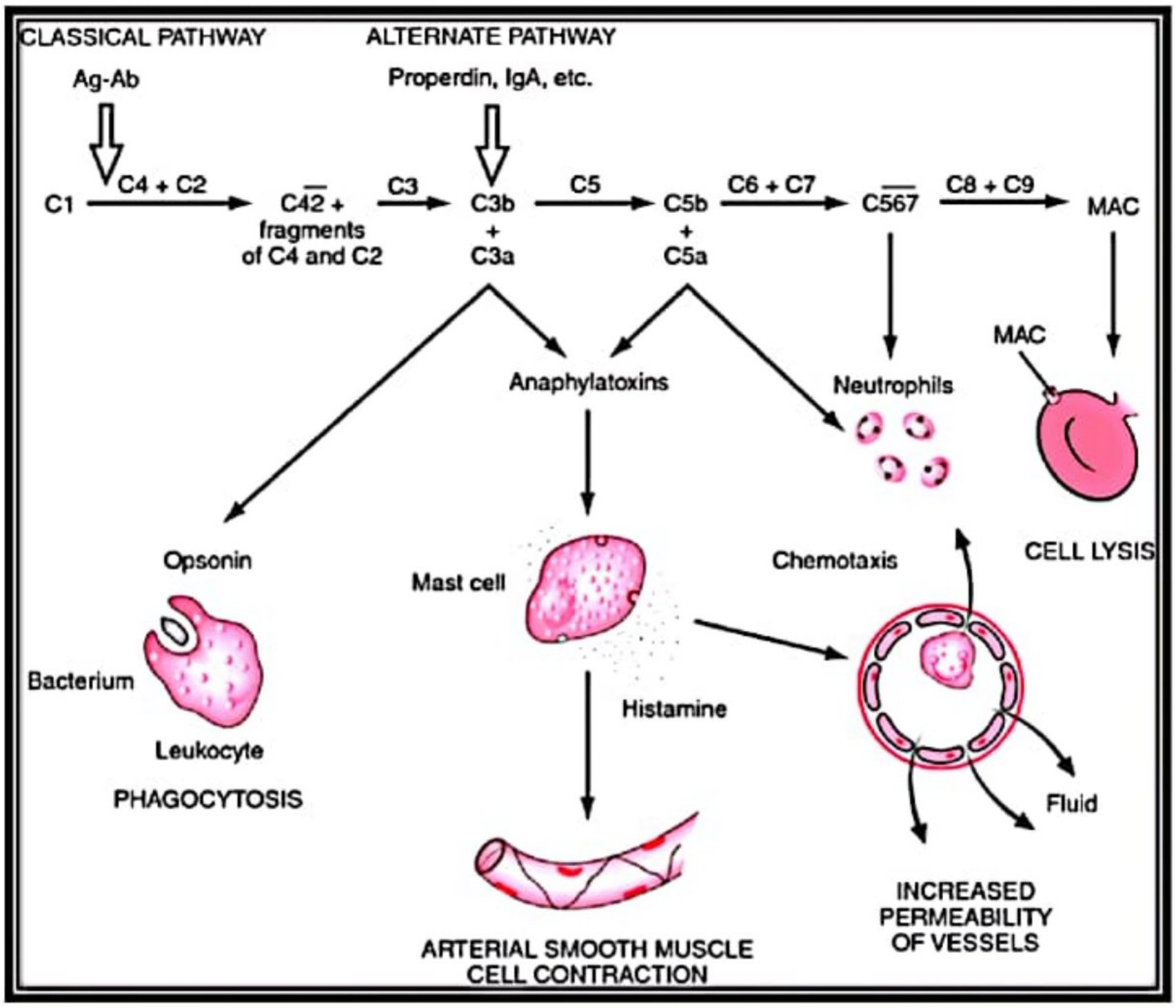


FIG. 3.10 Major roles of cytokines in acute inflammation. *PDGF,* Platelet-derived growt...



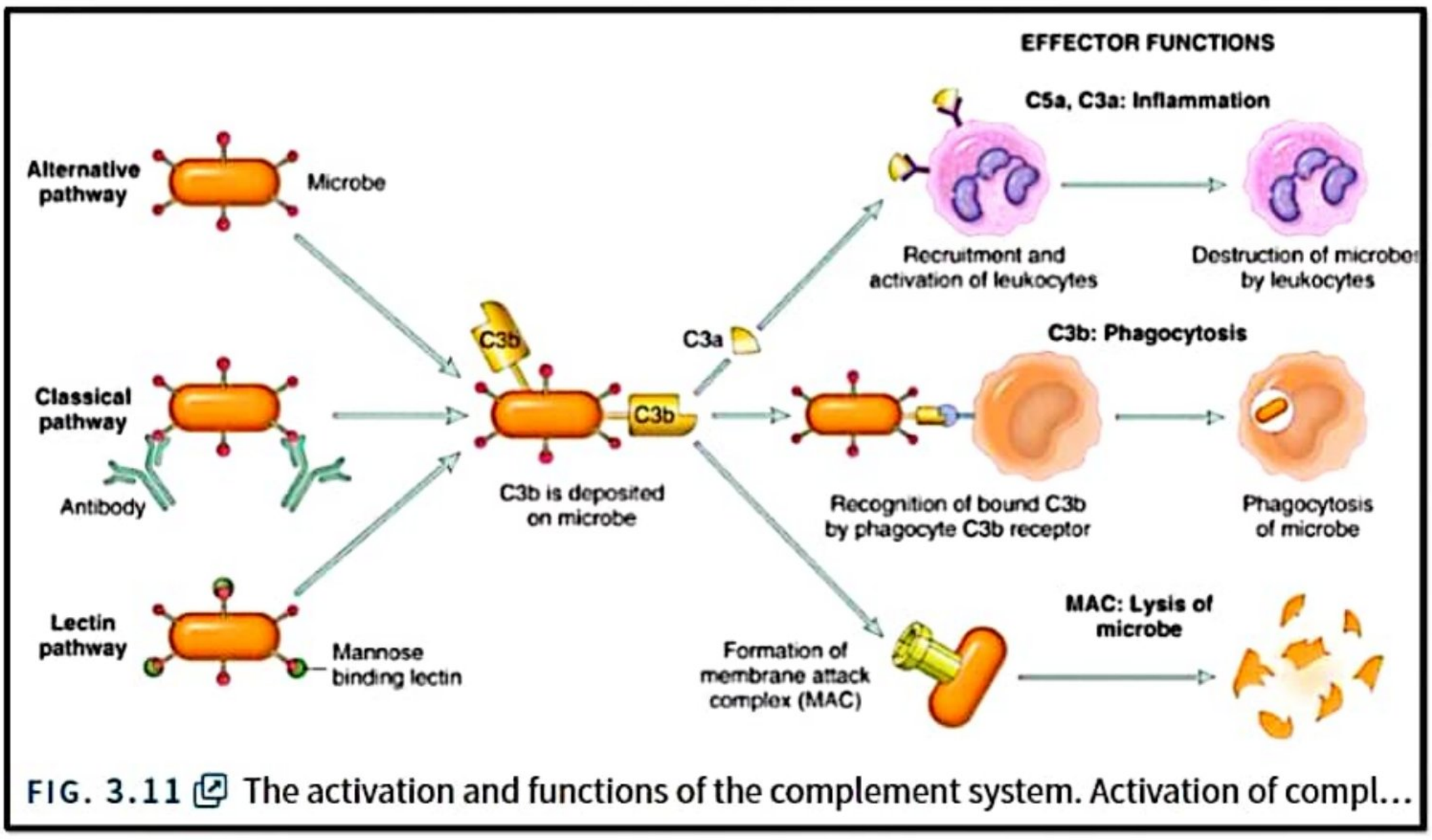
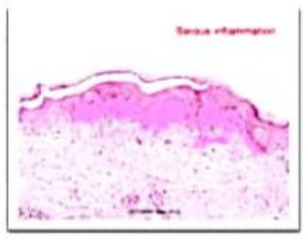


FIG. 3.11 The activation and functions of the complement system. Activation of compl...

