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THE CORPUSCULAR ELEMENTS OF BLOOD

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ABSTRACT:

Blood is a specialized connective tissue composed of plasma and corpuscular (cellular) elements. The corpuscular elements include erythrocytes (red blood cells), leukocytes (white blood cells), and thrombocytes (platelets). They constitute approximately 45% of total blood volume and play critical roles in oxygen transport, immune defense, and hemostasis. This scientific review provides an in-depth analysis of the morphology, physiology, hematopoiesis, laboratory diagnostics, clinical significance, and the latest research findings (2025–2026) on blood corpuscular elements, including CRISPR-based gene therapy, artificial intelligence (AI) in blood smear analysis, and novel functions of platelets. The article serves as a comprehensive resource for modern hematology and clinical medicine.

Introduction: Blood is the primary transport and protective system that maintains homeostasis in the human body. It consists of plasma (55%) and corpuscular elements (45%), the latter including erythrocytes, leukocytes, and thrombocytes. These cells originate from hematopoietic stem cells (HSCs) in the red bone marrow. Any change in the number, shape, function, or molecular composition of these elements serves as a key indicator of

hematological disorders such as anemia, leukemia, thrombocytopenia, and other systemic diseases.

The purpose of this review is to provide a scientific-level analysis of the normal structure and functions of corpuscular elements, their regulatory mechanisms, pathological conditions, modern diagnostic methods, and the latest scientific achievements from 2025–2026 (including results from the ASH 2025 conference, CRISPR gene therapy, AI diagnostics, and the new role of platelets).

Erythrocytes (Red Blood Cells)

Morphology and Ultrastructure

Erythrocytes are biconcave, anucleate disc-shaped cells with a diameter of 7–8 μm and a rim thickness of 2 μm. This shape provides a large surface area for gas exchange and allows flexibility when passing through narrow capillaries. Mature erythrocytes lack mitochondria, Golgi apparatus, and ribosomes, creating optimal conditions for hemoglobin storage (approximately 270 million hemoglobin molecules per cell).

Molecular Composition and Functions

Hemoglobin (Hb) is an iron-containing tetrameric protein that binds oxygen in the lungs and releases it in peripheral tissues. Erythrocytes also participate in carbon dioxide transport (in the form of carbaminohemoglobin and bicarbonate) and blood pH buffering. Their average lifespan is 120 days.

Production and Regulation (Erythropoiesis)

Erythropoiesis is the process of differentiation from hematopoietic stem cells through proerythroblasts to mature erythrocytes. The primary regulator is erythropoietin (EPO), produced by the kidneys in response to hypoxia. Other essential factors include iron, folic acid, and vitamin B12.

Clinical Significance and Pathophysiology

- Anemia: Reduction in the number or function of erythrocytes (iron deficiency, megaloblastic, hemolytic anemias). Peripheral blood smears reveal microcytosis, hypochromia, and poikilocytosis (target cells, sickle cells, spherocytes).

- Polycythemia: Increase in erythrocyte count (primary or secondary).

Recent studies have also highlighted erythrocyte deformation and hypervesiculation in babesiosis (Blood, 2025).

Table 1. Normal Erythrocyte Indices (CBC)

- RBC: Males 4.5–6.0 × 10^{12}/L, Females 4.0–5.5 × 10^{12}/L

- Hb: Males 130–180 g/L, Females 120–160 g/L

- Hematocrit: 40–50% (males), 36–46% (females)
- MCV: 80–100 fL

Leukocytes (White Blood Cells)

Normal Count and Classification

4,000–11,000/μL. Granulocytes (neutrophils 50–70%, eosinophils 1–4%, basophils 0.5–1%) and agranulocytes (lymphocytes 20–40%, monocytes 2–8%)

Molecular Mechanisms and Functions

- Neutrophils: Phagocytosis and formation of neutrophil extracellular traps (NETs) as the first line of defense against bacteria.
- Eosinophils: Key role in parasitic infections and allergic reactions (via major basic protein).
- Basophils: Release of histamine and heparin.
- Lymphocytes: B cells (antibody production), T cells (cell-mediated immunity), NK cells (tumor surveillance).
- Monocytes: Differentiation into macrophages and dendritic cells.

