MEDLAB BASICS · STUDY SHEET

White Cells, Leukemia and Lymphoma

Maturation stages, reactive and inherited changes, the WHO 5th edition framework for myeloid and lymphoid neoplasms, cytochemistry, flow cytometry markers and PNH flow

36 sources + more detail
medlabbasics.com/sheets/lab-wbc-leukemia.html
checked Nov 2026

1 Normal white cells and the ASCP ranges

Descriptions follow Adewoyin 2014. The nucleus condenses and loses its nucleoli as the cell matures. Primary (azurophilic) granules are made at the promyelocyte stage; secondary (specific) granules are added from the myelocyte stage on, so a mature neutrophil holds both.

STAGE (GRANULOCYTE LINE)	NUCLEUS	CYTOPLASM
Myeloblast (earliest recognizable)	Large, round to oval; fine, open (reticular) chromatin; 2 to 5 nucleoli	Scant, blue (basophilic); no or few granules
Promyelocyte (slightly larger)	Nucleoli still visible; chromatin a little more condensed	Primary (azurophilic) granules
Myelocyte (smaller)	Round or oval; no nucleoli; condensed chromatin	More cytoplasm; secondary (specific) granules first appear at this stage
Metamyelocyte	Indented (kidney-shaped)	Like the myelocyte
Band	Unsegmented (not yet divided into lobes)	Like the segmented neutrophil
Segmented neutrophil	Lobes joined by thin strands	Pink or nearly colorless, with azurophilic and specific granules

MATURE CELL	WHAT IDENTIFIES IT
Eosinophil	Slightly larger than a neutrophil, usually bilobed nucleus, orange-red granules
Basophil	Slightly smaller than a neutrophil; large, deep blue-purple granules that may hide the nucleus
Monocyte	Largest normal blood cell; blue-gray "ground glass" cytoplasm; large folded nucleus, often horseshoe-shaped
Small lymphocyte	Round, high nucleus-to-cytoplasm ratio, scant pale to dark blue cytoplasm
Large granular lymphocyte	More cytoplasm with azurophilic granules: cytotoxic T cells or NK cells

ASCP BOC composite reference ranges, MLS guideline of June 9, 2026 (for exam use, not clinical use). Absolute count = WBC × the fraction; see the ANC and WBC Corrected for nRBCs calculators.

ASCP COMPOSITE RANGE	ABSOLUTE, ×10³/ML (×10⁹/L)	RELATIVE
Total WBC	3.6–10.6	—
Neutrophils	1.7–7.5	50–70%
Lymphocytes	1.0–3.2	18–42%
Monocytes	0.1–1.3	2–11%
Eosinophils	0–0.3	1–3%
Basophils	0–0.2	0–2%
nRBC	0 per 100 WBC	—

2 Reactive and inherited changes

FINDING	WHAT IT LOOKS LIKE	SEEN IN
Left shift	More bands and earlier precursors than normal (bands normally under about 8%, metamyelocytes under 0.5%)	Bacterial infection, inflammation; severe left shift with neutrophilia is a leukemoid reaction
Toxic granulation	Coarse, dark granules in neutrophil cytoplasm (retained primary granules)	Severe infection and sepsis, G-CSF therapy, marrow recovery
Döhle bodies	Pale blue-gray oval or elongated patches near the cell edge: strands of rough endoplasmic reticulum	Infection, sepsis, inflammation; look-alike inclusions in MYH9-related disease (May-Hegglin)
Cytoplasmic vacuoles	Clear round holes in neutrophil cytoplasm	Part of "toxic change" with toxic granulation and Döhle bodies in sepsis
Hypersegmentation (right shift)	At least one neutrophil with 6 or more lobes, or at least 5% with 5 lobes	Megaloblastic anemia (B12, folate); also familial, iron deficiency, renal failure
Reactive (activated) lymphocyte	Large, abundant blue cytoplasm that flows around neighboring red cells; indented or irregular nucleus, sometimes nucleoli	Infectious mononucleosis, CMV, hepatitis, other viral infections
Pelger-Huët anomaly (inherited)	Bilobed "pince-nez" (dumbbell) or round nuclei with coarse clumped chromatin; normal granules; affects most neutrophils	Autosomal dominant lamin B receptor defect, about 1 in 6000; benign
Pseudo-Pelger-Huët (acquired)	Same nuclear shape, often with hypogranular cytoplasm; only some cells	MDS and AML (dysplasia), some drugs and infections
May-Hegglin (MYH9-related disease)	Döhle-like blue inclusions in neutrophils with giant platelets and thrombocytopenia	Most frequent inherited thrombocytopenia
Chédiak-Higashi	Giant granules in neutrophils, eosinophils, monocytes and lymphocytes	LYST gene defect; poor bacterial killing
Alder-Reilly	Large dark (aberrant) granules in neutrophils, sometimes lymphocytes and monocytes, in a well patient	Mucopolysaccharidoses (stored glycosaminoglycans)

EXAM TIP Exams pair each inherited anomaly with its look-alike: Pelger-Huët with pseudo-Pelger (MDS), May-Hegglin with Döhle bodies (check the platelets), Alder-Reilly with toxic granulation (no infection), Chédiak-Higashi with toxic granulation (granules are giant and in every cell type).

