Physiology practice

2024/2025

2nd semester

SZTE SZAOK

Physiology practice

Requirements

Attendance at the practice sessions is mandatory. Missing more than 3 sessions will result in the denial of the semester signature, and the student will not be allowed to take the exam. The practices will begin in the framework of in-person education, with maximum consideration of current epidemic regulations. Arriving more than 10 minutes late is considered an absence. In case of absence, there is an opportunity to make up ONE practice during the designated make-up week.

Except for the first and last teaching weeks, the two groups scheduled for one timetable slot will conduct the practice with alternating schedules and different themes. In even weeks, even-numbered groups, while in odd weeks, odd-numbered groups will perform experimental laboratory practices (6 laboratory practices). Simultaneously, members of the twin group will conduct online practice on the Coospace platform, with an online submission of the lab report (6 online practices).

During laboratory practices, students individually or in small working groups perform designated tasks under the guidance of the practice leader. Students are expected to prepare in advance for the practice material, the themes of which, along with the theoretical summary and lab report templates, can be found on the Institute's website. The practice leader may check the preparation at the beginning of the practice; in case of insufficient preparation, the student may be denied completion of the practice. Furthermore, the practice leader has the right to deny acceptance of the practice due to the student's unworthy behavior or disregard of instructions; in this case, the student is considered absent from the practice. To complete the practice and obtain attendance, the student must present a laboratory report confirming the completion of that week's practice, which the practice leader evaluates on a 3-level scale (unsatisfactory, satisfactory, well done). The condition for accepting the practice and confirming attendance is at least a "satisfactory" evaluation. When evaluating the lab report, the practice leader rewards the work of a student who received a "satisfactory" evaluation with 1 practical point, and the work of a student who received a "well done" evaluation with 2 practical points. Thus, a total of 12 practical exam points can be collected in the 6 laboratory practices, which count towards the result of the colloquium exam.

Acceptance of online practices is linked to the successful submission of the online lab report.

Units, prefixes:

Amount of substance:

mole (mol)	$6*10^{23}$
osmole (Osm)	$6*10^{23}$ based on osmotic effect
equivalent (Eq)	$6*10^{23}$ based on chemical reactivity

Volume:

liter (l)	cubic decimeter (dm^3)
milliliter (ml)	cubic centimeter (cm^3)
microliter (µl)	cubic millimeter (mm^3)

Pressure:

1 Bar	100 kPa	1019 cmH_2O	750 mmHg
1 Atm	101.3 kPa	1033 cmH_2O	760 mmHg

Prefixes:

tera	T	10^{12}
giga	G	10^{9}
mega	M	10^{6}
kilo	k	10^{3}
-	-	10^{0}
milli	m	10^{-3}
micro	µ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}
femto	f	10^{-15}

Urinalysis

This practical demonstrates the basics of urinalysis, based on physical, chemical, and microscopic aspects. Besides urine sample analysis, detailed information about the function of the excretory system can be obtained through examining blood composition and the glomerular and tubular functions of the kidney. The validity of results obtained during urine sample analysis depends fundamentally on proper urine sampling.

Urine Sample Collection

Sample collection can be performed via (1) spontaneous urination (mid-stream urine collection), (2) catheterization, (3) in infants, using a urine collection bag attached to the body surface above the external urinary tract, or (4) direct sampling from the bladder (suprapubic aspiration, providing an uncontaminated sample suitable for anaerobic pathogen culture).

Prerequisites for urine sample collection include proper hydration of the individual and disinfection of the external urogenital area (methods 1, 2, 3) or the sampling site (4). A clean collection container suitable for urine collection is also required.

Often, **random sampling** is sufficient, which can be done at any time of day and is suitable for both chemical and microscopic examination. However, for microbiological and routine urinalysis, a **contamination-free urine sample** is more appropriate: collection of 10 ml of fresh, mid-stream urine in a clean, dry container (morning first urine is most concentrated and most suitable for examination). If necessary, contamination-free urine samples can also be obtained through suprapubic aspiration. For protein or creatinine clearance studies, as well as for monitoring carbohydrate metabolism, **24-hour urine collection** may be necessary, collected in one or two parts (12-12 hour samples).

General Rules for Handling Urine Samples

Wearing gloves is always mandatory during urinalysis! Only room temperature urine samples should be examined. If the sample cannot be examined within 2 hours of collection, it must be immediately refrigerated. The sample can be stored at **2-8°C** for 24 hours. **Storage at room temperature for extended periods can give false results** because:

- Bacteria multiplying in urine break down glucose and promote the conversion of urea to ammonia, increasing urine pH, which leads to calcium and phosphate precipitation
- Urobilinogen oxidizes to urobilin, therefore it must be determined from fresh but cooled urine
- Red blood cells, white blood cells, and casts degrade, while
- Some urine constituents may crystallize

On the following pages, we discuss the theory of physical, chemical, and microscopic examination of urine separately.

Physical Examination of Urine

Urine samples have directly observable physical properties, thus simple visual inspection can provide useful information.

Volume

Physiologically typically **900-1500 ml/24 hours**, however, it is influenced by the quantity and quality of fluid intake (e.g., coffee, alcohol, etc. increase diuresis).

Decreased urine volume (<600 ml/24 hours) is **oliguria**, which can be caused by dehydration, decreased GFR. In extreme decrease (<100 ml/24 hours), we speak of **anuria**, which can be caused by circulatory shock and renal failure. Increased urine volume is called **polyuria** (>2500ml/24 hours), which can be caused by filtration of some osmotically active substance or minimal tubular water reabsorption.

Color

Urine is normally straw yellow in color. Food and medications can also cause urine discoloration, so it's important to know what foods and medications the patient consumed in the 36 hours preceding urine collection. Common colors and their possible causes are summarized in the following table:

	straw yellow	normal urine color induced by urobilinogen
	colorless	~dilute urine, may indicate high fluid intake, diabetes insipidus
	dark yellow	~concentrated urine, may indicate dehydration
	light brown	may indicate presence of bilirubin
	dark brown	may indicate presence of porphyrin or melanin
	red	may indicate presence of heme (hematuria or hemoglobinuria) but can also be caused by increased iron intake and certain foods (e.g., beetroot)
	greenish blue	may indicate *Pseudomonas* infection, or presence of certain anti-inflammatory drugs

It's important to note that red urine does not equal blood in urine. If the test strip (see later) doesn't indicate hemoglobin, and microscopic examination of the sediment doesn't suggest blood, the change is likely due to medication or food. Even with a positive test strip, there may be no RBCs in the sediment; in this case, myoglobin (in case of striated muscle injury) or hemoglobin excretion occurs (**hemoglobinuria**). Hemoglobin only appears in urine when the hemoglobin-binding protein is saturated, and tubular reabsorption reaches its transport maximum. If the urine test strip indicates hemoglobin and we also see RBCs (or RBC casts) in the sediment, it's called **hematuria**. The morphology of RBC forms can indicate the origin of the blood (lower urinary tract injury: intact RBCs; glomerular damage: abnormal RBC forms).