Leukocytes migrate into tissues via diapedesis. Their activation is regulated by cytokines (IL-3, IL-6, G-CSF).

Clinical Significance

- Leukocytosis: Infection, inflammation, leukemia.
- Leukopenia: Viral infections, chemotherapy.
- Differential count is crucial (neutrophilia in bacterial infections, lymphocytosis in viral infections).
- Malignant conditions: Acute and chronic leukemias (appearance of blasts).

Thrombocytes (Platelets)

Morphology and Origin

Small (2–4 μm), anucleate fragments derived from megakaryocytes through cytoplasmic fragmentation. Normal count: 150,000–450,000/μL. Lifespan: 7–10 days.

Functions

Primary hemostasis: Adhesion to damaged endothelium (via von Willebrand factor), aggregation (ADP, thromboxane A2), and release of procoagulant factors.

Recent Scientific Discoveries (2025)

Beyond hemostasis, platelets function as “DNA vacuum cleaners,” actively capturing and storing cell-free DNA fragments from the bloodstream, including mutated tumor DNA. This discovery opens new possibilities for non-invasive cancer screening and liquid biopsy

(Swansea University / Oxford study, Science, 2025). Tumor-educated platelets (TEPs) are also emerging as a promising tool in cancer diagnostics.

Clinical Significance

- Thrombocytopenia: Increased bleeding risk (immune thrombocytopenia – ITP, bone marrow failure).
- Thrombocytosis: Increased thrombosis risk (essential thrombocythemia).
- New Therapy: Ropeginterferon alfa-2b demonstrated superior efficacy over anagrelide in essential thrombocythemia (SURPASS-ET Phase 3 trial, 2025), achieving durable clinical response and significant reduction in JAK2 V617F allele burden.

Hematopoiesis and Regulation

All corpuscular elements originate from pluripotent hematopoietic stem cells (HSCs). The process is tightly regulated by cytokines and growth factors:

- Erythropoietin (EPO) — erythrocytes
- Thrombopoietin (TPO) — platelets
- G-CSF, GM-CSF, interleukins — leukocytes

In adults, hematopoiesis occurs mainly in the pelvis, sternum, and vertebrae. Disruptions lead to aplastic anemia, myelodysplastic syndromes, or myeloproliferative neoplasms.

Laboratory Diagnostics and Modern Methods

Primary Test: Complete Blood Count (CBC) with differential. Peripheral blood smear examination remains the “fifth vital sign.”

Modern Technologies (2025–2026):

- AI-based Analysis: Generative AI models such as CytoDiffusion outperform human experts in blood cell classification, anomaly detection, and resistance to distributional shifts (Nature Machine Intelligence, 2025). It generates synthetic blood cell images indistinguishable from real ones by expert hematologists. Commercial platforms like CellaVision and Scopio achieve AUC values of 0.92–0.99.
- Flow cytometry, next-generation sequencing (NGS), and measurable residual disease (MRD) monitoring.

Recent Advances and Future Directions (2025–2026)

- Gene Therapy: Exagamglogene autotemcel (exa-cel, Casgevy) — a one-time CRISPR/Cas9 gene-edited autologous therapy — demonstrates durable clinical benefits in severe sickle cell disease (SCD), eliminating vaso-occlusive crises (VOC) in over 91% of patients with long-term follow-up up to 5.6 years. It also shows promising results in children

aged 5–11 years (CLIMB SCD-121, CLIMB SCD-151, and CLIMB THAL-141 trials, ASH 2025).

- AI Diagnostics: Revolutionary progress in automated blood smear analysis for faster and more accurate detection of hematological malignancies.
- Platelet Biology: Platelets' ability to store DNA offers potential for early cancer detection.
- Other highlights from ASH 2025 include advances in platelet disorders and classical hematology.

Conclusion: The corpuscular elements of blood — erythrocytes, leukocytes, and thrombocytes — form a complex biological system that ensures oxygen transport, immunity, and hemostasis. A deep understanding of their structure, functions, regulation, and pathological changes is essential for the diagnosis and treatment of hematological and systemic disorders. The breakthroughs of 2025–2026 (CRISPR gene therapy, AI-powered diagnostics, and the discovery of platelets' DNA storage function) are elevating hematology to a new level, bringing us closer to functional cures and personalized medicine.

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