A leukemoid reaction is a neutrophil count above 50,000/µL (50 × 10⁹/L) from a normal marrow.

	LEUKEMOID REACTION	CML
Marrow	Normal, reacting	Clonal (BCR::ABL1)
Blasts	Never high	Few in chronic phase; 20% or more is blast phase
Neutrophils	Toxic granulation, Döhle bodies, vacuoles	Little toxic change; full range of precursors
Basophils	Normal	Increased (often 5–10%), with eosinophilia
LAP (older test)	Normal or high	Low
Confirm	Find the cause (infection, inflammation, drugs)	BCR::ABL1 by PCR or FISH; Philadelphia chromosome t(9;22)

3 Myeloid neoplasms (WHO 5th edition)

- AML generally needs 20% or more blasts in blood or marrow. Blasts and blast equivalents are myeloblasts, monoblasts and promonocytes.
- AML with a defining genetic abnormality needs NO set blast count, except AML with BCR::ABL1 and AML with CEBPA mutation, which still need 20%.
- AML, myelodysplasia-related (AML-MR) needs 20% blasts plus MDS-type cytogenetics or mutations, or a history of MDS or MDS/MPN; dysplasia on the smear alone no longer defines it.
- The 20% line between MDS and AML is kept. MDS has under 20% blasts.
- Older names: "myelodysplastic syndromes" are now myelodysplastic neoplasms (still MDS); the accelerated phase of CML is dropped.

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3 Myeloid neoplasms (WHO 5th edition) CONTINUED

AML TYPE	GENETICS	WHAT THE LAB SEES
Acute promyelocytic leukemia (APL)	t(15;17), PML::RARA	Abnormal hypergranular promyelocytes, bundles of Auer rods (faggot cells); microgranular variant has few granules, bilobed nuclei and a high WBC. CD34 and HLA-DR negative (the microgranular variant may express CD34), CD13, CD33, CD117 positive, MPO strong, high side scatter. DIC with low fibrinogen.
AML with RUNX1::RUNX1T1	t(8;21)	Large blasts with an indented nucleus and a clear zone at the indentation, long slender Auer rods, dysplastic neutrophils. Relatively favorable.
AML with CBFB::MYH11	inv(16) or t(16;16)	Myelomonocytic picture with abnormal marrow eosinophils carrying large basophilic granules (these eosinophils stain with chloroacetate esterase and PAS). Favorable.
AML with NPM1 mutation	NPM1	Diagnosed at any blast count
AML with BCR::ABL1, AML with CEBPA	BCR::ABL1; CEBPA	20% blasts still required

⚠ **SAFETY** Suspected APL is a call-now result: hemorrhage is the main cause of early death, and treatment (all-trans retinoic acid) starts at first suspicion, before PML::RARA is confirmed. Report the smear finding at once and send coagulation studies (PT, aPTT, fibrinogen, D-dimer, platelets).

GROUP	KEY LAB FEATURES
MDS	Cytopenias with dysplasia in at least 10% of a lineage: hypogranular neutrophils, pseudo-Pelger cells; macrocytosis and high RDW. Low blasts (MDS-LB): under 5% marrow and under 2% blood. Increased blasts: IB1 5–9% marrow or 2–4% blood; IB2 10–19% marrow or 5–19% blood, or Auer rods.
CML	BCR::ABL1 from t(9;22); high WBC with all stages of granulocytes, basophilia and eosinophilia; platelets normal or high
Polycythemia vera	High hemoglobin or hematocrit, often high WBC and platelets; JAK2 V617F (about 90%) or JAK2 exon 12; erythropoietin low or low-normal
Essential thrombocythemia	Platelets above 450 × 10^3/µL; JAK2 (about 50%), CALR or MPL; giant platelets on the smear
Primary myelofibrosis	Teardrop cells, nRBCs with immature granulocytes (leukoerythroblastic picture), marrow reticulin fibrosis; JAK2, CALR or MPL
CMML (MDS/MPN)	Persistent monocytes at least 0.5 × 10^9/L and at least 10% of the WBC, blasts under 20%