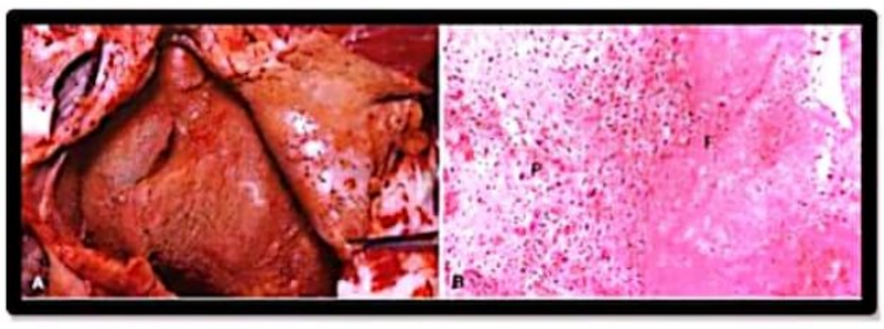
SEROUS INFLAMMATION:



- **Cell poor fluid (transudate)**
- **Serous effusions**
- **Skin blisters**
- **Seromas**

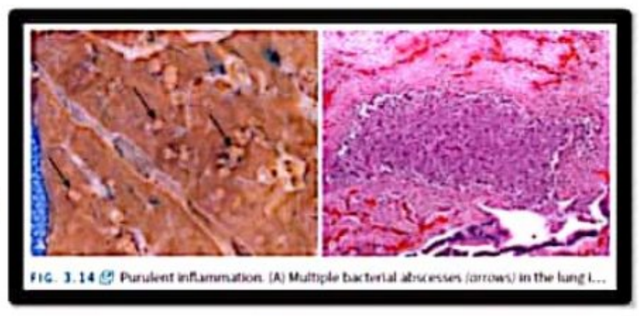
FIBRINOUS INFLAMMATION:

- **Large vascular leakage + coagulation**
- **Body cavities: pericardium**



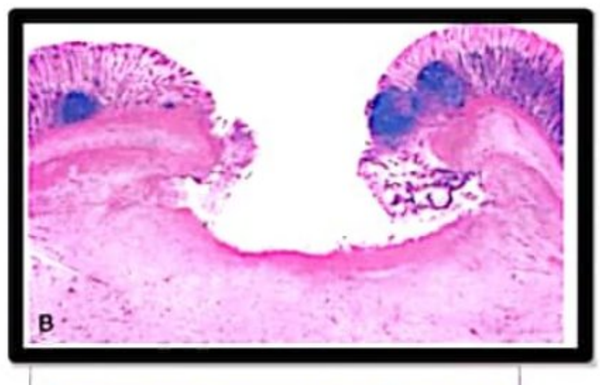
PURULENT (SUPPURATIVE) INFLAMMATION, ABSCESS:

- **Pus: exudate rich in PMNs + debris + edema**
- **Bacteria (staph.)**
- **Abscess: localized collection of pus**



ULCERS:

- **Defect on a surface**
- **Common in mucosal surfaces and skin**
- **Mostly acute and chronic inflammation**



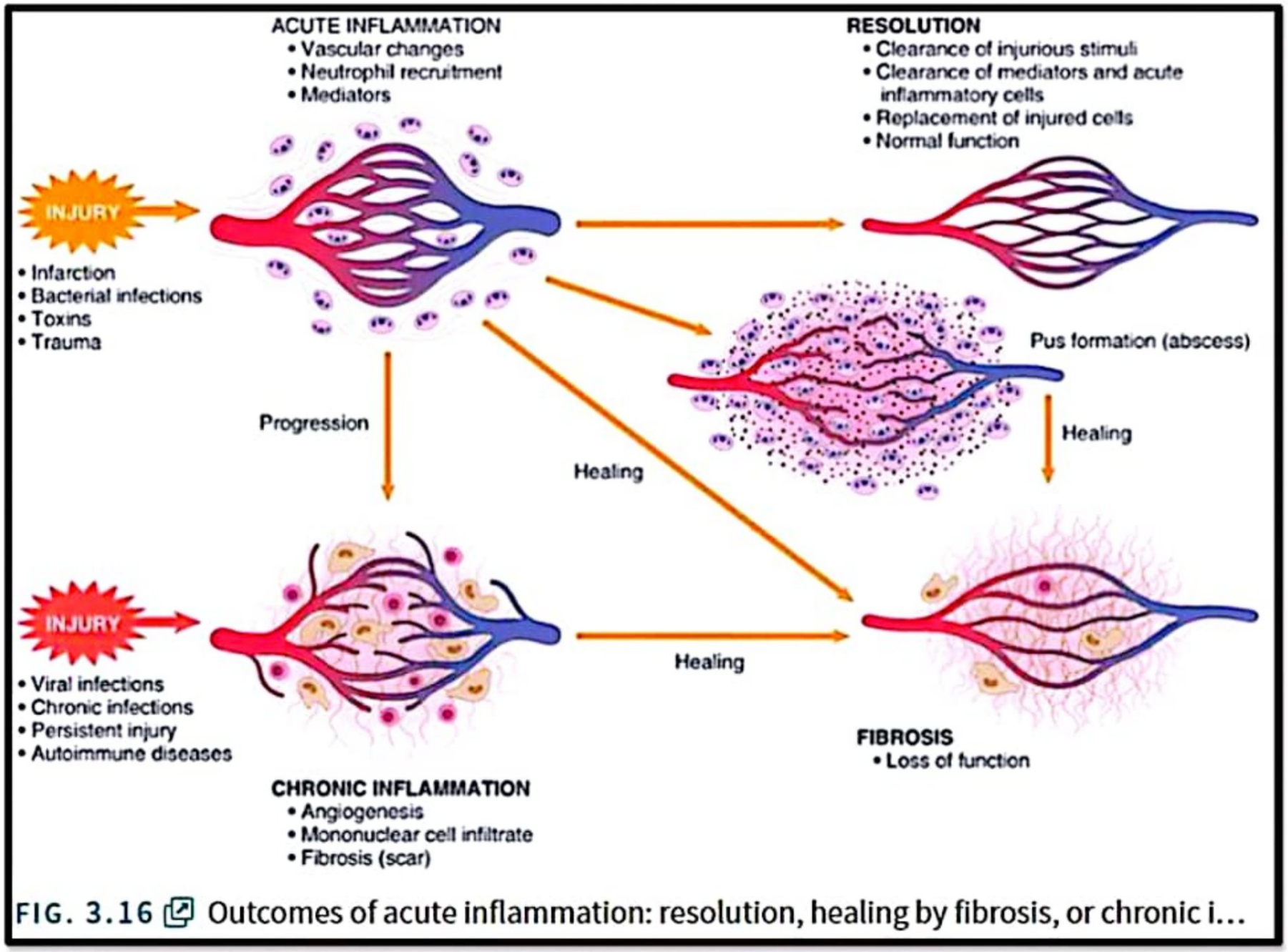


FIG. 3.16 Outcomes of acute inflammation: resolution, healing by fibrosis, or chronic i...