Transparency (light transmission)

Urine is normally translucent and doesn't scatter light. If urine transparency decreases, urinalysis should be supplemented with microscopic, chemical (nitrite), and microbiological examinations. Transparency is shown in the following table (the 'x' in the color sample shows how printed text would appear when looked at through the urine sample):

x	clear	normal, freshly voided urine
x	white opaque	may indicate presence of white blood cells, epithelial cells, bacteria
	milky	may indicate fat, cystin crystal, amorphous phosphate, or leukocytes
x	cloudy	concentrated urine, urinary tract infection, phosphate, urate, uric acid
x	red, cloudy	In hematuria

Odor

Under physiological conditions, fresh, dilute urine has a weak aromatic odor. "Bad" smelling urine can have different causes depending on the character of the odor, thus identifying the odor can indicate the etiology of the change (e.g., sweet smell in ketonuria).

pH

The physiological/normal pH value of urine is between **4.5-8** depending on the quality of food consumed. Among pathological conditions, pH determination has an important role in examining acid-base balance, identifying causes of stone formation, and classifying tubular damage.

Specific Gravity

Determining urine specific gravity (especially when comparing results of multiple measurements) can provide important information about the kidney's concentrating ability. Its value can be given in kg/L, or as a dimensionless number relative to distilled water (1.000 kg/L).

The normal urine density range for first morning urine is **1.003-1.035 kg/L**, for 24-hour samples 1.015-1.030 kg/L. Increase in urine specific gravity/density is **hypersthenuria**, which can develop in e.g., glucosuria, proteinuria. Decrease in urine specific gravity/density (dilute urine) is **hyposthenuria**, e.g., in ADH deficiency due to decreased water reabsorption. If urine specific gravity consistently equals that of protein-free plasma, i.e., ~1.010 kg/L, then the kidney likely cannot concentrate or dilute (asthenuria/isosthenuria in end-stage renal failure).

Specific gravity can be measured by the following methods:

- Urometer: determines density using a calibrated float (immersion densitometer) floating in urine, essentially based on Archimedes' principle. We will use this in the current practical (see practical execution section.
- Refractometer: the refractive index determined by refractometer is directly proportional to the amount of dissolved particles in urine. Its advantage is the small urine volume requirement.
- Reagent strip: gives an approximate value as part of the test strip (see later)

Chemical Analysis of Urine

During chemical composition analysis of urine, we detect substances that entered the urine as a result of glomerular filtration, tubular reabsorption, and secretion (e.g., urobilinogen, glucose, bilirubin, ketone, blood, protein, nitrite, leukocyte esterase).

Forms of chemical analysis:

- Qualitative, which allows us to verify the presence of a given substance using chemical reactions (see practical execution).
- Semiquantitative, examination with urine test strips, which allows us to quantify the value range within which the actual concentration of the given substance lies. This examination is also based on chemical reactions; however, it requires very small amounts of urine, multiple urine constituents can be determined simultaneously within 1-2 minutes, with little financial investment as it has no special instrumental requirements (see practical execution).
- Quantitative determination, suitable for precise qualitative and quantitative determination of individual urine constituents but comes with high cost and special instrumental requirements (e.g., photometer, electrophoresis, liquid chromatograph, mass spectrograph).

Relationship between substances determined in the practical and urine:

- Glucose: filters through the glomerulus but is normally completely reabsorbed (proximal tubule). Its appearance in urine (glucosuria) indicates that plasma glucose concentration has exceeded the tubular transport maximum (>~10mmol/L, typically in diabetes), or there is tubular dysfunction with normal plasma glucose levels.
- Bilirubin: under physiological conditions, water-soluble conjugated bilirubin (cBi) formed in the liver and entering the digestive tract via bile does not return to systemic circulation. If cBi appears in circulation, it can freely filter through the glomerulus and enter urine (bilirubinuria). Unconjugated bilirubin is normally present in circulation binds to albumin; thus, its filtration capability is also limited.
- Urobilinogen: cBi that enters the digestive tract is converted to urobilinogen (UBG) by bacterial action. Part of the UBG is excreted in feces, while another part enters portal circulation and returns to the liver. However, hepatocytes can only take up a small fraction of UBG, while the remainder continues to systemic circulation and is filtered in the glomerulus. Due to lack of tubular transport mechanism, UBG normally appears in urine, while its elevated value indicates increased bilirubin excretion. Absence of UBG in urine, however, indicates that cBi (the substrate for UBG metabolism) did not enter the digestive tract due to bile duct obstruction.
- Ketone bodies: when glucose availability is low, hepatocytes synthesize ketone bodies. This occurs in "normal" cases during fasting or low carbohydrate (ketogenic) diet but is more characteristic of diabetes mellitus. Ketone bodies appearing in circulation filter freely but are mostly reabsorbed through reabsorption mechanisms and only appear in urine at high levels (ketonuria).
- Blood: the glomerular filter normally filters out RBCs, so they should not appear in urine. Blood appearance in urine may indicate glomerular filter damage or lower urinary tract injury.
- Protein: normally, proteins mostly do not filter through the glomerulus, and smaller proteins that do pass through return to circulation via tubular reabsorption, so protein quantity excreted in urine is <150 mg/day. In case of protein excretion (proteinuria), it's important to clarify the extent, quality, and origin of protein excretion.

- Nitrite: normally not present in urine. Conversion of nitrates to nitrites usually occurs during infection by bacterial (gram-negative) enzymes found in urine.
- Leukocyte esterase: enzyme found in white blood cells/granulocytes; the physiological glomerular filter filters out these cells too, so they should not appear in urine. Urine leukocyte esterase positivity indicates an increase in urine white blood cell/granulocyte count, indicating infection.

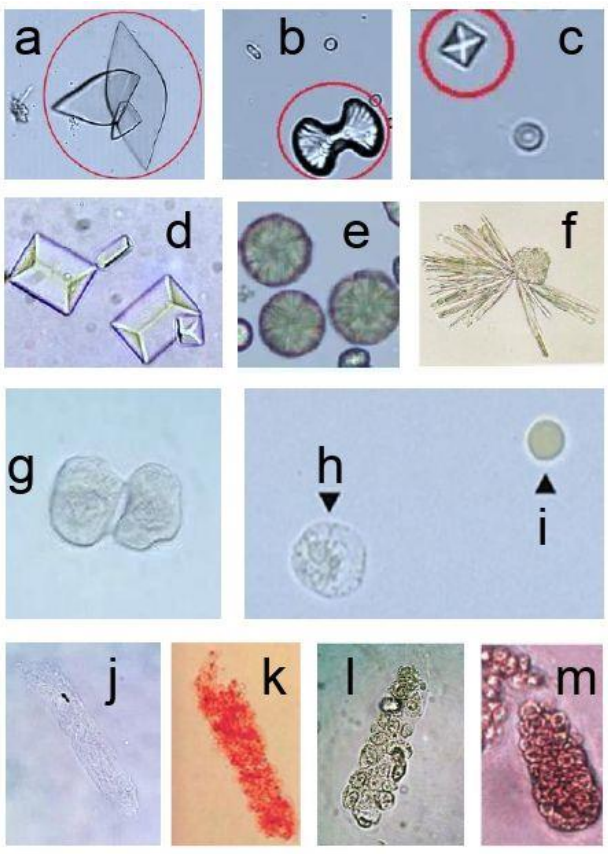
Microscopic Examination of Urine

During microscopic examination, we examine formed elements in urine (crystals, cells, casts, microorganisms). Some of these may occur physiologically, while others are clearly pathological.

