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SITUATION TASKS: PATHOPHYSIOLOGY OF THE BLOOD SYSTEM
(to laboratory and practical classes on the pathological physiology)

СИТУАЦІЙНІ ЗАВДАННЯ: ПАТОФІЗІОЛОГІЯ СИСТЕМИ КРОВІ
(до лабораторно-практичних занять з патологічної фізіології)

Навчально-методичний посібник

для здобувачів другого (магістерського) рівня вищої освіти
денної форми навчання за спеціальністю 211 – «Ветеринарна медицина»

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К-60. Situation tasks: pathophysiology of the blood system. Ситуаційні завдання: патофізіологія системи крові [Текст]: навч.-метод. посіб. для здобувачів другого (магістерського) рівня вищої освіти денної форми навчання за спеціальністю 211 – «Ветеринарна медицина». / І. О. Костюк, І. О. Жукова, О. С. Кочевенко; Держ. біотенх. ун-т. – Харків, 2024. 30 с.

Метою навчально-методичного посібника є розвиток вмінь та навичок студентів аналізувати практичні ситуації підчас досліджень крові тварин, розуміти механізми патологічних реакцій і хвороб. Матеріали підготовані як для іноземних студентів так і для україномовних, які поряд з навчанням, передбачають усвідомлення здобувачем лабораторних та клінічних термінів іншомовного професійного спілкування. Тестові завдання подано у вигляді задач, які мають ключі для самоперевірки. Інформаційний матеріал - у вигляді тексту, а також таблиць з нормальними показниками крові у різних видів тварин. Видання призначене здобувачам першого (бакалаврського) рівня вищої освіти денної форми навчання за спеціальністю 211 – «Ветеринарна медицина».

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Відповідальний за випуск І.О. Жукова, доктор вет. наук

1. **Topic:** Pathology of the blood system.
2. **Form of work:** Preparation for practical exercises.
3. **Questions for self-study:**
1. Etiopathogenesis of anemias, leucosis, erythrocytosis.
2. Classification of anemia according to the pathogenetic principle.
3. Posthemorrhagic anemia. Etiology, pathogenesis, hematological syndrome.
Hemodynamic disturbances and compensatory phenomena in acute blood loss.
The role of erythropoietin in the regulation of erythropoiesis.
4. Hemolytic anemia. Etiology, pathogenesis. Hereditary and acquired hemolytic anemias.
5. Diserythropoietic anemia. B12 and folate deficiency anemia. Etiology, pathogenesis, hematological syndrome.
6 Aplastic anemia. Etiology, pathogenesis, hematological syndrome.
7. Iron deficiency anemia. Etiology, pathogenesis, hematological syndrome
4. **Goal:**
Be able to interpret the change in the main indicators of the red blood system.

Plan:

Part 1. Situation tasks.

Part 2. Lab practical information: RBC analysis by modern methods using the hematology analyzer.

Part 3. Lab practical information: Complete blood count – CBC.
Part 4. Routine Hemogram Reference Intervals.

Part 1. Tasks.

Hematology is the science of the number and morphology of the cellular elements of the blood - erythrocytes (erythrocytes), leukocytes (leukocytes) and platelets (platelets) and the use of these results in the diagnosis and monitoring of disease.

Erythrocytes (RBC) in mammals mostly have the shape of biconcave discs, they are called discocytes. Normally, disc cells make up 80% of the total number of erythrocytes. There are also other forms of erythrocytes — planocytes (have a flat surface), spherocytes (spherical), echinocytes (have spikes), etc. Such a variety of forms is normally designated by the term physiological poikilocytosis. When the number of altered forms of erythrocytes exceeds 20%, the same phenomenon is called pathological poikilocytosis.

The main function of erythrocytes is to carry oxygen from the lungs to the tissues and carbon dioxide from the tissues to the lungs. Therefore, any structural changes in erythrocytes, as well as a decrease in their number, which occur in anemia, lead to the development of a state of hemic hypoxia.

White blood cells are the main component of the body's immune system. There are usually five main types of white blood cells (neutrophils, lymphocytes, monocytes, eosinophils, and basophils), and different types are brought into play when the immune system responds to various stresses or disorders. Counting the number of leukocytes of each type (differential formula of leukocytes) can tell the doctor possible reasons for changes in the total number of leukocytes. For example, suppose an animal with cold symptoms has an elevated white blood cell count due to an increase in neutrophils. In that case, a doctor is more likely to suspect bacterial pneumonia than a viral infection because neutrophils are more likely to be recruited to fight bacterial infections.

The doctor can examine these cells under a microscope to get more information about white blood cells. With microscopic examination, it is possible to reveal cell features characteristic of certain diseases. For example, a large number of white blood cells that have a very immature appearance (blasts) may indicate leukemia (cancer of the white blood cells).

Platelets are cells that help blood clot by gathering at the site of bleeding and sticking together to form a plug. Platelets are also counted as part of the CBC (Complete blood count).

The number of platelets is an important indicator of blood's ability to form blood clots (blood clot formation is the body's defense mechanism to stop bleeding). Too few platelets can impair blood clotting. A high number of platelets (thrombocytosis) can cause excessive blood clotting in small blood vessels, especially in the heart or brain.

Hemogram number 1

Blood was taken from a puppy (age 5 months) for hematological studies. At the same time, it was established:

Hemoglobin 153 g / l

Erythrocytes 6.4 x 10^{12} / l

Color indicator 0.9 units

Leukocytes 9.7 x 10^9 / l

    basophils 0.5%

    eosinophils 2.8%

    neutrophils:

        myelocytes 0%

        metamyelocytes 0%

        stab 2%

        segmented 68%

lymphocytes 29%

monocytes 1%

        Platelets 324 x 10^9 / l

        Reticulocytes 2.0% In a

smear: normochromia.

Question: indicate - are there pathological changes in the puppy's peripheral blood?

Hemogram number 2

Three groups of experimental animals with post-hemorrhagic anemia were injected with the following hormonal preparations: the first group
- androgens; the second is estrogens; the third isoxytocin. Results of one of the groups: Hemoglobin 180 g / l ↑

Erythrocytes 8.6 x 10^{12} / l ↑Leukocytes

10.5 x 10^9 / l

    basophils 0.5%

    eosinophils 3.5%

    neutrophil:

        metamyelocytes 0%

        stab 1.3%

        segmented 57.7%

lymphocytes 30%

monocytes 5%

        Platelets 300 x 10^9 / l

        Reticulocytes 2.4% ↑

Question: indicate - under the influence of which of the specified hormones is the activation of erythropoiesis observed?

Hemogram number 3

A dog with suspected gastric bleeding was admitted to the clinic. Blood was taken for analysis on the 4th day of the disease. A blood test revealed:

Hemoglobin 82 g / l ↓

Erythrocytes 3.0 x 10^{12} / l ↓

Color indicator 1.0 unit

Leukocytes 8.0 x 10^9 / l

    basophils 1%

    eosinophils 4%

    neutrophils:

        myelocytes 0%

        metamyelocytes 0%

        stab 5%

        segmented 50%

    lymphocytes 37%

    monocytes 3%

        Platelets 120 x 10^9 / L ↓

        Reticulocytes 3.2% ↑

In a smear: normochromia, an increased number of reticulocytes.