Chronic pneumonia

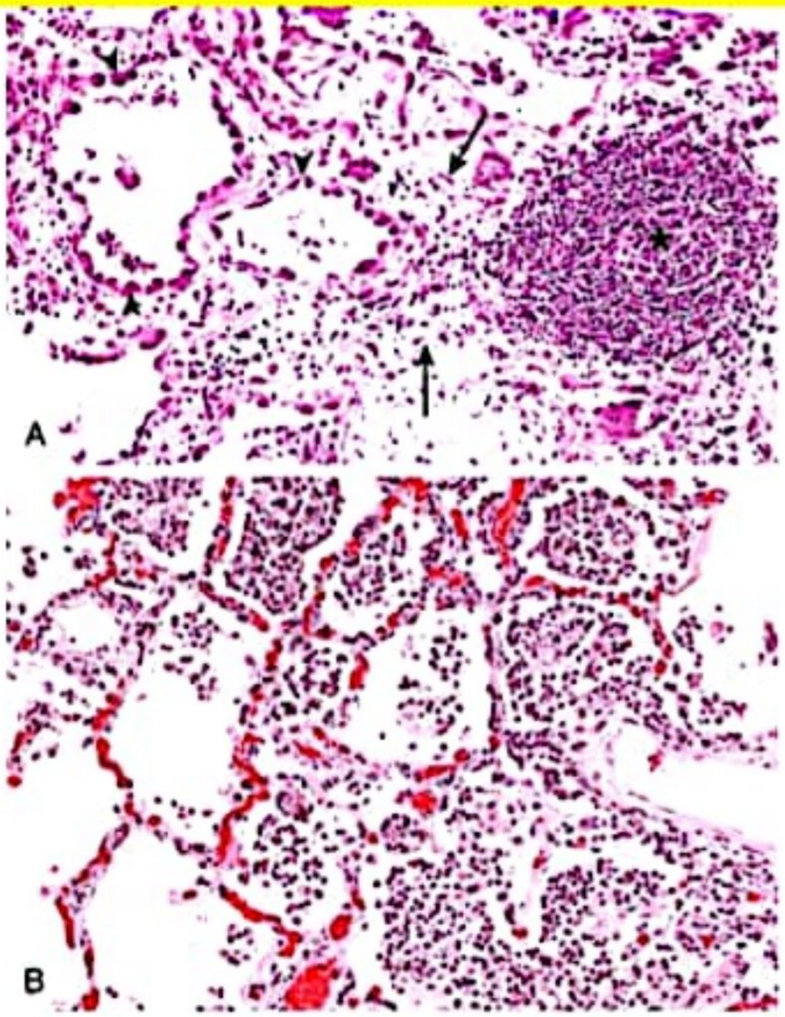
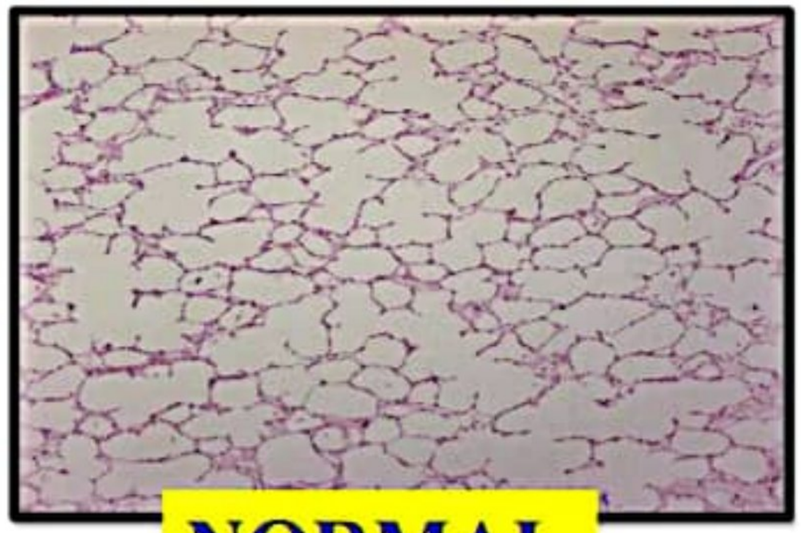
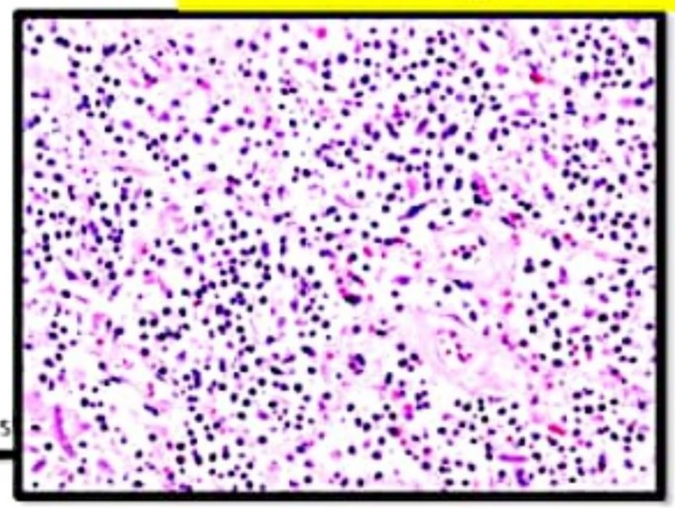


FIG. 3.17 (A) Chronic inflammation in the lung, showing all three characteris



NORMAL

Acute pneumonia



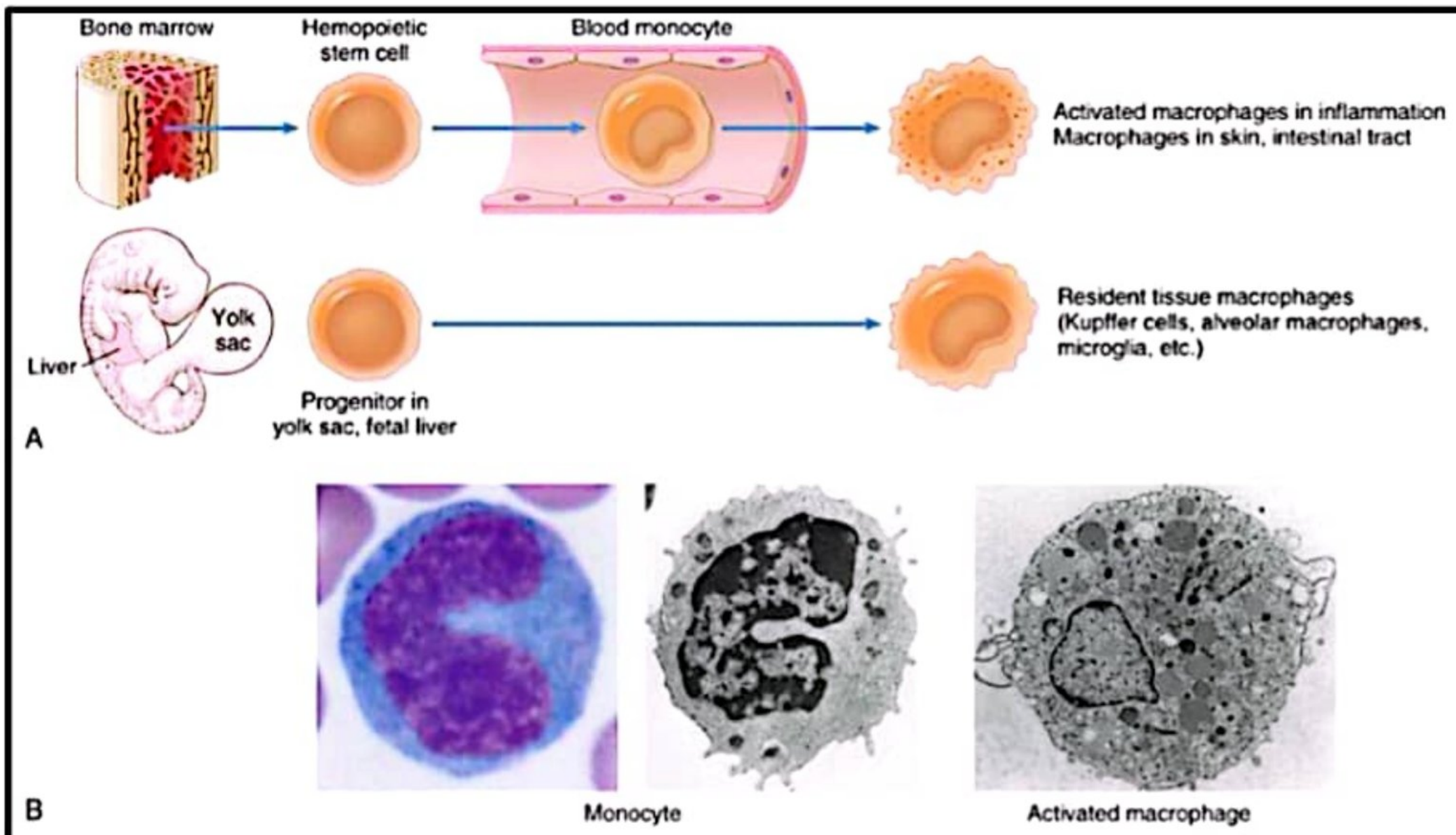


FIG. 3.18 Maturation of mononuclear phagocytes. (A) During inflammatory reactions, t...