Sediment examination requires centrifugation of the urine sample. The sediment settled at the bottom of the tube is resuspended in a smaller volume, and this sample is placed on a slide and examined under microscope. Results are reported per field of view, in LPF (low power field) at low magnification, in HPF (high power field) at high magnification.

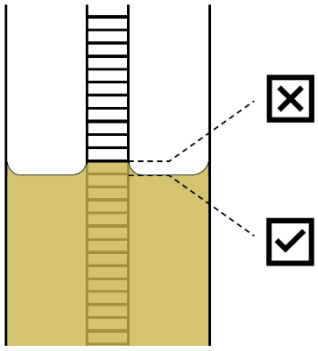
Elements occurring in sediment:

- **Crystals:** form from substances present in high concentration in urine, their formation is pH dependent.
  In acidic urine:
  a. Uric acid
  b. Ca-oxalate monohydrate
  c. Ca-oxalate dihydrate
  In alkaline urine:
  d. Mg-ammonium-phosphate
  e. Ca-carbonate
  f. Ca-phosphate
- **Cells:** may occur normally in small numbers, but their number may increase in inflammation and injury.
  g. Tubular epithelial cell
  h. Granulocyte (max. 1-2/field)
  i. RBC (max. 1, every 3-5 fields)
- **Casts:** casts of precipitated proteins and cells from the distal convoluted tubule or collecting duct (i.e., distal nephron). Normally, only hyaline casts occur.
  j. Hyaline
  k. Hemoglobin
  l. Epithelial
  m. RBC



01 Urinalysis practical execution

I. Measuring Urine Specific Gravity with Urometer



The urometer is calibrated to room temperature (20°C), thus it can only be used with urine at appropriate temperature. The urometer is immersed in a measuring cylinder filled with urine. For measurement, the urometer must float, therefore it's important to have sufficient sample volume, and the device must not touch the container wall. On the urometer scale, **the value at the height of the urine surface must be read** (see figure).

The measurement may contain potential errors, so it's important that measurement follows the specifications (in given cases, we can verify that the specific gravity of distilled water is indeed 1.000 kg/L, and in case of deviation, we can correct with the measured difference).

II. Chemical Urinalysis

<u>Glucose detection with Fehling's test:</u>

- Mix 1-1 ml of Fehling I (3.5% $CuSO_4$) and Fehling II solution (17% K-Na-tartrate dissolved in 5% NaOH)
- Boil the reagent mixture
- Add 2-3 drops of urine to the still hot, azure blue solution
- The solution turns red due to copper(I) oxide formation in the presence of reducing sugar (e.g., glucose), in its absence, it remains blue.

<u>Protein detection with sulfosalicylic acid test:</u>

- Add 2-3 drops of sulfosalicylic acid to 3 ml urine
- If opalescence, turbidity, or precipitation occurs, the sample contains protein.

<u>Ketone detection with Rothera's test:</u>

- Place Rothera mixture on filter paper (10g sodium nitroprusside, 200g $(NH_4)_2SO_4$, 200g Na_2CO_3)
- Then drop urine onto it.
- Purple discoloration occurs in the presence of ketone bodies.

III. Urine Test Strip

When working with urine test strips, proper storage as prescribed and use within expiration date are important. Usage instructions may vary by manufacturer; here we detail the use of the CYBOW test strip used in this practical:

- Do not touch the reaction zone with hands!
- The strip should be dipped in urine for max 1-2 seconds
- Excess urine must be removed from the test strip (remove excess urine from the back side in horizontal position)
- The test strip must be kept horizontal until reading
- Reading should be done 1 minute after dipping (except leukocytes: 2 minutes)
- Read the test strip holding it in the direction indicated on the box
- Each reaction zone must be evaluated separately (using the color scale on the box)

Substance	Normal	Abnormal						Basis of detection	Alternative test
UBG (µmol/L)	(1.6-16)			(33)	(66)	(131)		Ehrlich reaction (benzaldehyde substitution)	
Glucose (mmol/L)	neg.	(5.5)	(14)	(28)	(55)			Sugar oxidation → Metal ion reduction	**Fehling's test**
Bilirubin [Bi]	neg.		+	++	+++			Bi+diazonium → azo dye	
Ketone bodies (mmol/L)	neg.	(0.5)	(1.5)	(3.9)	(10)			Nitroprusside reaction	**Rothera's test**
Specific gravity (g/L)	(1000)	(1005)	(1010)	(1015)	(1020)	(1025)	(1030)	Polyelectrolyte + ions → pH change	**Urometer**
Blood (#/µL)	neg.	hemolysis + (10)	hemolysis ++ (50)	hemolysis +++ (250)	non-hemolysis + (10)	non-hemolysis ++ (50)		Hb + H_2O_2 →Benzidine oxidation	
pH	5	6	6.5	7	8	9		pH indicator mixture	
Protein (g/L)	neg.	nyom	+ (0.3)	++ (1)	+++ (3)	++++ (10)		Protein indicator mixture	**Sulfosalicylic acid test**
Nitrite	neg.	nyom	poz.					Griess reaction (nitrite+sulfanilamide →diazonium→azo dye)	
White blood cells (#/µL)	neg.	+ (25)	++ (75)	+++ (500)				Leukocyte esterase +indoxyl ester+diazonium →azo dye	

Potential errors when using urine test strips:

- Incorrect urine sample collection, storage, transport
- If test strip use doesn't follow instructions
- Factors affecting color reactions (e.g., ascorbic acid may cause false results for glucose, heme, bilirubin, nitrite, and white blood cells).

01 Urinalysis task sheet

name: date:
group: evaluation:

I. Measuring Urine Specific Gravity with Urometer

Measure the specific gravity/density of urine samples 1 and 2 with urometer. During measurement, the urometer must not touch the measuring cylinder wall, which can be prevented by spinning the float. Based on the results, fill in the following table.

Sample	Specific gravity	Evaluation	Presumed cause
1			
2			

II. Chemical Urinalysis

Continue with the samples used for specific gravity measurement. Perform Fehling's, sulfosalicylic acid, and Rothera tests on both samples. Record the results in the table below.

Sample	Fehling	Sulfosalicylic acid	Rothera
1			
2			

Can the sugar/protein/ketone content explain the specific gravity difference?_____

Which sample appears abnormal?_____

What could be the origin of the disease?_____

Why might glucose appear in urine?_____

Why might ketone bodies appear in urine?_____

Why might protein appear in urine?_____

III. Urine Test Strip

Perform urine test strip examination on all four samples! Record the results in the table below and try to match the four urine sediment images to the samples.

Minta	UBG	Glu	Bi	Ketone	Sp.grav.	Blood	pH	Protein	Nitrite	Leu	sediment
1											
2											
3											
4											

Which parameters might suggest infection?_____

Is there a corresponding sample (if yes, which one)?_____

Which parameters indicate disturbance in bilirubin metabolism?_____

Is there a corresponding sample (if yes, which one)?_____

Which parameters indicate disturbance in carbohydrate metabolism?_____

Is there a corresponding sample (if yes, which one)?_____

Sports physiology

In this practical session, we will examine the effects of physical activity on fundamental cardiovascular and respiratory parameters. Additionally, we will learn about the metrics used to characterize general physical condition.

Effects of Muscular Work on Circulation and Respiration

Muscle activity is an energy-intensive process, where skeletal muscles directly obtain their chemical energy from ATP breakdown. The increased ATP demand during work is met by the metabolism (aerobic or anaerobic) of macronutrients (primarily carbohydrates) in skeletal muscles.