Question: Are the results obtained typical for acute blood loss?

Hemogram number 4

A 9-year-old dog has a chronic liver disease -fatty hepatosis. Blood test results: Hemoglobin 102 g / l ↓

Erythrocytes 5.0 x 10^{12} / l ↓Color

indicator 1.0 unit

Leukocytes 8.7 x 10^9 / l

    basophils 0%

    eosinophils 2%

    neutrophils:

        myelocytes 0%

        metamyelocytes 0%

        stab 1.2%

        segmented 80.0%

    lymphocytes 15%

    monocytes 1%

        Platelets 300 x 10^9 / l

        Reticulocytes 0.6%

In a smear: normochromia, macrocytes. **Question:** Determine the changes in the hemogram.

Hemogram number 5

The cat is 3 years old, after surgery for 3 days.
Blood tested:
Hemoglobin 87 g / 1 ↓
Erythrocytes 4.9 x 10^{12} / 1 ↓
Color indicator 0.5 units. ↓
Leukocytes 25 x 10^9 / 1 ↑
    basophils 1%
    eosinophils 11%
    neutrophils:
        myelocytes 0%
        metamyelocytes 0%
        stab 14% ↑
        segmented 48% ↑
lymphocytes 36%
monocytes 1%
        Platelets 550 x 10^9 / 1 ↑
        Reticulocytes 2.6% ↑
In a smear: poikilocytosis, polychromatophilia.

Question: Describe the existing changes in hematological parameters. Which of them indicate the inclusion of compensatory mechanisms on the part of hematopoiesis?

Hemogram number 6

A dog at the age of 11 has rapid fatigability, a significant decreasein body weight in 2-3 weeks, the subcutaneous lymph nodes are enlarged, painless. Dense consistency. The liver and spleenare moderately enlarged.
Hemoglobin 80 g / 1 ↓ Erythrocytes 4.2 x 10^{12} / 1 ↓Leukocytes 12.4 x 10^9 / 1 ↑
basophils 2%
  eosinoph ils 2%
  neutrophi ls:
      myelocytes 2%
      metamyelocytes 1%
      stab 6%
      segmented 61%
  lymphocytes 16% ↓
  monocytes 4%
  blast cells 6%
      Platelets 200 x 10^9 / 1
In a smear: undifferentiated cells,reticulocytosis, hypochromic erythrocytes.
Question: name the pathological changes inthe blood, determine the diagnosis.

Hemogram number 7

In a cat, 1 day after a bruise in the chest area, there is pallor of the mucous membranes, tachycardia, weak pulse filling, shortness of breath, depression.
Hemoglobin 72 g / 1 ↓
Erythrocytes 4.9 x 10^{12} / 1 ↓
Leukocytes 10 x 10^9 / 1
    basophils 0%
    eosinophils 3%
    neutrophils:
        myelocytes 0%
        metamyelocytes 0%
        stab 9%
        segmented 48% ↑
lymphocytes 36%
monocytes 4%

      Platelets 530 x 10^9 / 1
In a smear: normochromia.
Question: what caused the changes in hematological parameters? What is the presumptive diagnosis?
.

Hemogram number 8
In a cat after 8 months. after childbirth, an increase and hardening of the mammary glands,on palpation in one lobe, focal seals were found,subcutaneous lymph nodes were enlarged, t =
38.0 C.
Hemoglobin 91 g / 1 ↓
Erythrocytes 5.4 x 10^{12} /
l ↓Leukocytes 33.6 x
10^9 / 1 ↑

  basophils 0%
  eosinophils
  2%
  neutrophils:
    myelocytes 2% ↑
    metamyelocytes 1% ↑
    stab 1%
    segmented 40%
lymphocytes 53% ↑
monocytes 1%
    Platelets 210 x 10^9 / 1
    Reticulocytes 2.7%
Question: What are the possible causes ofhematological changes and the diagnosis?

Hemogram number 9

Kitten at the age of 1 month emaciated, the belly is enlarged, the coat is ruffled, dull, the appetite is perverted, the mucous membranesare pale.

Hemoglobin 76 g / 1 ↓↓↓
Erythrocytes 6.0 x 10^{12} / 1 ↓
Color indicator 0.5 units. ↓
Leukocytes 18 x 10^9 / 1
    basophils 0%
    eosinophils 10% ↑
    neutrophils:
        myelocytes 0%
        stab 3%
        segmented 40%
lymphocytes 44%
monocytes 3%
      Platelets 100 x 10^9 / 1
      Reticulocytes 0.4%
In a smear: hypochoma erythrocytes, poikilocytosis, anulocytes.
Question: What is the presumptive diagnosis?

Hemogram number 10

The dog showed clinical signs of leptospirosis 10 days after contact with a rat. There is jaundice, yellowness of the mucous membranes,inflammation of the conjunctiva, itching, vomiting mixed with blood, t = 40.0 C. Urine is dark yellow with a reddish tint.

Hemoglobin 89 g / 1
↓ Erythrocytes 4.5 x 10^{12} / 1 ↓Leukocytes
10 x 10^9 / 1
    basophils 0.5%
    eosinophils 3.0%
      myelocytes 0%
      stab 2%
      segmented 68.5%
lymphocytes 25%
monocytes 1%
      Platelets 320 x 10^9 / 1
      Reticulocytes 1.9%
In a smear: poikilocytes, schizocytes.
Question: name the reasons for the changes inhematological parameters.

Hemogram number 11

After prolonged use of antibiotics, the stallion (age 2.5 years) has general weakness, physical inactivity, indigestion in the form of frequent intestinal colic, and also reduced body weight, mucous membranes are anemic.

Hemoglobin 69 g / 1 ↓
Erythrocytes 5.5 x 10^{12} / 1 ↓
Color index 0.5 units ↓
Leukocytes 10 x 10^9 / 1
    basophils 0%
    eosinophils 2%
    neutrophils:
        myelocytes 0%
        stab 4%
        segmented 52%
    lymphocytes 39%
monocytes 3%
      Platelets 250 x 10^9 / 1
      Reticulocytes 0.7%
In a smear: anisocytosis, macrocytes, poikilocytosis, schizocytosis, erythrocytes with a nucleus are found.
Question: Name the possible causes of hematological changes and the presumptive diagnosis.

Hemogram number 12

A dog was admitted to the clinic at the age of 10years, within 6 months. exacerbation of enterocolitis is periodically observed. During anexacerbation - diarrhea with mucus and blood. At the time of examination: the abdomen is tense, painful, mucous membranes are pale.