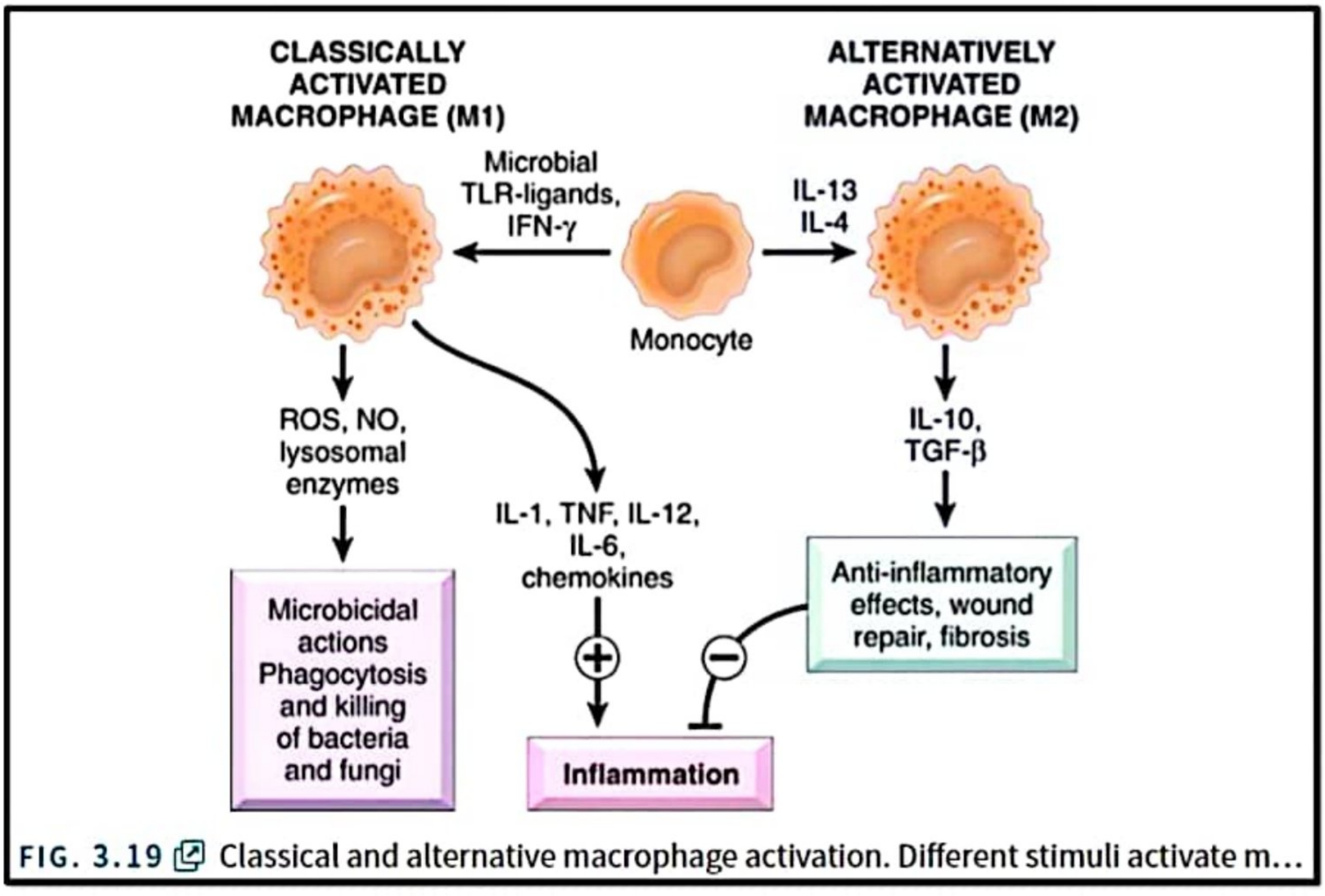


FIG. 3.19 Classical and alternative macrophage activation. Different stimuli activate m...

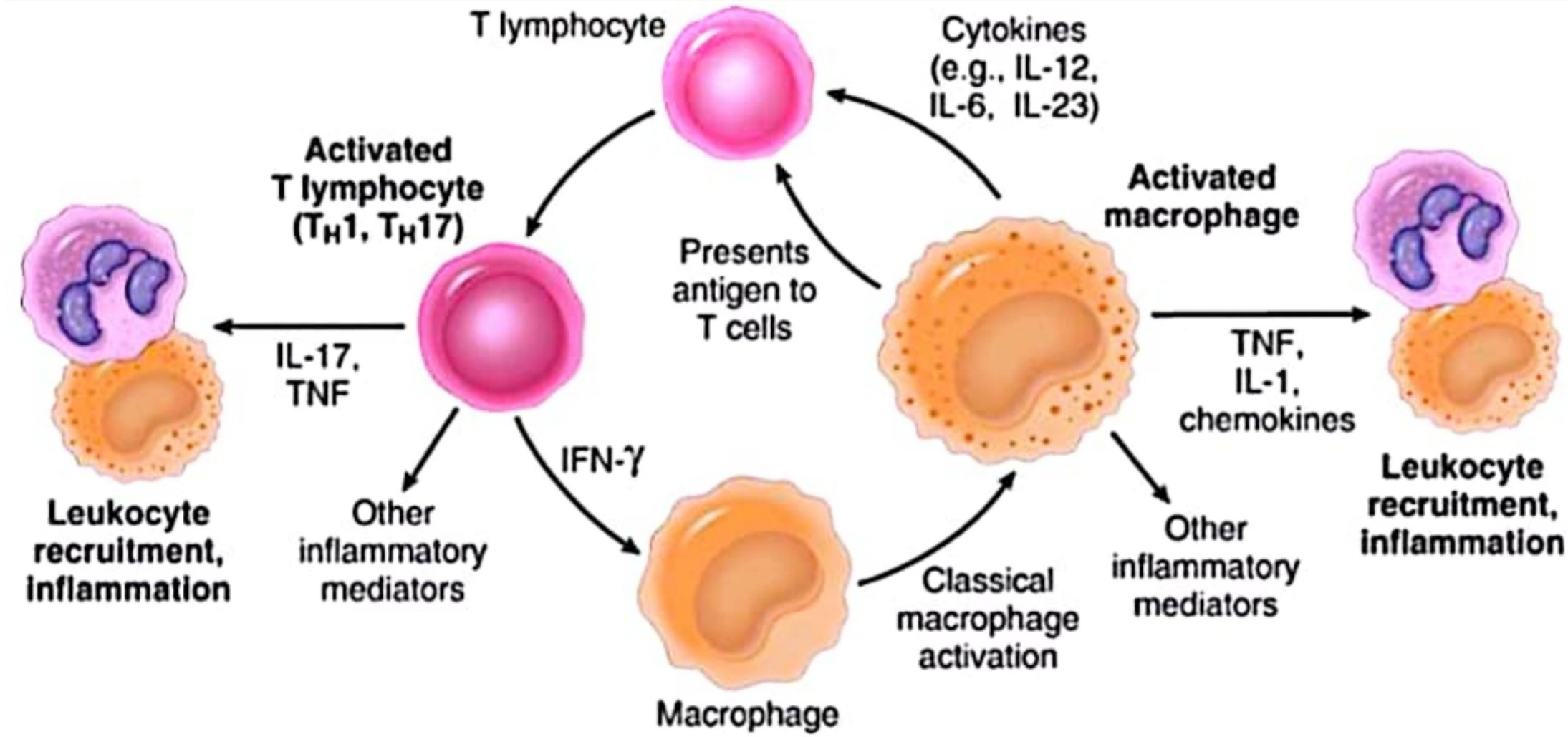
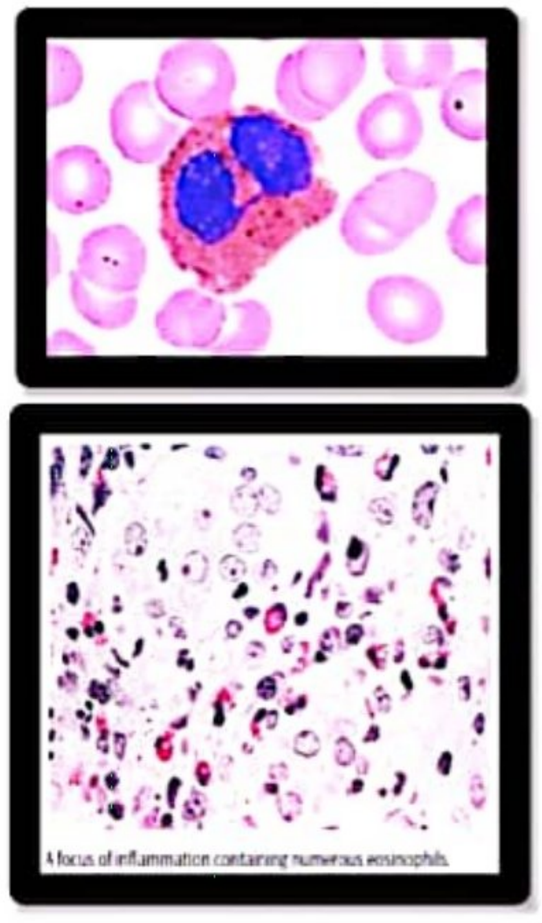


FIG. 3.20 Macrophage–lymphocyte interactions in chronic inflammation. Activated T c...