During **aerobic metabolism**, carbohydrates (primarily glucose) are completely oxidized. This is the primary mode of energy production during moderately intense and prolonged muscular work. The required O_2 is supplied/transported to the working muscles by the respiratory and cardiovascular systems, which therefore also limit performance. In untrained individuals, maximum O_2 consumption (VO_2max) is determined by the muscles' O_2 utilization capacity, while in trained individuals, it is determined by the cardiovascular system's O_2 transport capacity. Regular training increases both muscle O_2 utilization capacity and cardiovascular system efficiency.

O_2 consumption in working muscles can increase to many times the resting level, up to 10-fold. For the respiratory system to meet this demand with air's 21% O_2 content, it must adapt: tidal volume and frequency increase, consequently leading to significantly increased minute ventilation. The cardiovascular system adapts similarly: blood supply to active muscles increases, heart rate and stroke volume rise, resulting in overall increased cardiac output and blood pressure. Maximum heart rate (HR max) largely depends on age, although available formulas can only estimate an individual's maximum pulse with significant variation. The simplest formula for determination is HR max ≈ 220-age (but with a standard deviation of 12, meaning the obtained value ±24 will contain the actual max pulse with 95% probability). The difference between resting and maximum pulse is called pulse reserve, and work intensity increases the utilization of this reserve (0-100%).

During maximum muscular work (or in untrained individuals even during moderate physical activity), energy consumption becomes faster than the rate of oxidative energy production, causing muscle to switch to **anaerobic metabolism**. Carbohydrate breakdown is incomplete in this case, producing lactic acid, which reduces performance and ultimately leads to muscle fatigue. Regular training increases this anaerobic threshold, delaying the onset of fatigue.

Anthropometry

Anthropometry involves the morphological examination of the human body, measuring various parameters, comparing the measured data, and seeking relationships between them.

Anthropometry can assist in children's sports selection. One of the most determining physical attributes is height, which can be predicted with over 80% probability through anthropometric measurements. It also helps determine biological development, body composition, and characteristic body type. These properties are as important in sport selection as joint flexibility, results of various fitness tests (e.g., Cooper test), or which sport the child enjoys.

Body Composition Determination, Caloric Requirements

Basal Metabolic Rate (BMR) indicates the energy requirements for the body's basic physiological processes. It is significant in intensive therapy and diet. The normal BMR value is 6500-7100 kJ/day (1 kJ = 0.24 kcal).

Average energy requirements for various activities:

- Sedentary work: BMR × 1.2
- Light physical work: BMR × 1.37
- Moderate physical work: BMR × 1.55
- Heavy physical work: BMR × 1.725
- Extreme physical work: BMR × 2.2

Ideal body weight (Broca index) only considers height in determining optimal weight; therefore, it is merely indicative and approximately suitable for determining nutritional status. **Body Mass Index (BMI)** also doesn't account for body composition, and its categories are determined on a statistical basis. Therefore, in certain cases (e.g., large muscle mass), results may be misleading. Evaluation is as follows:

- BMI < 20 - underweight
- 20 < BMI < 25 - normal
- 25 < BMI < 30 - overweight
- 30 < BMI – obese

The ideal body weight can be most accurately determined through complete body composition (muscle, fat, bone) analysis (DEXA). **Body fat** quantity in anthropometry is measured using calipers. A caliper is a millimeter-scaled instrument used to measure skinfold thickness at specific body points. Evaluation is done using tables according to age and sex. Fat-free body mass and body fat percentage can be estimated using formulas after measuring various body parameters. The obtained result can be verified using an impedance-based scale.

02 Sports physiology practical execution

I. Cardiorespiratory Effects of Physical Work

This task should be performed in pairs (or groups of maximum 3)! The subject performs physical work while the examiner records the measured data.

- Calculate estimated maximum heart rate using the formula ***HR max ≈ 220-age***
- The examiner measures the subject's resting blood pressure, pulse rate, and respiratory rate at rest. An automatic blood pressure monitor can be used for blood pressure measurement, and a pulse oximeter for pulse rate measurement. Measurements should be taken in a sitting position, following learned criteria (left arm at heart level, back supported, feet on ground). For respiratory rate measurement, place one hand on the subject's chest and the other on their back, counting breaths for one minute.
- Physical Work
  The subject begins work while the examiner records the specified parameters. Work can be **static** or **dynamic**, at least one task from each work type must be performed. Muscle work should be performed until fatigue (or max 5 minutes) (elapsed time should be measured with a stopwatch, and the examiner records time to fatigue). Depending on fitness level, the subject may perform more challenging tasks.
  STATIC work:
  - Arm work (holding arms forward/sideways freely or with weights)
  - Leg work (wall sit with bent knees, or horse stance without wall)

  DYNAMIC work:
  - Arm work (repeated push-ups against wall or desk)
  - Leg work (repeated squats or step-ups to platform)
- **Immediately after completing the work** (marked as 0' in the table), blood pressure, pulse rate, and respiratory rate measurements must be repeated and recorded. Then the examiner records the pulse shown by the pulse oximeter every half minute (+1') until return to resting pulse rate.

II. Anthropometric Measurements

Evaluate your own anthropometric data/condition using the provided tables

- Fill in the following basic data in the provided table: sex, age (A), weight (W), height (H), waist circumference, hip circumference, wrist circumference, forearm circumference
- Calculate basal metabolic rate (BMR) using the provided formulas:
  - female: $BMR = 665 + (9.6 \times W) + (1.7 \times H) - (4.7 \times A)$
  - male: $BMR = 660 + (13.7 \times W) + (5 \times H) - (6.8 \times A)$
- Calculate ideal body weight according to Broca index using the following formula:
  - $(H - 100) \times 0.9$
- Calculate BMI value using the following formula:
  - $BMI = W/H^2$
- Calculate body fat % using the worksheet tables and compare with the impedance-based measurement value.

02 Sports physiology task sheet

name: date:
group: evaluation:

I. Cardiorespiratory Effects of Physical Work

HRmax	

Resting State

Blood Pressure (mmHg)	
Respiratory Rate (/min)	
Pulse Rate (/min)	

Effects of Physical Work

		Static		**Dynamic**	
		arm	leg	**arm**	**leg**
Order					
Work duration					
Blood pressure (mmHg)	0’				
Respiratory Rate (/min)	0’				
Pulse Rate (/min)	0’				
	1’				
	2’				
	3’				
	4’				
	5’				
	6’				
	7’				
	8’				
	9’				
	10’				

Which exercise form was the most difficult (fastest fatigue)?_____

Which exercise form increased blood pressure the most (calculate mean arterial pressure)?

_____

Is there a correlation between pulse rate and respiratory rate increase?_____

Compare results with your group mates. In terms of fitness level, who fatigues more slowly and whose resting pulse returns faster?