Hemoglobin 87 g / 1
Erythrocytes 3.9 x 10^{12} / 1 ↓
Color index 0.6 units. ↓
Leukocytes 11.5 x 10^9 / 1 ↑
    basophils 0%
    eosinophils 3%
    neutrophils:
        myelocytes 0%
        stab 8% ↑
        segmented 58%
lymphocytes 30%
monocytes 1%
      Platelets 655 x 10^9 / 1
      Reticulocytes 2.6% ↑
In a smear: normocytes, poikilocytosis, minormicrocytosis.
Question: name the changes in the hemogram.What pathology are they typical for?

Reference materials: information for solving situational tasks on the topic Pathophysiology of the blood system

The number of erythrocytes and leukocytes in the blood of healthy animals

Animals	Erythrocytes (million/μL)	Leukocytes (thousands/μl)
Cattle	5,0-7,5	4,5-12,0
Sheep	7,0-12,0	6,0-14,0
Goats	12,0-17,0	6,0-12,0
pigs	6,0-7,5	8,0-16,0
Horses	6,0-9,0	7,0-12,0
Chickens	3,0-4,0	20,0-40,0
Dogs	5,8-8,4	8,5-10,5
Cats	6,6-9,4	10,0-15,0

AMOUNT OF HEMOGLOBIN IN THE BLOOD OF ANIMALS

Species of animals	HEMOGLOBIN		Species of animals	HEMOGLOBIN	
	g/100 ml	g/l		g/100 ml	g/l
cattle	9,9—12,9	99—129	foxes	12,0—17,0	120—170
Sheep	9,0—13,3	90—133	Mink	15,0-17,5	150—175
goats	10,0—15,0	100—150	Sable	13,0—16,0	130—160
camels	13,0—14,5	130—145	Martens	12,2—19,5	122—195
reindeer	11,0—14,0	110—140	rabbits	10,5—12,5	105—125
buffaloes	4,7—11,7	47—117	Guinea pigs	12,0—16,0	120—160
Yaks	6,0—13,0	60—130	Rats are white	13,0—19,0	130—190
Moose	14,0—18.0	140—180	Mice white	14,0—18,0	140—180
Marals	12,1—17,7	121—177	Hamsters gold	11,0—15,6	110—156
Horses	8,0—14,0	80—140	hedgehogs	12,0—14,0	120—140
donkeys	14,0-16,0	140—160	chickens	8,0—12,0	80—120
Mules	14,0—17,0	140—170	geese	9,0—13,5	90—135
Pigs	9,0—11,0	90—110	ducks	10,0—12,5	100—125
Dogs	11,0—17,0	110—170	pigeons	10,0—17,0	100—170
cats	10,0—14,0	100—140	Turkeys	7,0—11,0	70—110
Foxes gray-black	12,0—16,0	120—160	Guinea fowl	8,0—12,0	80—120
			frogs	6,5-8,5	65—85

The number of erythrocytes, leukocytes and plateletsin the blood of animals

Species of animals	Erythrocytes mln/µl; 10^{12}/L	Leukocytes thousand/µl; 10^9/L	platelets thousand/µl; 10^9/L
Cattle	5,0—7,5	4,5—12,0	260,0-700,0
Sheep	7,0—12,0	6,0—14,0	270,0—500,0
goats	12,0-18,0	8,0—17,0	300,0—900,0
camels	9,5—12,0	6,0—10,0	200,0—400,0
reindeer	6,5—8,5	5,0—7,0	200,0—500,0
buffaloes	5,3—7,1	5,5—19,6	220,0—380,0
Yaks	5,3—10,3	7,4-11,2	
Moose	6,5-8,5	7,5—9,5	250,0—450,0
Marals	5,6—13,0	3,8—13,1	-
Horses	6,0—9,0 ,	7,0—12,0	200,0—500,0
donkeys	5,0—7,0	7,0—9,0	200,0—500,0
Mules	5,5-7,5	7,0— 8,0	200,0—400,0
Pigs	6,0—7,5	8,0—16,0	180,0—300,0
Dogs	5,2— 8,4	8,5—10,5	250,0—550,0
cats	6,6—9,4	10,0—20,0	100,0—500,0
Silver-black foxes	5,2—13,6	2,0—15,2	250,0—450,0
Mink	7,7—13,1	2,5—10,5	190,0—380,0
foxes	4,9—11,4	3,5—14,0	215,0—525,0
Sable	9,0—13,6	4,0—10,0	150,0—400,0
Martens	9,2—14,3	5,0—8,5	
rabbits	4,5—7,5	6,5—9,5	125,0—250,0
Guinea pigs	4,5—6,0	7,0-13,0	80,0—160,0
Rats are white	5,5—11,0	8,0-23,0	200,0—600,0
Mice white	8,0—11,0	6,0—13,0	200,0—400,0
Hamsters are golden	2,8—8,5	3,9-7,9	
hedgehog	9,0—12,0 .	5,0—10,0	50,0—200
chickens	3,0—4,0	20,0—40,0	32,0-100,0
Geese -	2,5—3,5	20,0—30,0	35,0—80,0
ducks	3,0—4,5	20,0—40,0	35,0—80,0
pigeons	3,0—4,0	10,0—30,0	10,0—35,0
Turkeys	2,5—3,5	20,0—40,0	30,0—70,0
Guinea fowl	3,0—4,2	20,0—40,0	50,0—90,0
frogs	0,3—0,4	2,0—20,0	100,0—300,0

Animal blood leukogram, leukoformula, %

Species of animals	Basophil	Eosino-phil	Neutrophils				lymphocyte	Mono-cyte
			myelocyte	immature, young	banded	segmented		
cattle	0—2	5—8	0	0—1	2—5	20-35	40-65	2-7
Sheep	0—1	4—12	0	0—2	3—6	35-45	40-50	2-5
goats	0—1	3—12	0	0	1—5	29-38	47-64	2-4
camels	0-1	4—12	0	0—2	1-6	40-52	29-45	1-5
reindeer	0-1	3—7	0	0—1	2—5	55-66	21-37	1-4
buffaloes	0-2	3—10	0	0	1—6	24-46	45-66	2-5
Yaks	0—2	2—3	0	0—1	2—8	20-43	40-76	2-9
Moose	0—1	2—9	0	0	2—6	48-58	28-42	1-5
Marals	0—2	2—28	0	0—4	1-9	23-56	24-68	0-3
Horses	0—1	2—6	0	0—1	3—6	45-62	25-44	2-4
donkeys	0—1	2—4	0	0	2—6	50-80	18-38	1-3
Mules	0—1	2—7	0	0	1—4	50-65	26-38	1-5
Pigs	0-1	1—4	0	0—2	2—4	40-48	40-50	2-6
Dogs	0-2	3—9	0	0	1—6	43-71	21-40	1-5
cats	0—1	2—8	0	0—1	3—9	40-45	36-51	1-5
Foxes gray-black	0—1	3—20	0	0-1	3—10	20-50	22-60	2-4
foxes	0—1	1—9	0	0—2	1—25	29-54	25-78	1-8
Mink	0—1	2—8	0	0—1	5-10	45-65	26-45	2-4
Sable	0—2	3—13	0	0—2	2—8	15-35	40-75	2-5
rabbits	0—2	1—3	0	0	5-9*	33-	43-62	1-3
Guinea pigs	0—2	4—12	0	0	1—5	30-45	36-54	3-8
Rats are white	0-1	1—5	0	0	1—4	20-35	55-75	1-5
Mice white	0—2	0—4	0	0	1—5	18-30	60-78	2-5
Gold. hamsters	0-1	0—1	0	0	3—10	22-32	58-72	1-2
hedgehogs	1—5	2—7	0	0	2—4	15-30	57-80	0-3
chickens	1—3	6-10	—	—	—	24-	52-60	4-10
geese	1—4	3—9	—	—	—	30-	40-	2-6
ducks	0—5	4—12	—	—	—	30-	42-59	2-7
Turkeys	0—3	0—3	—	—	—	30-	49-60	4-8
pigeons	1—5	2—8	—	—	—	28-	38-54	1-5
Guinea fowl.	0—3	6—10	—	—	—	30-	45-	2-6
frogs	10-20	3—10	0	0	2—4	20-30	40-60	1-3