EOSINOPHILS:

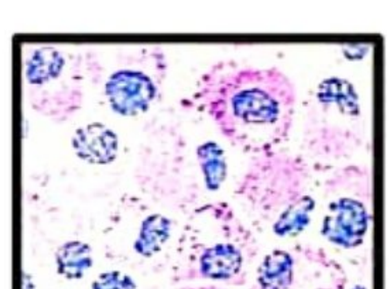
- **IgE and parasitic infections**
- **Granules contain major basic proteins toxic toparasites**
- **May cause tissue damage**
- **Eosinophilic inflammation**



MAST CELLS:

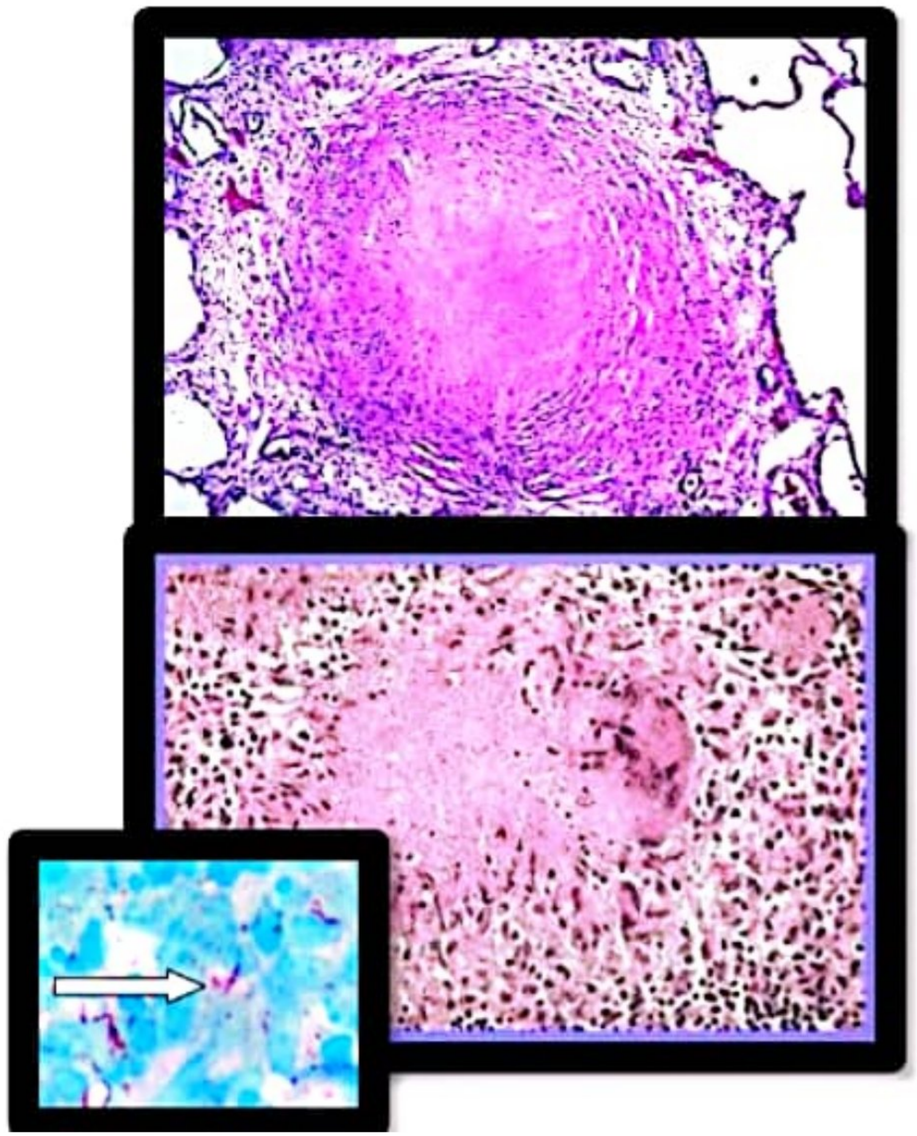
- **Abundant in soft tissues**
- **Active in both acute and chronic inflammation**
- **MC and basophils express FcεRI binds with FC portion of IgE leading to degranulation releasing Histamine and PG (food allergy, venom, drug allergy)**
- **In chronic inflammation**