_____

What other factors might influence these values?_____

II. Anthropometric Measurements

	Notes	Values
sex		
age (years)	**A**	
weight (kg)	**W**	
height (cm)	**H**	
waist circumference (cm)	(measured at navel level)	
hip circumference (cm)	(measured at widest point)	
wrist circumference (cm)	(measured at widest point)	
forearm circumference (cm)	(measured at widest point)	

Basal Metabolic Rate (BMR) (kcal/day)_____

Ideal Body Weight (Broca-index)_____

Body Mass Index (BMI) (kg/m²)_____

Body Fat Percentage

For Women (25-30% = normal, >35% = obesity)

factor 1	(weight × 1.614) + 8.987	
factor 2	wrist circumference / 7.98	
factor 3	waist circumference × 0.0062	
factor 4	hip circumference × 0.098	
factor 5	forearm circumference × 0.171	
fat-free body mass	(factor 1 + factor 2 + factor 3 + factor 4 + factor 5) × 0.4536	
fat mass	W - fat-free body mass	
body fat % (formula)	(fat mass × 100) / W	
body fat % (impedance)	(measurement result)	

For Men (15-20% = normal, >35% = obesity)

fat-free body mass	(1,1 × W) - 1,28 × [W^2/ (100 × H^2)]	
fat mass	W - fat-free body mass	
body fat % (formula)	(fat mass × 100) / W	
body fat % (impedance)	(measurement result)	

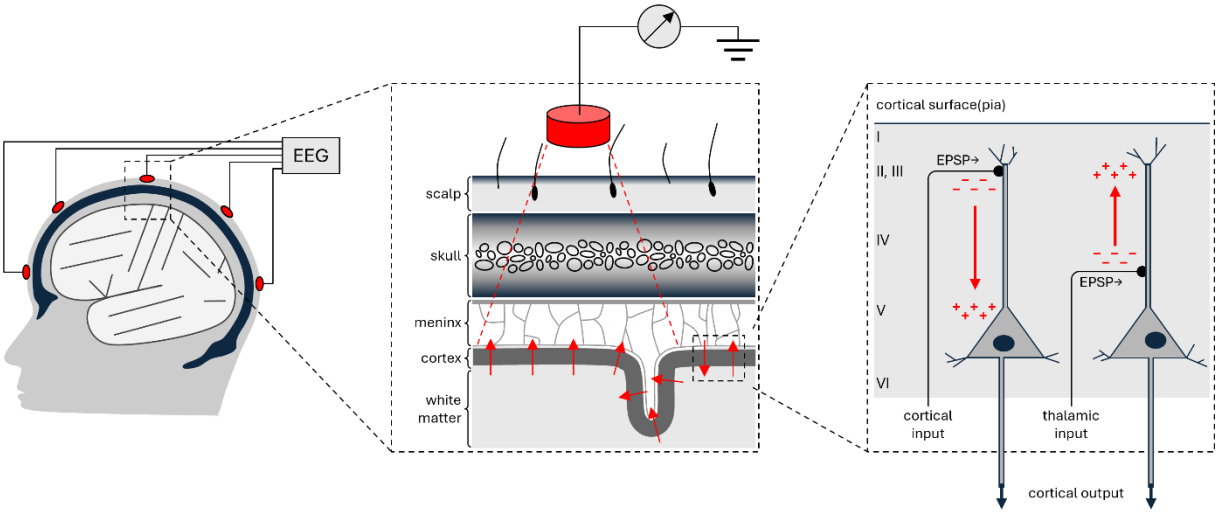
Central Nervous System Examination

This practical session presents direct and indirect examination of central nervous system function. **Electroencephalography** (**EEG**) is a noninvasive functional examination that directly studies electrical signals from the cerebral cortex. Its clinical significance is mainly in epilepsy and sleep diagnostics, and it is also used as a research tool. Simpler **clinical tests and scales** examine various aspects of higher-level central nervous system function, from alertness (Glasgow Coma Scale) through general mental state (mini mental test) to assessment of higher cognitive abilities.

Theory of EEG Technique

The most striking characteristic of the human brain compared to other mammals is the size of cortical gray matter, the extensive neocortex. During cortical function, electrical signals are generated and transmitted along neuronal processes. These electrical signals - similar to ECG - can be detected from the body surface, though they require much greater signal amplification (while ECG signal amplitude is in the mV range, EEG signal is only in the **μV** range). Although both ECG and EEG measure voltages arising in the extracellular space, the two types of signals originate from different types of potential changes. During cardiac muscle function, (prolonged) action potentials generate an extracellular current measurable from the body surface. However, the (brief) action potentials of cortical neurons cannot be measured from the scalp, mainly due to the filtering effect of the skull and other tissues. Therefore, the EEG signal originates not from action potentials but typically from the extracellular projection of postsynaptic potentials (PSPs). The cellular-level origin of the EEG signal is summarized below.

The central element of cortical functions is the operation of pyramidal cells, which provide cortical output. The main input process of pyramidal cells, the apical dendrite, is positioned perpendicular to the cortex. The dendritic tree contains numerous synapses from various sources. Generally, inputs from the thalamus synapse in deeper layers of the cortex (IV), while inputs from other cortical areas synapse more superficially (II, III). The pyramidal cell can send action potentials via the axon process from its base if the summed potential change of active synaptic inputs reaches the threshold value. PSPs created by synaptic activity not only change membrane voltage but also create voltage differences in the extracellular space. The location of PSP formation (within the dendritic tree) has determining significance for the polarity of the measured signal (see figure, right panel: a "vector" pointing toward the electrode appears as a positive signal).

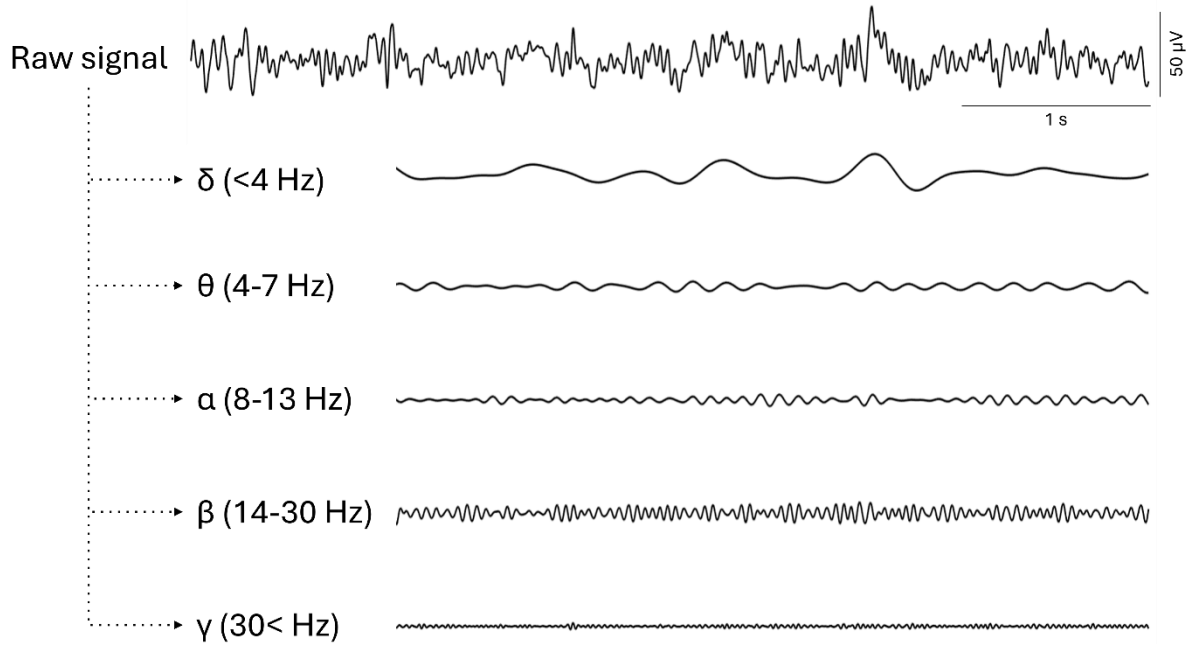


Due to attenuation by intervening tissue layers (scalp, skull, CSF), each EEG electrode's leads collect signals from only a limited cortical area (~6 cm²). The deeper brain gray matter nuclei, basal and mesial cortical areas, and depths of sulci are "invisible" to EEG. In the clinical standard 10-20 electrode system (figure), we distinguish frontal (F), temporal (T), central (C), parietal (P), and occipital (O) electrodes. Such a multi-channel EEG recording thus provides information about how cortical activity develops in different brain regions. Increasing the number of electrodes (up to a certain level) can improve spatial resolution of the measurement, however, it's important to note that EEG's spatial localization capability is very limited by itself.