* Pseudo-eosinophils (special granulocytes)

Answers

Hemogram number 1
Question: indicate - are there pathological changes in the puppy's peripheral blood?
Answer: indicators are within normal limits.

Hemogram number 2
Question: indicate - under the influence of which of the specified hormones is the activation of erythropoiesis observed?
Answer: under the influence of androgens.

Hemogram number 3
Question: Are the results obtained typical for acute blood loss?
Answer: post-hemorrhagic anemia.

Hemogram number 4
Question: Determine the changes in the hemogram.
Answer: hypoplastic anemia.

Hemogram number 5
Question: Describe the existing changes in hematological parameters. Which of them indicate the inclusion of compensatory mechanisms on the part of hematopoiesis?
Answer: post-hemorrhagic anemia.

Hemogram number 6
Question: name the pathological changes in the blood, determine the diagnosis.
Answer: hemoblastosis.

Hemogram number 7
Question: what caused the changes in hematological parameters? What is the presumptive diagnosis?
Answer: post-hemorrhagic anemia.

Hemogram number 8
Question: What are the possible causes of hematological changes and the diagnosis?
Answer: hemoblastosis.

Hemogram number 11
Question: Name the possible causes of hematological changes and the presumptive diagnosis.
Answer: hypoplastic anemia, hypovitaminosis B_{12}.

Hemogram number 12
Answer: posthemorrhagic and hypoplastic anemia.

Part 2. Lab practical information: RBC analysis by modern methods using the hematology analyzer.

Laser-based hematologic analyzers allow RBC
to pass through in single file througha
flow cell containing a laser.

The most important signs of red blood cells:
- **RBC:**The red blood cells number in the peripheral blood,
- **PCV:** hematocrit
- **Hb:** hemoglobin concentration.
- **MCV:** average volume of the red blood cell
- **MCH:** average hemoglobin mass in each red blood cell,
- **MCS:** average hemoglobin concentration in each erythrocyte.

Automated Hemograms and Panels

The hematology analyzer used in the Clinical hematology can perform an automated hemogram in dogs, cats, horses, cattle, sheep, goats, pigs, certain species of monkeys, rats and mice. We recommend this test primarily for researchsamples.

Automated hemogram

This provides the following parameters:
- Total leukocyte count

Differential leukocyte count (absolute values):

This includes neutrophils, lymphocytes, monocytes, eosinophils, basophils andlarge unstained cells (LUC). Large unstained cells are either large or reactive lymphocytes, monocytes or leukemic blasts. In most animals, they are large lymphocytes or monocytes.

- Red cell parameters:
  RBC count, Hgb concentration, HCT, red cell indices (MCV, MCH, MCHC andRDW).

- Platelet parameters:
  Platelet count and MPV. A platelet count will only be provided if the Advia provides a relatively accurate count. If the Advia detects platelet clumps, thiswill be flagged on the report.

A blood smear examination, plasma appearance and total protein (by refractometer) assessment is not performed with an auomated CBC.

Furthermore, a reticulocyte count is not automatically added to samples

from dogs (HCT < 39%) and cats (HCT < 25%). The total leukocyte count (and absolute differential cell counts) are not corrected for nucleated red blood cells, as these are not individually quantified by the analyzer. Therefore, the automated hemogram does not providethe following information:

- Assessment of red cell morphology
- Assessment of white cell morphology:
  This includes details such as toxic change. The analyzer cannot quantify a left shift(bands are included in the total neutrophil count).
- Evaluation for erythroparasites or other infectious agents (e.g. Ehrlichia).

Doctors select tests that will help diagnose blood disorders based on symptoms and physical examination results. Sometimes a blood disease does not cause symptoms, but is detected during a laboratory test for another reason. For example, a complete blood count that is performed as part of a routine examination may reveal a low level of red blood cells (anemia). If a blood disorder is suspected, a complete blood count and other tests may be needed to make a specific diagnosis.

The example of analyzing the result of a dog's blood (using a hem analyzer)
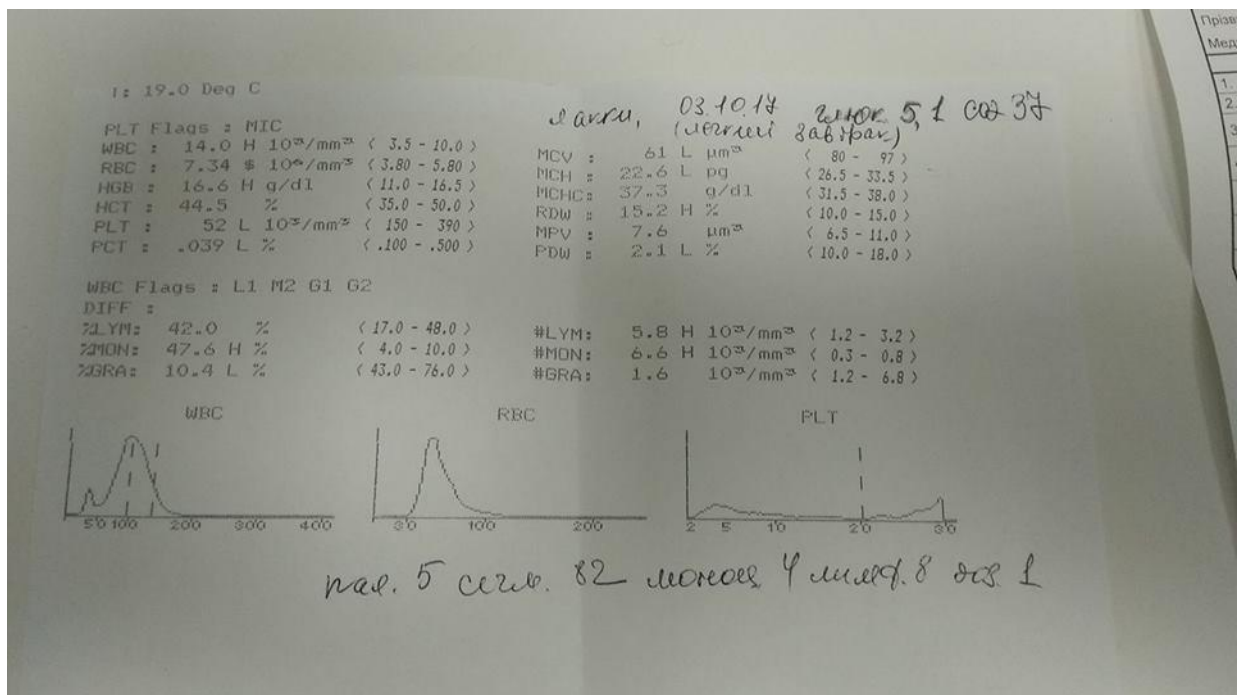
Part 3. Lab practical information: Complete blood count - CBC