  cytokines

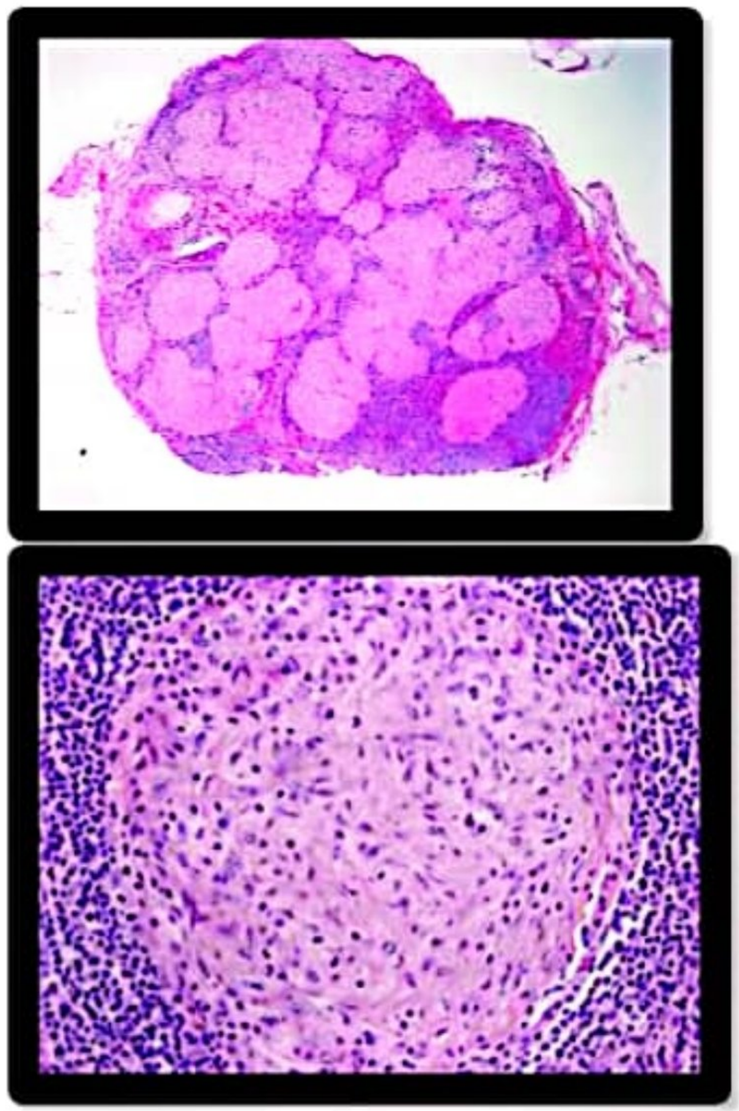


MORPHOLOGY OF GRANULOMATOUS INFLAMMATION

NECROTIZING GRANULOMA



NON-NECROTIZING GRANULOMA



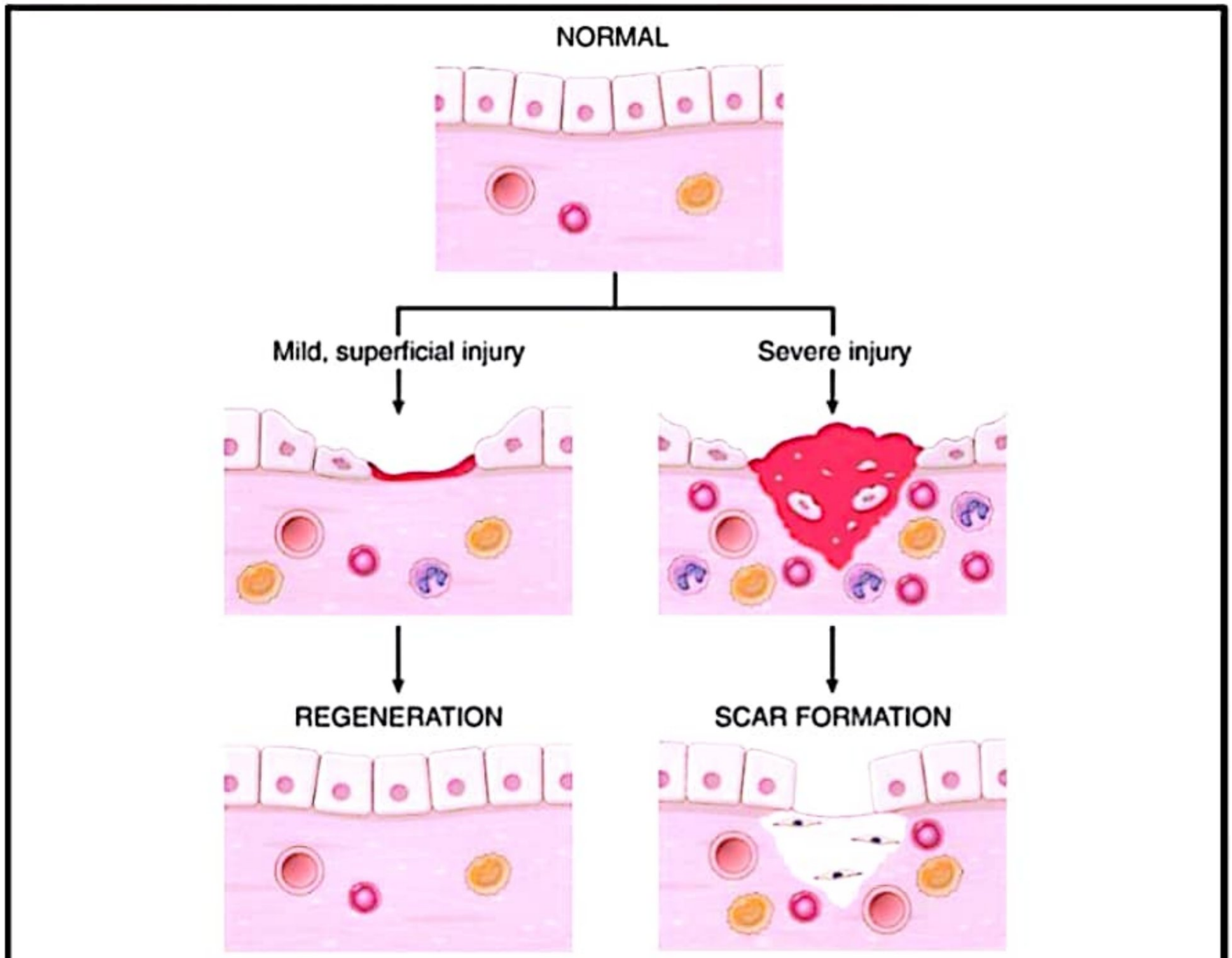


FIG. 3.23 Mechanisms of tissue repair: regeneration and scar formation. Following mil...

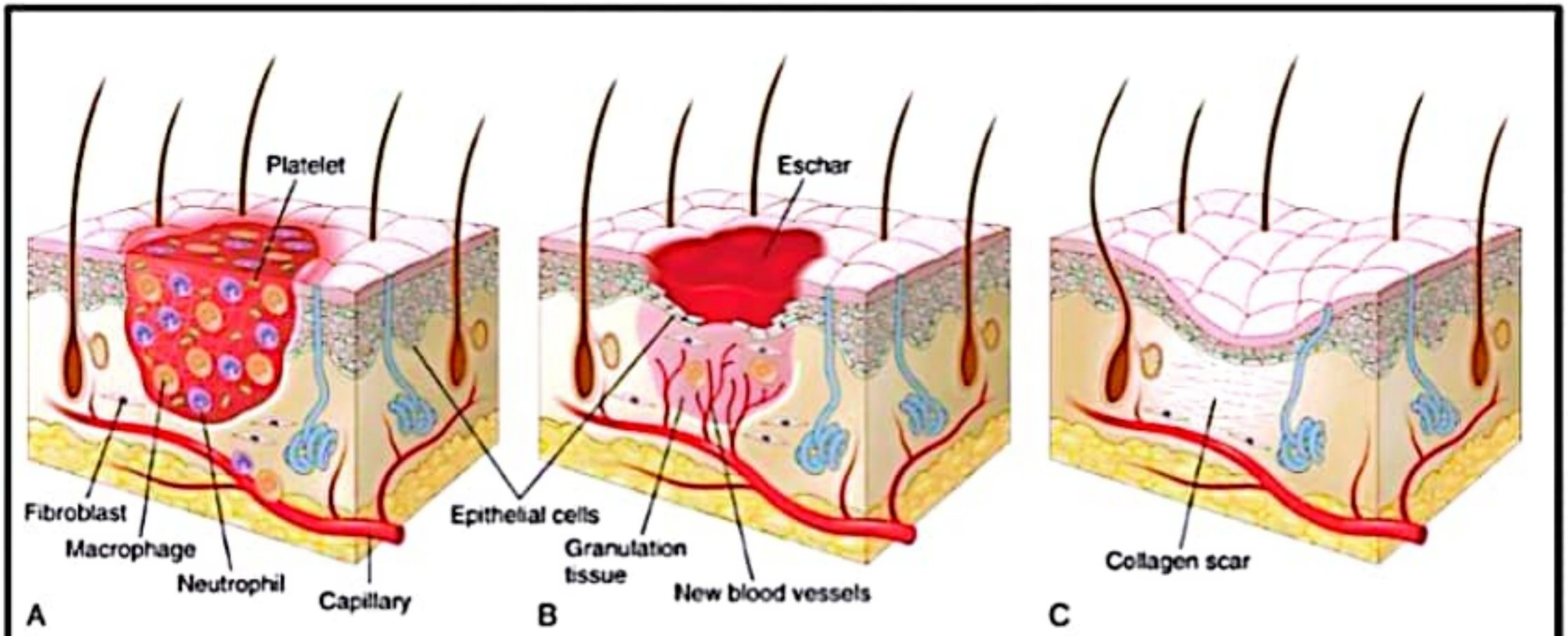


FIG. 3.24 Steps in repair by scar formation: healing of a large wound in the skin. This is ...