EEG Signal Characteristics and Clinical Utility

During normal brain function, the EEG signal can be observed as complex wave activity. The activity's frequency typically ranges between 1 and 30 Hz, and its amplitude between 20 and 100 µV. Brain waves can be divided into the following frequency bands: **α** (alpha) 8-13 Hz, **β** (beta) 14-30 Hz, **γ** (gamma) 30< Hz, **δ** (delta) <4 Hz, **θ** (theta) 4-7 Hz. The ratio of activity in different frequency bands can be characteristic of alertness state:

- In active wakefulness, higher frequency (beta, even gamma during increased mental activity), low amplitude activity is characteristic, mainly in frontal areas
- During quiet wakefulness, especially with closed eyes, strong alpha activity can be observed, mainly in occipital and parietal regions (disturbance of quiet, opening eyes results in desynchronization of the EEG signal, alpha decreases and beta increases)
- Theta and delta waves are characteristic during drowsiness and non-REM sleep phases
- In REM sleep phase, we see waves characteristic of wakefulness



When local cortical cell groups operate synchronously, their electrical activity sum becomes larger, meaning EEG signal amplitude increases. This can occur normally during sleep (e.g., sleep spindles), but is particularly characteristic of epilepsy disorders. In epilepsy, the function of certain cortical neural networks becomes pathologically increased, which can cause epileptic seizures, but "spikes" indicating abnormal synchronization can also be observed between seizures. In focal epilepsy, the source of abnormal activity is a circumscribed brain area, where EEG can play an important role in localization. In generalized epilepsy, the exact source cannot be determined; abnormal activity appears to emerge everywhere

simultaneously. Epileptic seizures with uncontrollable cortical activity can involve motor and sensory components and loss of consciousness, indicating the function of affected cortical areas.

The EEG technique can detect not only increased neural activity but also the absence of cortical activity. It may be present as a supplementary examination in brain death diagnostics.

In continuous EEG recording, electrical signals related to neural processing of a newly appearing stimulus (e.g., visual or auditory) could theoretically be observed. However, this is complicated by the inherently "noisy" nature of EEG, as numerous processes occur simultaneously in the cortex. With repeated stimulation, however, EEG signals timed to stimulus appearance can be averaged, allowing us to examine so-called **evoked responses** to the stimulus. During averaging, random background noise is filtered out, while the consistently occurring evoked signal emerges. For example, delay in certain wave components of the clinically used visual evoked potential (VEP) may indicate optic nerve demyelination due to slower conduction.

Examination of Consciousness

In clinical practice, consciousness examination is part of basic neurological examination and is an important step when assessing an injured patient of unknown condition ("are they conscious?"). Here we examine two aspects of consciousness: alertness (**vigilance**) and content (**integrity**). Alertness can be normal (alert/vigil), decreased (in order: clouded consciousness [Benommenheit] > somnolence > sopor > coma), or increased (ecstatic state). An established method for examining alertness is the **Glasgow Coma Scale** (**GCS**), which examines the patient's eye opening, verbal response, and best motor response (see practical execution). In alert state, consciousness content can also be well examined, meaning how well the patient knows their own and their environment's condition, can give adequate responses, execute actions. Normally consciousness is ordered, but states of decreased integrity (confused) or states narrowed to certain contents can occur. General state of consciousness and basic cognitive functions are examined by the **Mini Mental Test** (Mini Mental State Examination, **MMSE**), in practice mainly used for dementia screening (see practical execution). During sleep, we deal with a normally occurring variant of decreased consciousness state, most clearly distinguished from pathological conditions by arousability.

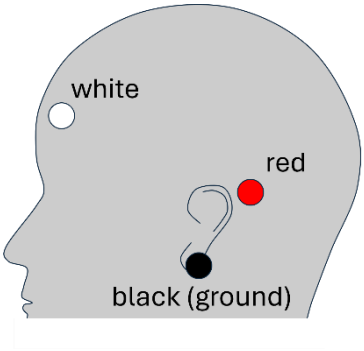
Reaction Time

An important tool for quantifying sensation and perception is psychophysics, which is a collective term for methods examining psychological responses to physical stimuli (light/sound/object/etc.). Common metrics in psychophysical tasks are the ratio of correct responses and average response time (time elapsed from stimulus appearance to response). Such a task might be comparing two stimuli (e.g., deciding which is brighter/louder/heavier/etc.) We call it **simple reaction time** when merely the fact of a simple stimulus's appearance needs to be indicated. Reaction time includes the time of sensory processing, perception based on this, decision making, and planning and execution of motor response. Reaction time distribution characteristically shows right-skewed rather than normal distribution, meaning there is a lower limit below which we cannot produce shorter reaction times, while cognitive process noise can extend response time to varying degrees. Therefore, besides average reaction time, reaction time median is also a useful indicator.

The following tasks should be performed preferably in pairs (max. 3 people). When recording GCS and MMSE, the subject and examiner should be switched. Reaction time measurement should be done individually.

I. EEG

RECORDING



- Start the Biopac Student Lab (BSL) program and select lesson L03-EEG-1. Be clear about who is the subject and who is the examiner.
- Apply adhesive electrodes and connect colored cables as shown in the diagram. Place electrodes on the same side, ground on earlobe, measuring electrodes on forehead and bare scalp behind ear.
- After connecting electrodes, the subject should **sit down and relax for at least 5 minutes** (important for proper electrode adhesion).
- **DURING CALIBRATION AND MEASUREMENT, THE SUBJECT SHOULD REMAIN MOTIONLESS, AVOID BLINKING IF POSSIBLE, AND SHOULD NOT BE STIMULATED IN ANY WAY.**
- For calibration, press the *Calibrate* button and wait for the 15-second calibration recording. If the curve is flat (no large deflections), measurement can begin; otherwise, repeat calibration (*Redo Calibration*).
- To start measurement, press the *Record* button.
- The measurement consists of five 30-second blocks. Between blocks, the examiner communicates the task to the subject and records this time by pressing the **F9 key**. Only properly labeled recordings can be evaluated. The blocks are:
    - closed eyes, complete relaxation, for 30 seconds
    - open eyes, for 30 seconds
    - closed eyes, complete relaxation, for 30 seconds
    - closed eyes, mental task (e.g., counting backward from 100 by 7s), for 30 seconds
    - eyes opening, observing VEP stimulus (on desk "VEP.gif"), for 30 seconds
- To stop measurement, press the *Stop* button.
- If the data series is too noisy (contains large waves), repeat recording (*Redo*).
- Select frequency bands to analyze (press ***alpha, beta, delta, theta*** **buttons**), then click *Done*

ANALYSIS

- Identify blocks based on markers (F9)
- In each block, select at least 10 seconds of noise-free period with "I"-cursor. The **stddev** value in measurement windows characterizes amplitude of given channel.
- For frequency measurement, set measurement window to **frequency** option and mark single cycle (e.g., peak to peak) in given block and frequency band. For more accurate measurement, average results of multiple (e.g., 3) cycles.