4 Lymphoid and plasma cell neoplasms

NEOPLASM	KEY LAB FEATURES
B-lymphoblastic leukemia/lymphoma (B-ALL)	Lymphoblasts, TdT positive, MPO and SBB negative, PAS in coarse blocks or rings; CD19 with CD10, CD22 or CD79a. Peak age 2–5 years. Good risk: high hyperdiploidy, ETV6::RUNX1. Poor risk: BCR::ABL1 (about 25% of adults).
T-lymphoblastic leukemia/lymphoma (T-ALL)	TdT positive; cytoplasmic or surface CD3 defines T lineage; CD2, CD7; focal acid phosphatase
CLL/SLL	Monoclonal B cells 5 × 10^9/L or more: small mature lymphocytes, smudge cells. CD5, CD19, CD20, CD23 with one light chain. Under 5 × 10^9/L without other disease is MBL. Watch for autoimmune hemolysis (positive DAT); hypogammaglobulinemia is found in under 15% at diagnosis but in up to two-thirds over the course.
Hairy cell leukemia	Pancytopenia with monocytopenia, splenomegaly; cells with hair-like projections; CD11c, CD25, CD103, CD123 positive, annexin A1 and TRAP positive; BRAF V600E in at least 95%; marrow often a dry tap
Mantle cell lymphoma	t(11;14) IGH::CCND1 (in 95% or more) with cyclin D1 overexpression; CD5, CD19, CD20 positive but CD23 and CD200 negative, the opposite of CLL (CD5+, CD23+, CD200+); cells with notched or cleaved nuclei
Follicular lymphoma	t(14;18) IGH::BCL2 in classic cases; cleaved cells
Plasma cell myeloma	Clonal marrow plasma cells 10% or more, M-protein, organ damage (CRAB); rouleaux; plasma cells CD38 bright and CD138 positive with one cytoplasmic light chain

💡 **EXAM TIP** Smudge cells (Gumprecht shadows) are characteristic of CLL, but they are broken cells: count them with the lymphocytes or the differential will be wrong. CD5 alone does not mean CLL: mantle cell lymphoma is also CD5 positive, and CD23 separates them.

5 Cytochemistry and flow cytometry

STAIN	POSITIVE IN	NEGATIVE IN
Myeloperoxidase (MPO)	Myeloblasts and granulocytes (strong); Auer rods	Lymphoblasts; monoblasts and monocytes negative or faint
Sudan black B (SBB)	Same pattern as MPO (stains lipid in granules)	Lymphoblasts
Specific esterase (naphthol AS-D chloroacetate)	Neutrophil lineage	Monocytes, lymphoblasts
Nonspecific esterase (alpha-naphthyl butyrate or acetate)	Monoblasts, promonocytes, monocytes; inhibited by sodium fluoride	Granulocytes (negative or weak, not fluoride-sensitive)
Periodic acid-Schiff (PAS)	Lymphoblasts: coarse blocks or perinuclear rings of glycogen	Myeloblasts of t(8;21) AML
Tartrate-resistant acid phosphatase (TRAP)	Hairy cell leukemia	Other small B-cell lymphomas
TdT (immunostain or flow)	B and T lymphoblasts (nuclear)	Mature lymphoid cells

LINEAGE	MARKERS
All white cells	CD45 (gate on CD45 versus side scatter)
Immature (blasts)	CD34; TdT (lymphoblasts); HLA-DR on most myeloblasts but not on APL cells
Myeloid	MPO, CD13, CD33, CD117; neutrophils CD15, CD10, CD16
Monocytic	CD14, CD64, CD11c, CD36, HLA-DR
Megakaryocytic	CD41, CD61, CD42b
B cell	CD19, CD20, CD22, CD79a; CD10 on B-lymphoblasts; one light chain (kappa or lambda) means a clone
T cell	CD3 (cytoplasmic CD3 is lineage-defining), CD2, CD7; CD4 helper, CD8 cytotoxic
NK cell	CD56 positive, CD3 negative
Plasma cell	CD38 bright, CD138; cytoplasmic light chain

- PNH: an acquired PIGA mutation leaves cells without GPI-anchored proteins, including CD55 and CD59 (complement regulators).
- Flow cytometry is the reference test. Red cells: CD59 (type I normal, type II partial loss, type III complete loss). White cells: FLAER plus a GPI-anchored marker on neutrophils (CD24 or CD157) and monocytes (CD14 or CD157).
- Report the clone size from granulocytes and monocytes: hemolysis and transfusion make the red cell clone look smaller. FLAER is not used on red cells.
- Ham (acidified serum) and sucrose hemolysis tests are obsolete.

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