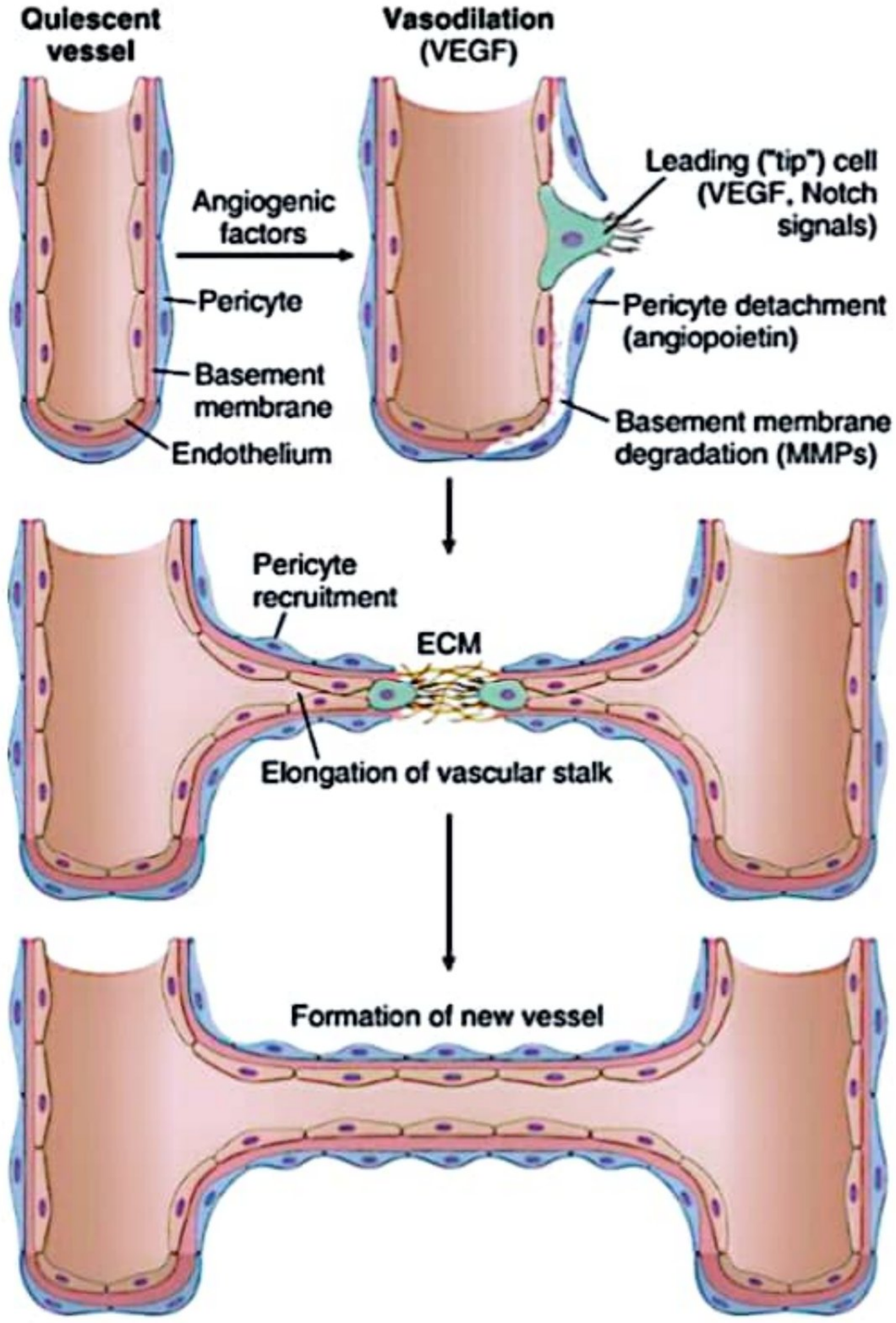
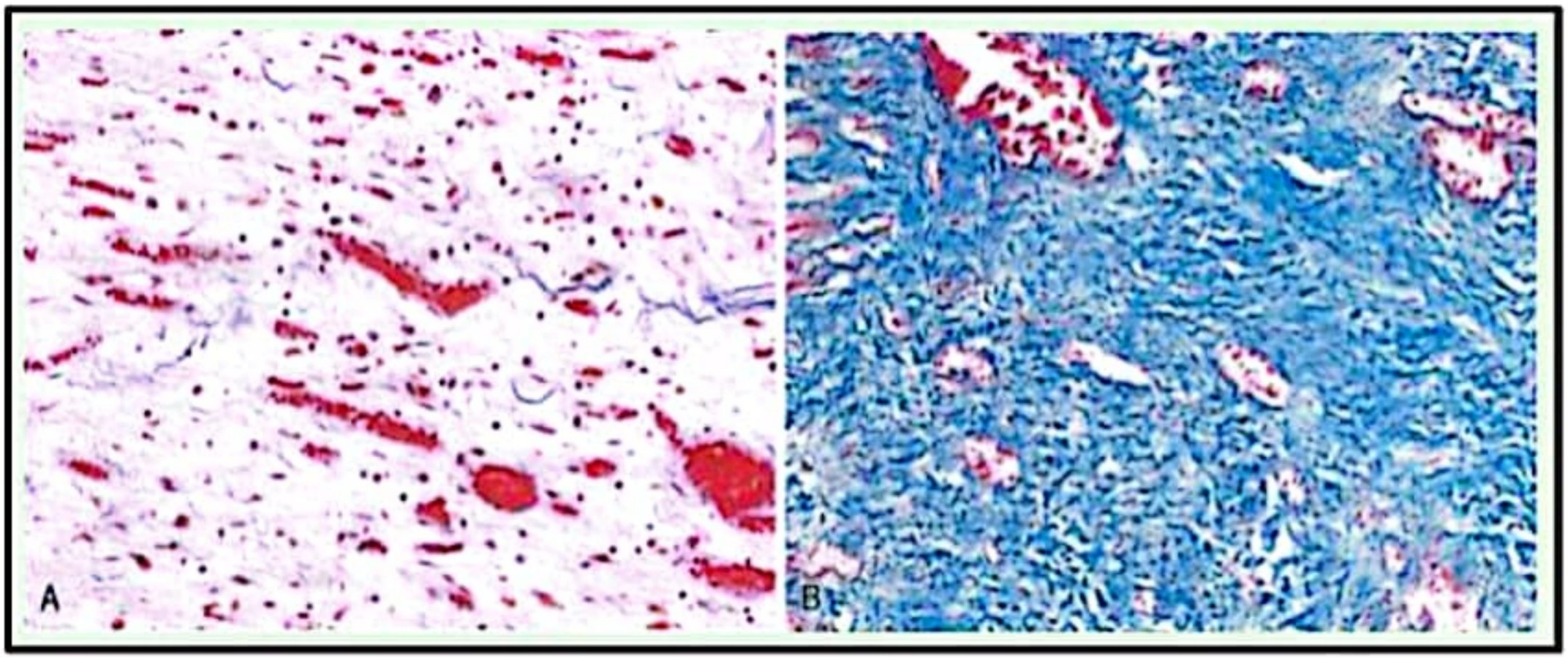


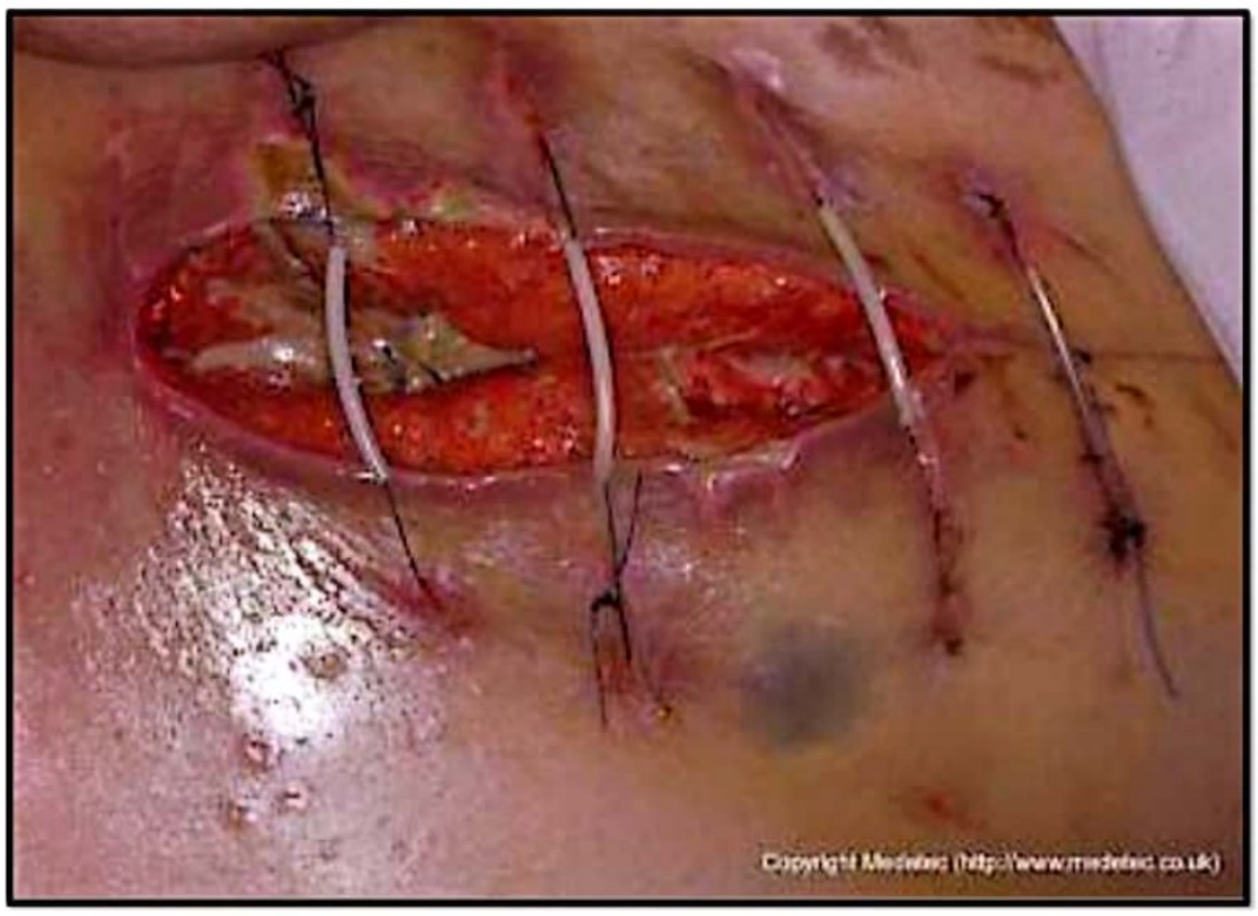
FIG. 3.25 Angiogenesis. In tissue repair, angiogenesis occurs mainly by the sprouting o...