Complete blood count - CBC

The blood test most commonly done is the complete blood count (CBC). The CBC is an evaluation of all the cellular components (red blood cells, white bloodcells, and platelets) in the blood. Automated machines do this test in less than 1 minute on a small amount of blood. The CBC is supplemented in some instancesby examination of blood cells under a microscope (blood smear).

Red blood cell parameters evaluated by **CBC** include
- Number of red blood cells (red blood cell count, RBCs)

- Proportion of blood made up of red blood cells (hematocrit, Hct)

- Amount of hemoglobin (the oxygen-carrying protein in red bloodcells) in the blood (hemoglobin, Hb)

- Average size of red blood cells (mean cellular volume, MCV)

- Variability of size of red blood cells (red cell distribution width,RDW)

- Amount of hemoglobin in an individual red blood cell (mean cellularhemoglobin, MCH)

- Concentration of hemoglobin in an individual red blood cell (meancellular hemoglobin concentration, MCHC)

Abnormalities in these parameters can alert laboratory workers to the presence of abnormalities in the red blood cells (which may then be further evaluated by examination under a microscope).

Abnormal red blood cells may be fragmented or shaped like teardrops, crescents (sickle-shaped), or a variety of other forms. Knowing the specific shape and size of red blood cells can help a doctor diagnose a particular cause of anemia. For example, sickle-shaped cells are characteristic of sickle cell disease, small cells containing insufficient amounts of hemoglobin are likely due to iron deficiency anemia, and large cells suggest anemia due to a deficiency of folate (the vitamin folic acid) or a deficiency of vitamin B12.

White blood cell parameters evaluated by the CBC include the
- Total number of white blood cells
- Percentages and numbers of the different types of white blood cells

Hematology refers

Blood Sample Preparation and Evaluation:

In hematologic investigations, with a minimum of specialist equipment, can provide almost as much information as a full laboratory analysis, although some estimations are qualitative rather than quantitative.

Blood for hematology should be collected into tubes containing EDTA anticoagulant and immediately mixed well to avoid clotting. Larger (2.5 mL) tubes yield better results than the smaller (1 mL) pediatric tubes and are less likely to clot. Nevertheless, it is essential to fill the tube exactly to the mark, so smaller tubes may be unavoidable for small patients. WBC morphology deteriorates most quickly, especially in equine blood, so if the sample cannot be analyzed immediately, a thin blood smear should be submitted to the laboratory with the blood sample.

PCV is measured by microhematocrit, which is the reference method. A capillary tube is filled ¾ full with well-mixed blood and sealed at one end; heat-sealing is best if a Bunsen burner is available, otherwise a proprietary clay pad is used. The tube is spun in a high-speed microhematocrit centrifuge for 6 min, and the PCV isread using a microhematocrit reader with a sliding cursor. The appearance of the plasma (eg, normal, icteric, hemolyzed, lipemic) and the thickness of the buffy coat, which gives a very rough guide to total WBC count, should be noted.

Further information is obtained from a blood film, smears. This is made by using one slide, with a corner broken off as a spreader, to pull a small drop of blood across a clean slide into a thin film. A suitable film is thin (one erythrocyte thick) and tapers to a feathered edge before the far end of the slide. The broken corner of thespreader slide ensures two straight edges parallel to the long edges of the slide.

Immediately after applying the film, it is quickly dried by blowing the glass with air. Air-dried smears can be sent to the laboratory on glass slides or stained and examined in practice. Industrial rapid Romanovsky-type staining requires only immersing the glass slide in three color solutions in a row. Cell morphology is clear and comparable to more persistent stains such as Leishman or May-Grunwald-Giemsa, although the quality deteriorates after several days. Dry the glass slide naturally or dry it with a hair dryer (without wiping it dry) and examine it in oil.

Clinically useful information can be easily obtained for all hematological variables. The main drawback is the absence of a numerical count of leukocytes, and therefore, numerical values of a differential count of leukocytes. This may

be acceptable for an interim emergency examination, and a hemocytometer slide may be attempted to determine the white blood cell count. A mirror slide with an improved Neubauer ruler can be used with a coverslip mounted so that Newton's rings are visible from both sides. The blood sample is diluted 1:20 with Turk's fluid or a similar solvent. To ensure accurate dilution, an automatic pipette capable of dispensing 0.95 mL and 0.05 mL (50 µL) should be used. The sample should be mixed well and left for 10 minutes until the stain is absorbed by the cells. Then the hemocytometer chamber is filled with a capillary (PCV) tube. The number of cells in each of the four large corner squares of the grid is counted, and the total is divided by 20 to calculate the total WBC count $\times$ 10 9/L. Several hematology tools are available for use in practice. Those based on centrifugation, in which the measurement of leukocytes is carried out by dispersing the dye buffy coat, are not real hematological analyzers, but give approximate indicators. Although a numerical estimate of the total white blood cell count is provided, the differential white blood cell count cannot distinguish between lymphocytes and monocytes, and the results do not always correlate well with standard methods. This method is suitable only in emergency cases, and it is always necessary to additionally examine the blood film. It is also advisable to check the PCV with a microhematocrit. Impedance counters (Coulter principle) are used by diagnostic laboratories and perform well in experienced hands. However, it is difficult to achieve optimal performance without trained technical staff. Instruments not based on the Coulter principle should be avoided for veterinary use, because their results do not necessarily compare well on nonhuman samples. Instruments providing automated differential counts perform poorly on nonhuman blood, and results must never be accepted without also checking a blood film. No hematology laboratory should be without the facility for examining blood films, and a blood film should be examined for every patient sample. Quality assurance issues are the same as those for biochemistry laboratories. If accuracy and reliability cannot be guaranteed to the same standard as the referral laboratory, then results should not be relied on without external confirmation.

Red Blood Cells:

The size, uniformity of size, and presence of microcytes, macrocytes, and abnormally shaped cells should be noted, along with cell color, uniformity of color, and the presence of hypochromasia, polychromasia, and nucleated RBCs. An overall descriptive assessment of the RBC picture should be made, including the degree of regeneration or hypochromasia, if any.