II. GCS assessment

When evaluating the Glasgow Coma Scale, we assess **eye opening** (1-4), **verbal response** (1-5), and **best motor response** (1-6) components (see table). We primarily

observe the patient's spontaneous behavior, if necessary attempting to rouse them by speaking or even shouting. If they don't respond to this, we try physical stimulation with pressure applied to fingertip, trapezius muscle, or glabella (pain stimulus). Points for responses in each component (see table) are added (3-15) or indicated individually (e.g., 4-5-6). If any component cannot be assessed, this must be clearly indicated (NT).

Score	Eye Opening	Verbal Response	Motor Response
6	-	-	**Obeys commands** (completes complex commands)
5	-	**Oriented** (able to state location, name, and time)	**Localizes pain** (raises hand above clavicle in response to head/neck pain)
4	**Spontaneous** (without stimulus, on their own)	**Confused** (disoriented but speech is comprehensible)	**Normal flexion response** (organized movement to pain, arm flexion)
3	**To verbal command** (to being addressed, or shouting)	**Words** (speaks meaningful words)	**Abnormal flexion response** (disorganized movement to pain, slow, decorticate arm flexion)
2	**To tactile stimulus** (pressure applied to fingertip)	**Sounds** (incomprehensible sounds)	**Extension response** (arm extension in response to pain)
1	**No response** (does not open eyes to any stimulus)	**No response** (no audible response)	**No response** (no limb movement to pain)
NT	**Not testable** (due to injuries, circumstances)	**Not testable** (due to injuries, circumstances)	**Not testable** (paralysis or other limiting factor)

For alert, healthy individuals, we expect maximum 15 points. A score below 10 indicates severe brain injury, and intubation/ventilation should be considered (important to know component scores!). From 8 points down, we're essentially dealing with coma.

III. MMSE assessment

Complete the MMSE questionnaire on the worksheet following the instructions. Total score evaluation depends on age and years spent in education. Deviation of at least 3 points from average may indicate cognitive dysfunction. In Hungary, for vascular dementia screening (55+ years), we evaluate according to the following thresholds: >24 points normal; 15-23 points mild dementia; 10-14 points moderate dementia; <10 points severe dementia.

IV. Reaction Time Measurement

You must respond with button press as quickly as possible to visual and auditory stimuli appearing at three intensity levels. At the end of the task, the program displays average reaction times grouped by modality and intensity.

Open the *ReactionTime.psyrun* program on the desktop, click the run (▶) button. Put on headphones. When the program starts, you can enter an identifier (*participant*) and number of repetitions for each stimulus (*repeats*). The default setting (10 repetitions) is sufficient for practical purposes, but higher numbers result in more accurate measurement.

03 CNS task sheet

name: date:
group: evaluation:

I. EEG examination

Measure the activity levels (stddev) of each frequency band during the five blocks.

Frequency band	**1st block** eyes closed	**2nd block** eyes open	**3rd block** eyes closed	**4th block** cognitive	**5th block** VEP
alpha (CH2)					
beta (CH3)					
delta (CH4)					
theta (CH5)					

In the table, highlight (e.g., by circling) which block showed the strongest activity for each frequency band. Does it match the theory? _____

Measure the frequency of spontaneous alpha rhythm with closed eyes: _____

During VEP stimulation, the image changes every 200 ms. What frequency is that?_____

Did the activity in the VEP frequency band increase in block 5?_____

II. GCS assessment

Assess your partner's GCS using the table.

Eye opening (E)	**Verbal (V)**	**Motor (M)**	**Total GCS**

Is it possible to "fake" a coma? _____

III. MMSE assessment

Using the questionnaire on the reverse side, record your partner's MMSE score.
Total score: _____

IV. Reakcióidő

Fill in the table below based on the reaction time experiment.

	VISUAL	**AUDITORY**
Low intensity		
Medium intensity		
High intensity		

What might explain the differences between intensities and modalities?
_____

03 CNS task sheet

Orientation

What day is it today?	[ ]	*Where are we now?*	[ ]	
What year is it?	[ ]	*Which floor are we on?*	[ ]	
What season is it?	[ ]	*What city are we in?*	[ ]	__/10
What month is it?	[ ]	*Which region is this city in?*	[ ]	
What date is it?	[ ]	*Which country are we in?*	[ ]	

Memory Registration

I will say three words. After I finish, repeat them after me:

- *apple* [ ]
- *penny* [ ]
- *table* [ ]

Maximum of three trials allowed, but only the first attempt is scored. __/3

Try to remember these words, as I will ask for them later.

Attention and Calculation

I ask you to subtract seven from 100. Now subtract seven from that. Subtract seven again! Subtract seven again! And subtract seven one more time!

- 93 [ ] - 86 [ ] - 79 [ ] - 72 [ ] - 65 [ ]

__/5

If unable to score 5 points, or refuses, then alternative task:

Spell the letters of the word WORLD (W-O-R-L-D). Now spell it backwards.

- D [ ] - L [ ] - R [ ] - O [ ] - W [ ]

Memory Recall

Earlier you repeated three words, and I asked you to remember them. What were these three words?

- lemon [ ] - key [ ] - ball [ ] __/3

Naming

Show two objects (e.g., wristwatch and pencil)

What is this called? And this? __/2

- watch [ ] - pencil [ ]

Repetition

Now repeat after me the following sentence: "No ifs, ands, or buts." [ ] __/1

Following Commands

Now I ask you to take this paper with your right hand, fold it in half, and give it back!

- takes with right hand [ ] - folds in half [ ] - gives back [ ] __/3

Reading

Read and follow the instruction written here!

Close your eyes! [ ] __/1

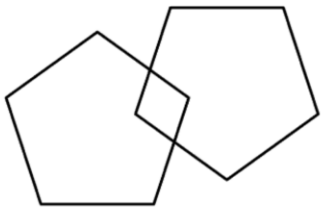
Writing

Write any sentence!

[ ] __/1

Drawing

Copy the drawing below!



Must have both pentagons and the intersections.