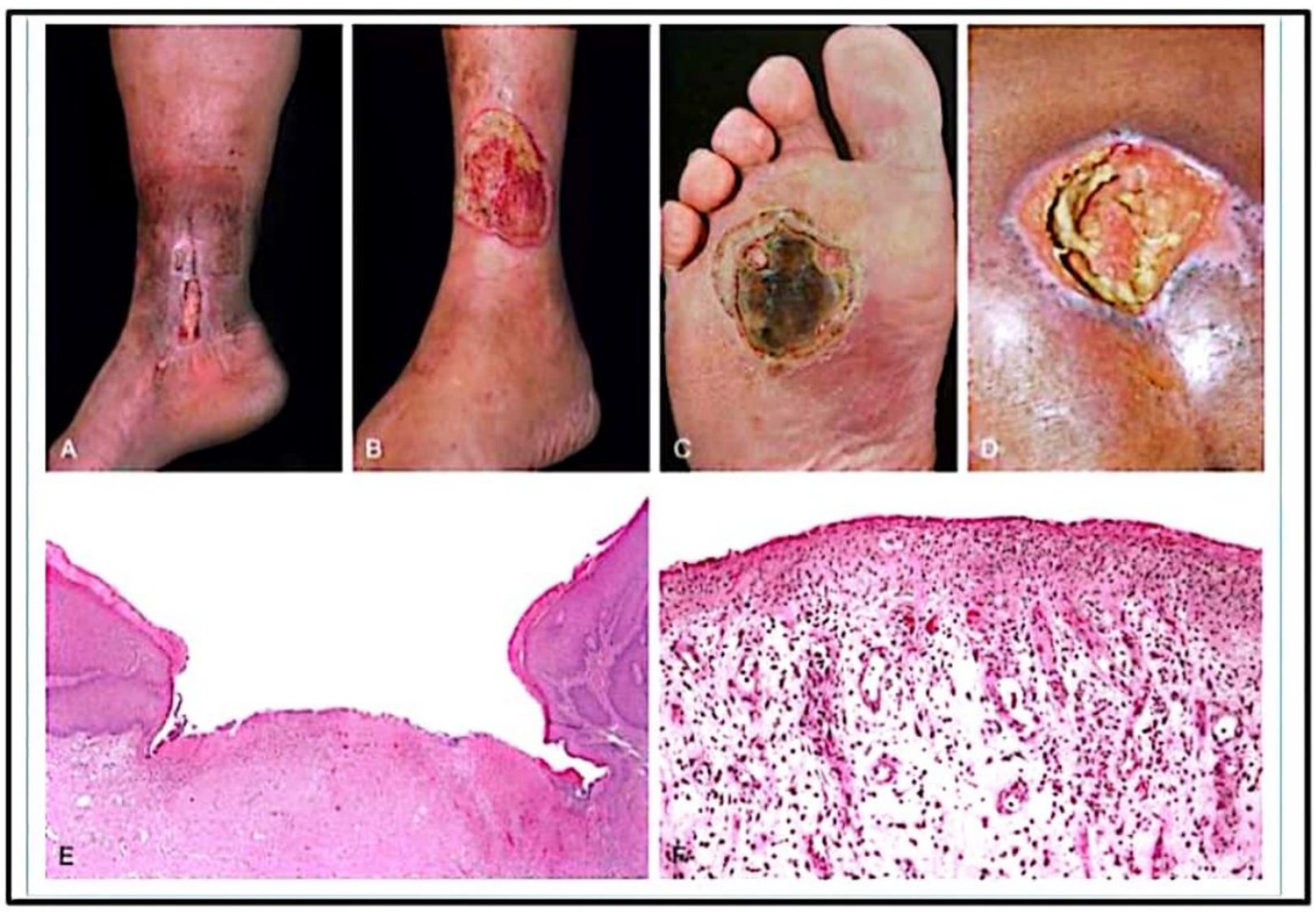
GRANULATIONS TISSUE VS MATURE SCAR



- **Venous leg ulcers**
- **Arterial ulcers**
- **Pressure sores**
- **Diabetic ulcers**
- ***** Wound dehiscence**

Wound dehiscence:





EXCESSIVE SCARRING:

- **Hypertrophic scar**
- **Keloid**
- **Exuberant granulation tissue (proud flesh)**
- **Aggressive fibromatosis (desmoid tumor)**
- **Contractures**

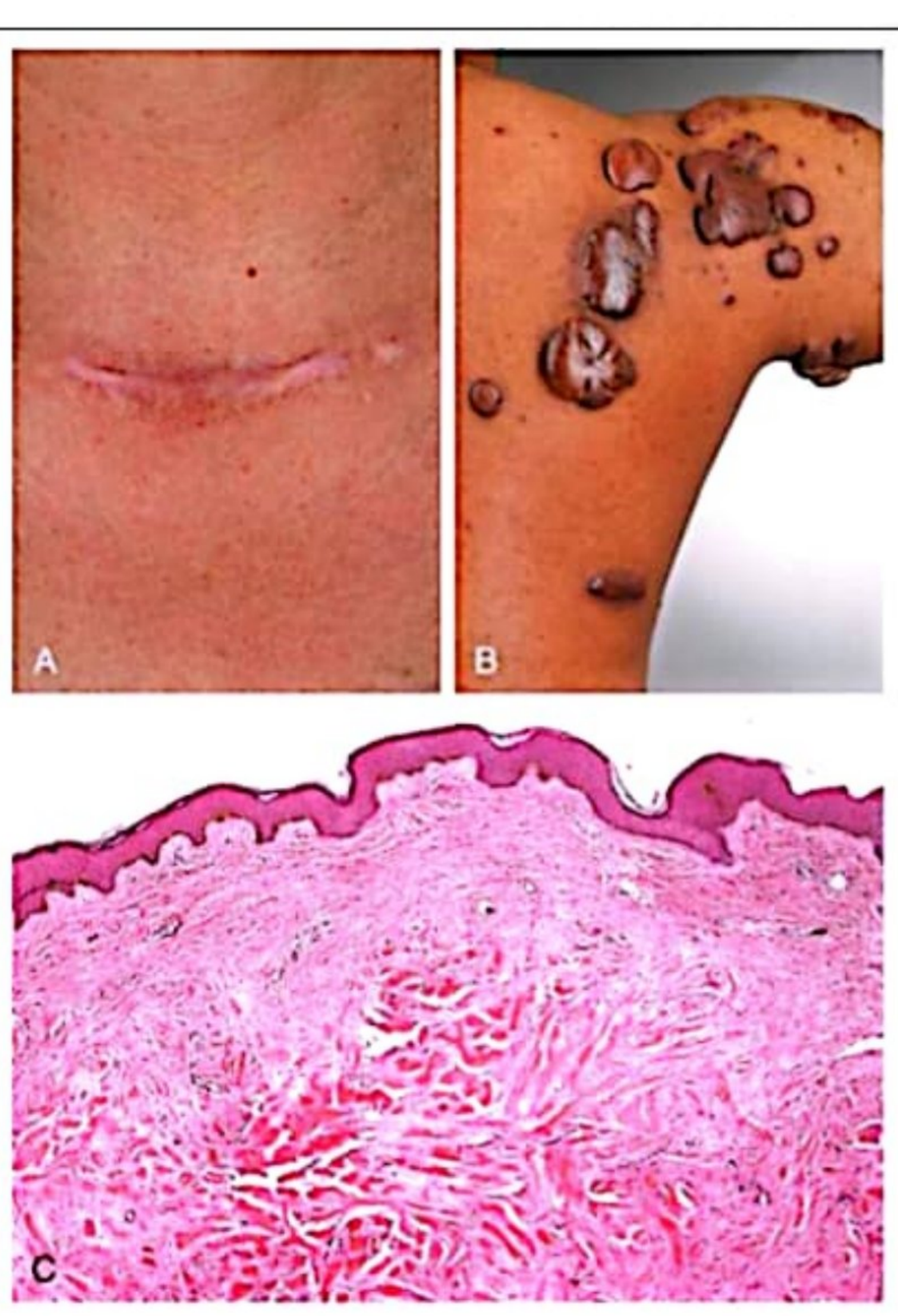


FIG. 3.28 Clinical examples of excessive scarring and collagen deposition. (A) Hypertro...