White Blood Cells:

A qualitative estimate of numbers should be made (very low, low, normal, high, very high). This can be remarkably consistent with practice. The

proportions of each cell type can be estimated, or preferably, a formal differential count of 100–200 cells performed. Unusual or abnormal WBC forms (band or toxic neutrophils), or pathologic cells (prolymphocytes, lymphoblasts, or mast cells) should be noted.

Platelets:

A qualitative estimate of platelet numbers, based on how many can be seen in a typical high-power field (oil immersion) should be made. Several fields should be examined, more if numbers appear low. Results can be ranked as none seen (on entire slide), rare (very few on entire slide), low in number (< 5 per high-power field), adequate (5–20 per high-power field), or abundant (>20 per high-power field). Normal platelet numbers in the horse are about half those of other species. In a sample more than a few hours old, platelets may clump into rafts, leaving areas of the slide apparently devoid of platelets. Slides should be scanned for rafts before reporting platelet numbers as low. Enlarged or macroplatelets should also be noted.

Blood smear, film.

Although automated machines can quickly count the number of different blood cells and provide information about the size and shape of red blood cells and types of white blood cells, examining a blood sample under a microscope can provide additional information.

To do this, a drop of blood is smeared on a glass slide, forming a thin layer that allows you to easily see individual blood cells.

The slide is then stained with colored chemicals to reveal specific characteristics of the blood cells and examined under a microscope. An experienced expert can often obtain better information about cell number, size and shape, and specific cell characteristics than a machine.

Reticulocyte count

The reticulocyte count determines the number of newly formed (young) erythrocytes (reticulocytes) in a certain volume of blood. Reticulocytes normally make up approximately 0.5-2.5% of the total number of erythrocytes. When the body needs more red blood cells, such as after blood loss, the bone marrow usually responds by producing more reticulocytes. Thus, the number of reticulocytes is an indicator of the bone marrow's ability to produce new red blood cells.

Red Blood Cells measurements:

Three RBC measurements are routinely done: packed cell volume (PCV), the proportion of whole blood volume occupied by RBCs; hemoglobin (Hgb) concentration of whole lysed blood; and RBC count, the number of RBCs per unit volume of whole blood. Although these are separate estimations, they are in effect three ways to measure the same thing, and it is incorrect to attempt to interpret them as separate variables. Inasmuch as they do vary in relation to each other, they allow calculation of two further meaningful parameters, mean corpuscular volume (MCV) and mean corpuscular hemoglobin concentration (MCHC).

$$MCV\ (fL) = \frac{PCV(decimal\ fraction) \times 1,000}{RBC(\times 10^{12}/L)}$$

$$MCHC\ (g/L) = \frac{Whole\ blood\ hemoglobin\ concentration\ (g/L)}{PCV\ (decimal\ fraction)}$$

MCV varies widely between mammalian species, from ~15 fL in goats to ~90 fL in people. Avian and reptilian red cells are even larger, up to 300 fL. Nevertheless, MCHC varies little with species (or erythrocyte size), at ~330 g/L.

Several artifacts can cause significant and potentially misleading alterations to measured RBC parameters: 1) old samples cause RBCs to swell, thus increasing PCV and MCV and decreasing MCHC; 2) lipemia causes a falsely high Hgb reading, and hence a falsely high MCHC; 3) hemolysis causes PCV to decrease while Hgb remains unchanged, again leading to a falsely high MCHC; 4) underfilling of the tube causes RBCs to shrink, causing PCV and MCV to decrease and MCHC to increase; 5) autoagglutination causes a falsely low RBC count, and hence a falsely high MCV.

Visual description of RBC morphology on a Romanowsky stain also provides useful diagnostic information.

The most common terms include 1) normocytic — cells are of normal size; 2) macrocytes — abnormally large cells, usually polychromatophilic; 3) microcytes — abnormally small cells, usually caused by a lack of hemoglobin precursors; 4) anisocytosis — variation in size of cells due to macrocytes, microcytes, or both; 5) normochromic — cells are of normal color; 6) polychromasia — variation in color of the cells, which usually describes the appearance of large, juvenile, bluish-staining polychromatophilic macrocytes (these broadly correspond to the "reticulocyte" seen with new methylene blue staining, in which the reticulum represents the remnants of the nucleus); 7)

hypochromasia — decrease in staining density of the cells, usually due to a lack of hemoglobin precursors, especially iron; and 8) annulocyte — extreme form ofhypochromic cell with only a thin rim of hemoglobin.

PCV is the variable usually used to assess the basic status of the erythron — increased in polycythemia, decreased in anemia—although if a sample is too hemolyzed to allow measurement of PCV, a meaningful Hgb measurement maystill be obtained. RBC count as such should not be interpreted clinically.

An abnormally high PCV (polycythemia) may be relative, due to a change in the proportion of circulating RBCs to blood plasma without any change in the size of the erythron, or absolute, due to a real increase in erythron size. Absolute polycythemia may be primary (eg, polycythemia vera or, rarely, erythropoietin- producing tumors) or secondary (a consequence of disease in another organ system).

Polycythemia vera and erythropoietin-producing tumors should be suspected only when PCV is very high, normally >0.7. The former is characterized by normal, mature RBCs and a normal (or low) erythropoietin concentration, whereas the latter may show a regenerative RBC picture with high erythropoietin concentration. Relative polycythemia may also be associated with very high PCV values, and normal, mature RBCs. Secondary polycythemia generally shows a more modest increase in PCV, often with evidence of regeneration (more so whenthe cause is pulmonary or cardiac, less so when the cause is hormonal). It is often possible to make the differential diagnosis of polycythemia on clinical grounds.

Abnormally low PCV (anemia) may be caused by loss of blood (hemorrhage), breakdown of RBCs in circulation (hemolysis), or lack of production of RBCs bythe bone marrow (hypoplasia or aplasia). Presentation varies according to whether the condition is acute or chronic. Aplastic anemia is always chronic in onset, because anemia occurs gradually as existing cells reach the end of their lifespan.

In acute hemorrhagic anemia, external blood loss is easily appreciated clinically, but blood loss into a body cavity may be determined only on paracentesis.

Initially, all hematologic parameters may be normal, because it may take 12 hr for fluid shifts to produce a decrease in the PCV. Within a few days, RBCs become regenerative, with juvenile forms appearing in circulation (except in horses, in which circulating evidence of regeneration is not readily appreciable). These consist of polychromatophilic macrocytes and normoblasts

(nucleated RBCs). Late normoblasts have a small, nonviable nucleus and a moderate amount of cytoplasm colored similarly to that of the polychromatophilic macrocytes, whereas early normoblasts have a larger, viable nucleus and scanty cytoplasm.

These are most easily distinguished from lymphocytes by their more denselystaining nucleus.

If substantial amounts of blood have been lost from the body, the RBC picture may become hypochromic. This type of anemia shows an increase in MCV and a decrease in MCHC. If bleeding is into a body cavity, hypochromasia may not be evident because hemoglobin precursors will be recycled. However, slight jaundice may be seen as the sequestered cells are broken down. Some sequestered cells may also be returned to the circulation intact, if somewhat misshapen.

In acute hemolytic anemia, PCV will decrease immediately, and in the early stages some jaundice will be evident. In the very early stages, even a sample collected with extreme care may be markedly hemolyzed. As with hemorrhagic anemia, the RBCs will become regenerative within a few days, with polychromatophilic macrocytes and nucleated RBCs evident. Because hemoglobin precursors are not lost from the body, true hypochromasia is not seen.

Chronic hemorrhagic anemia may be difficult to appreciate if blood is lost in the feces or urine, or due to bloodsucking ectoparasites. Anemia may be severe, and the RBC picture will be regenerative on presentation. Hypochromasia is usually very marked. In very longstanding conditions, depletion of iron and other hemoglobin precursors can become so marked that most of the cells are microcytic, and MCV may paradoxically decrease. Intermittent intra-abdominal hemorrhage leads to a somewhat different picture, because blood shed into the peritoneal cavity can be returned to the circulation. PCV may therefore recover quickly (until the next episode), and signs of depletion of hemoglobin constituents do not emerge.

In chronic hemolytic anemia, RBCs are regenerative on presentation, except that some cases of autoimmune hemolytic anemia (AIHA) paradoxically show little orno regeneration until treatment has been initiated. Hypochromasia is less marked than in hemorrhagic conditions, and misshapen RBCs (including target cells and folded cells) are more common. The spherocyte, in which the erythrocyte loses itsclassic biconcave shape, is essentially pathognomonic for AIHA. Jaundice may be absent, because the products of the destruction of the RBCs may be cleared by the reticuloendothelial system and the liver as quickly

as they are formed.

Hypoplastic and aplastic anemia may be mild if RBC production is merely depressed secondary to some other disease. Protein, mineral, or vitamin deficiencies may cause hypoplastic anemia, but these are more likely to be secondary to another disease (eg, chronic hemorrhage or malabsorption) than simple dietary deficiency. Other diseases may cause depression of erythropoietin production, eg, renal failure, deficiencies of hormones that usually stimulate erythropoietin production (eg, hypothyroidism, hyperadrenocorticism), and chronic, debilitating conditions (eg, chronic infections, chronic parasitism, and neoplasia). RBC morphology is nonregenerative and may be hypochromic if a deficiency state is involved. Paradoxically, vitamin B_{12} and/or folic acid deficiency produces a macrocytic RBC picture due to early maturation arrest of the erythrocytes. Neoplasia of the bone marrow may cause severe anemia as erythropoietic elements are crowded out, but some regeneration may be seen as the remaining bone marrow attempts to compensate. In this case, other bone marrow cell lines will also be affected.

True aplastic anemia refers to a failure of the entire bone marrow. The shorter-lived granulocytes and platelets decrease first, followed by a progressively severeanemia that is normocytic and normochromic.

White Blood Cells:

The WBCs consist of the granulocytes (neutrophils in most mammals, called heterophils in rabbits, reptiles, and birds [and these look like eosinophils in smears]; eosinophils; and basophils) and the agranulocytes (lymphocytes and monocytes). Although each type is traditionally counted by determination of its percentage of the total WBC population, meaningful interpretation requires that the absolute number of each type be calculated by multiplying the total WBC count by the fraction attributable to the individual cell type. Percentages of each cell type alone are not helpful. An increased percentage that is due to an absolutedecrease in another cell type is not an increase at all.

Mature **neutrophils** have a lobulated nucleus, but when demand is high, immature cells with an unlobulated band nucleus (no constriction of the nucleus is more than half the width of the nucleus) may be released into circulation. They function as phagocytes and are important in infectious conditions and in inflammation. Increased neutrophil counts (neutrophilia) are caused by inflammation, bacterial infection, acute stress, steroid effects, and neoplasia of the granulocytic cell line (granulocytic leukemia can be difficult to differentiate from a simple neutrophilia without special stains or bone marrow biopsy).

Decreased neutrophil counts (neutropenia) are caused by viral infections, toxinexposure (including foodborne toxins), certain drugs (eg, carbimazole and methimazole), autoimmune destruction of neutrophils, bone marrow neoplasia not involving the granulocytes, and bone marrow aplasia.

Eosinophils are characterized by prominent pink-staining granules on a Romanowsky stain. They inactivate histamine and inhibit edema formation. Increased eosinophil counts (eosinophilia) are caused by allergic/hypersensitivity reactions, parasitism, tissue injury, mast cell tumors, estrus, and pregnancy or parturition in the bitch. Some large dog breeds (eg, German and Belgian Shepherds, Rottweilers) normally have a relatively high eosinophil count.

Extremely high eosinophil counts (hypereosinophilic syndrome), possibly due to an out-of-control hypersensitivity reaction, and eosinophil leukemia (a form of chronic myeloid leukemia) are also described. Decreased eosinophil count (eosinopenia) is almost always caused by the action of glucocorticoids, either endogenous or therapeutic.

Basophils are rare in most species and are characterized by blue-staining granules on a Romanowsky stain. They are more easily seen in cattle. They are closely related to mast cells and, like them, initiate the inflammatory response by releasing histamine. An increased basophil count (basophilia) accompanies eosinophilia in some species as part of the hypersensitivity reaction.

Monocytes are large cells with blue-gray cytoplasm, which may be vacuolated, and a kidney bean-shaped or lobulated nucleus. Their main function is phagocytosis, and they are essentially identical to tissue macrophages. An increased monocyte count (monocytosis) may occur in any chronic disease, especially chronic inflammation, and may be very marked in neoplasia. Monocytes also increase as part of the steroid response in dogs.

Lymphocytes mainly develop outside the bone marrow in the lymph nodes, spleen, and gut-associated lymphoid tissue. They are the smallest of the WBCs, with a round, evenly staining nucleus and sparse cytoplasm. Larger, reactive lymphocytes can be seen after antigenic stimulation, and care must be taken to differentiate them from neoplastic lymphocytes. Their primary function is immunologic, including both antibody production and cell-mediated immune responses. Some survive only a few days, but many are long-lived. The number in circulation is a balance between populations in the blood, lymph, lymph nodes, and splenic follicles and does not necessarily reflect changes in lymphopoiesis.

An increased lymphocyte count (lymphocytosis) may occur for

physiologic reasons, especially in cats, but significant increases usually indicate leukemia. Immature or bizarre cells may also be recognized. Decreased lymphocyte counts (lymphopenia) are usually due to an effect of corticosteroids, either endogenous (stress or Cushing disease) or therapeutic, and may also accompany neutropenia in some viral infections, especially the parvoviruses. Lymphopenia may also be a feature of solid-organ lymphosarcomas, when leukemia is absent.

Platelets:

Mammalian platelets are pale blue granular fragments (much smaller than RBCs) shed from multinucleate megakaryocytes in the bone marrow; avian and reptilian platelets are true cells with nuclei. They maintain the integrity of the endothelium and act as part of the clotting process to repair damaged endothelium, where they ensure mechanical strength of the clot.

Increased platelet counts (thrombocytosis) occur as a reaction to consumption after injury, when large juvenile platelets may also appear; after splenectomy, as splenic stores are liberated to the circulation; after vincristine treatment, which increases platelet shedding from megakaryocytes; and in megakaryocytic leukemia.

Decreased platelet counts (thrombocytopenia) are caused by autoimmune reactions, thrombotic/thrombocytopenic purpura, bone marrow suppression and aplasia, bone marrow neoplasia, and equine infectious anemia. Signs are petechiation and ecchymosis more than frank hemorrhage, and little may be seen until the platelet count is $< 20 \times 10^9$/L. Platelet functional abnormalities present similarly, but platelet numbers and morphology are normal.

This information materials (for Part 3.) is obtained from official open online sources:

- [https://www.msdvetmanual.com/clinical-pathology-and-procedures/diagnostic-procedures-for-the-private-practice-laboratory/clinical-hematology?query=hematology%20analyzers];
- [https://www.merckmanuals.com/home/blood-disorders/symptoms-and- diagnosis-of-blood-disorders/laboratory-tests-for-blood-disorders]

Part 4. Routine Hemogram Reference Intervals

These reference intervals were established using Hematology Analyzer.

Test	Units	Canine	Feline	Equine	Bovine	Alpaca
Red Blood Cells						
HCT*	%	41 - 58	31 - 48	34 - 46	25 - 33	26 - 45
RBC*	x10^6/μL	5.7 - 8.5	6.9 - 10.1	6.6 - 9.7	5.0 - 7.2	10.6 - 18.4
Hgb*	g/dl	14.1 - 20.1	10.9 - 15.7	11.8 - 15.9	8.7 - 12.4	11 - 19.3
MCV*	fL	64 - 76	40 - 52	43 - 55	38 - 51	22 - 28
MCH*	pg	21 - 26	13 - 17	15 - 20	14 - 19	9 - 12
MCHC*	g/dL	33-36	32 - 35	34 - 37	34 - 38	42 - 49
RDW*	%	10.6 - 14.3	13.2 - 17.5	16.3 - 19.3	15.0 - 19.4	ND
NRBC	/100 WBC	0-1	0-1	0	0	0 - 3
Retic*	%	0.2 - 1.5	0.1 - 0.7	ND	ND	ND
Retic*	x 10^9/L	11 - 92	9-61	ND	ND	ND

The *asterixed values are obtained from the Advia. The remaining values are determined by bench methods, including the differential cell count (cells are counted in a peripheral blood smear), number of nucleated red blood cells/100 WBC, percentage and absolute reticulocyte counts (cats only).

White Blood Cells

WBC*	x10³/µL	5.7 - 14.2	5.1 - 16.2	5.2 - 10.1	5.9 - 14.0	7.1 - 18.6
Neuts	x10³/µL	2.7 - 9.4	2.3 - 11.6	2.7 - 6.6	1.8 - 7.2	3.5 - 11.7
Bands	x10³/µL	0 - 0.1	0 - 0.1	0	0	0
Lymphs	x10³/µL	0.9 - 4.7	0.9 - 6	1.2 - 4.9	1.7 - 7.5	1.1 - 5.5
Monos	x10³/µL	0.1 - 1.3	0 - 0.7	0 - 0.6	0 - 0.9	0 - 1.0
Eos	x10³/µL	0.1 - 2.1	0.1 - 1.8	0 - 1.2	0 - 1.3	0.1 - 4.3
Basos	x10³/µL	0 - 0.1	0 - 0.2	0 - 0.2	0 - 0.3	0 - 0.4

Platelets

PLT*	x10³/µL	186 - 545	195 - 624	94 - 232	252 - 724	220 - 817
MPV*	fL	8.4 - 14.1	9.1 - 24.3	5.3 - 8.4	5.7 - 8.0	4.4 - 6.9
TP-Ref.	g/dL	5.9 - 7.8	5.9 - 7.5	5.2 - 7.8	5.9 - 8.1	6.0 - 7.5

[https://www.vet.cornell.edu/animal-health-diagnostic-center/laboratories/clinical-pathology/reference-intervals/hematology]

Hematology Analyzer, Siemens ADVIA® 2120i

Hematology Bench (Manual) Percent Differential Reference Intervals

The PCV is directly measured from a microhematocrit centrifuge tube. The percentdifferential is determined by counting a minimum of 100 cells in stained peripheralblood smears.

Test	Units	Canine	Feline	Equine	Bovine	Alpaca
PCV	%	42 - 54	31 - 48	31 - 48	24 - 37	22 - 45

Test	Units	Canine	Feline	Equine	Bovine	Alpaca
Neuts	%	42 - 84	27 - 82	36 - 79	27 - 72	35 - 79
Bands	%	0 - 1	0 - 1	0	0	0
Lymphs	%	9 - 47	9 - 56	18 - 55	22- 64	10 - 47
Monos	%	2 - 12	0 - 6	0 - 7	0 - 10	0 - 8
Eos	%	1 - 18	1 - 15	0 - 16	0 - 12	1 - 29
Basos	%	0 - 1	0 - 2	0 - 3	0 - 3	0 - 3

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Recommended textbook and resaurses:

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2. Textbook of veterinary physiology. https://evolve.elsevier.com/Cunningham/physiology

3. Патологічна фізіологія / Березнякова А. І., Кузнєцова В.М., Філімонова Н.І. та ін. [підруч. для студ. вищ. фармац. навч. закл.].– Харків, видавництвоНФаУ, 2003.– 423 с.

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6. Clinical Hematology. By Trevor J. Whitbread. https://www.msdvetmanual.com/clinical-pathology-and-procedures/diagnostic- procedures-for-the-private-practice-laboratory/clinical- hematology?query=hematology%20analyzers

7. Laboratory Tests for Blood Disorders. https://www.merckmanuals.com/home/blood-disorders/symptoms-and-diagnosis-of-blood-disorders/laboratory-tests-for-blood-disorders

8. Routine Hemogram Reference Intervals. [https://www.vet.cornell.edu/animal-health-diagnostic-center/laboratories/clinical-pathology/reference-intervals/hematology]

9. Wingfield V.E. Secrets of emergency veterinary care. Part I, 2000

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11 http://www.pathophysiology.info/English/test_pdf_en.htm

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Навчальне видання

КОСТЮК І. О.

ЖУКОВА І. О.

КОЧЕВЕНКО О. С.

SITUATION TASKS: PATHOPHYSIOLOGY OF THE BLOOD SYSTEM
(to laboratory and practical classes on the pathological physiology)

СИТУАЦІЙНІ ЗАВДАННЯ: ПАТОФІЗІОЛОГІЯ СИСТЕМИ КРОВІ
(до лабораторно-практичних занять з патологічної фізіології)

Навчально-методичний посібник

(Англійською мовою)