[ ] __/1

Total Score: __/30

Hearing

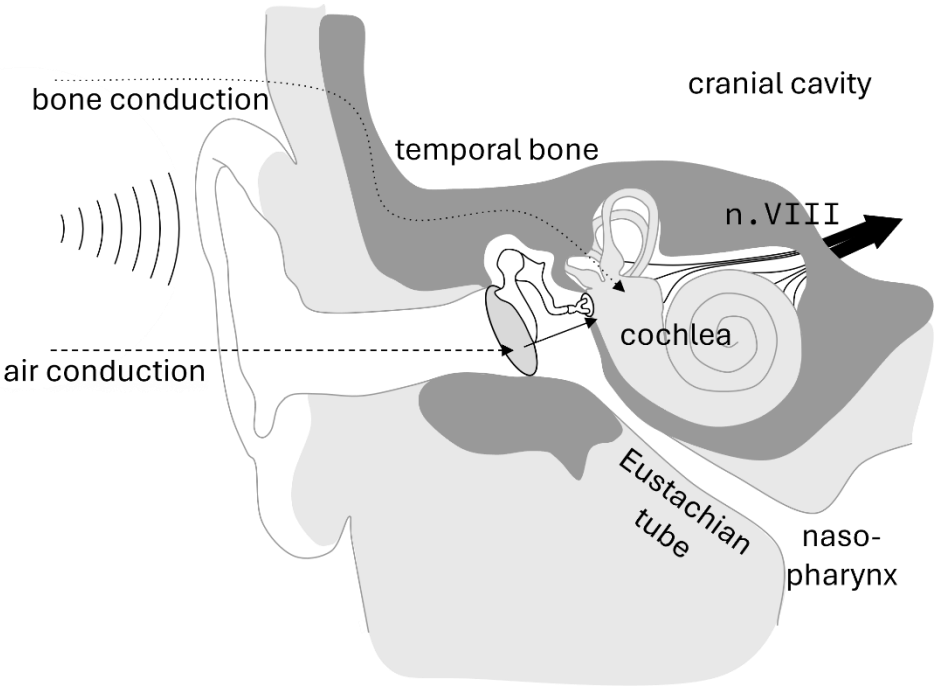
Below we present the most important theoretical knowledge necessary for the successful mastery of exercises examining the auditory system. The details of the anatomy and physiology of the auditory system are covered in the lectures and textbooks of the appropriate studies.

Physiological Basis of Hearing

During hearing, we perceive vibrations (sounds) propagating in the medium surrounding the body if they are within the frequency and intensity range detectable by the auditory organ. In the process of hearing, it is fundamentally important that sound stimuli reach the sensitive receptor cells. In accordance with human terrestrial lifestyle, our auditory organ (the ear) is primarily suited for detecting sounds propagating in air. The mechanism by which air vibrations reach the receptor cells in the cochlea is called air conduction.

Air conduction involves key structures including the external ear (consisting of the auricle and external auditory canal) and the middle ear structures formed by the tympanic membrane and the three ossicles of the ossicular chain. Airborne sounds travel through the external auditory canal to the tympanic membrane, causing it to vibrate. The essence of middle ear function is to convert gas vibrations into solid body vibrations, which can set the fluid spaces of the inner ear (perilymph and endolymph) into vibration without significant energy loss. Air vibrations are largely reflected from fluid surfaces (acoustic impedance). The function of the middle ear is most accurately expressed by the concept of "acoustic impedance matching."

Alternatively, certain sounds can directly cause the skull to vibrate, and vibrations traveling through the cranial bones can transfer to the inner ear fluid and stimulate the receptors. When sounds reach the cochlear receptors in this way, it is called bone conduction. Caution! The ossicles do NOT participate in bone conduction! Bone conduction plays a subordinate role in the perception of external sounds, but for example, we hear our own voice this way (and this is why our voice recorded with a microphone and played back through speakers -- thus perceived exclusively through air conduction -- sounds unfamiliar). The sound of a vibrating tuning fork placed on the cranial bone is also heard through bone conduction.



We speak of hearing impairment when a patient's hearing is significantly worse than that of the healthy average population (hearing loss). The causes of hearing loss can be divided into two major groups based on whether the disturbing deviation manifests in the transmission of sound stimuli to the receptor cells or in the signal processing by the receptor cells and associated neural structures. In the first case, we speak of "conductive" hearing loss, in the second case of "sensorineural" hearing loss, and naturally, both types of disorders can occur simultaneously in the same patient, even on the same side.

Conductive hearing loss is caused by obstruction of the external auditory canal (most commonly earwax plug, foreign body), or middle ear conditions (inflammation, pressure changes due to Eustachian tube blockage, degenerative changes in the ossicles) that impede the vibrations of the tympanic membrane and ossicular chain. In such cases, sounds have difficulty reaching the receptors, and the hearing threshold (the minimum stimulus intensity required to elicit sound sensation) is elevated. In conductive hearing loss, the inner ear receptors become more sensitive to vibrations arriving through bone conduction, which is utilized by the Weber test (see later).

Hearing Examination

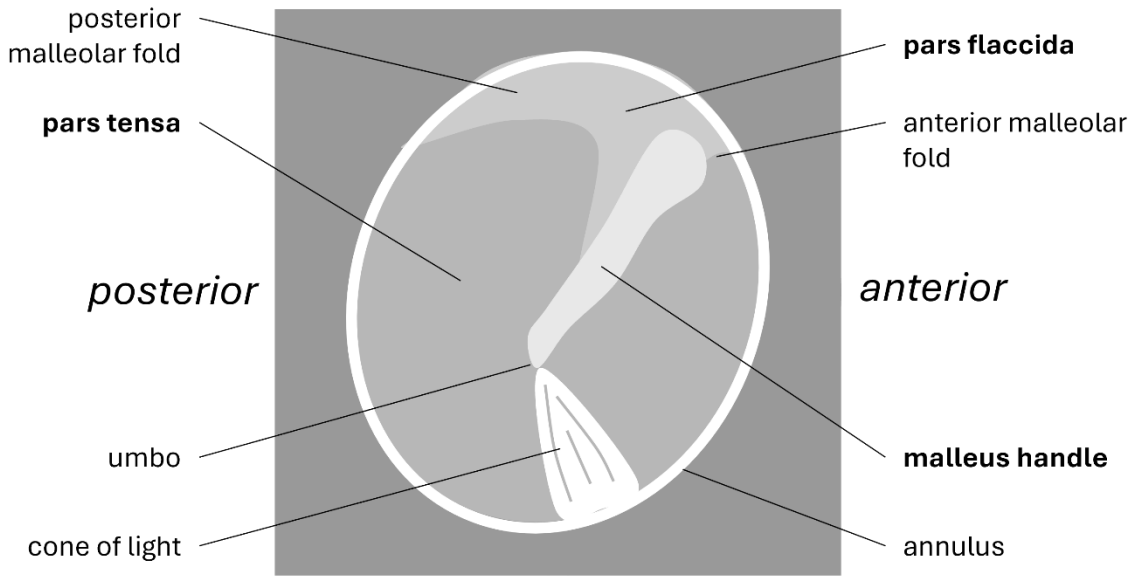
At the beginning of a hearing examination, it is advisable to first examine the patency of the external auditory canal and the integrity of the tympanic membrane using otoscopy, as the most easily remedied cause of (conductive) hearing loss is clearing an obstructed auditory canal.

In each ear separately, (air conduction) hearing acuity can be subjectively assessed by repeating whispered speech (two-syllable words whispered with reserve air from 5 meters, with the other ear masked by the patient rhythmically pressing the tragus), and accurately across multiple frequencies of the hearing range using objective threshold audiometry, the latter method also being suitable for determining the bone conduction threshold.

Audiometry is complemented by tuning fork tests. The Rinne test compares bone conduction and air conduction in the same ear, while the Weber test compares bone conduction sensitivity between the two ears.

1. Otoscopy

Otoscopy is a clinical procedure that provides information about the condition of the external auditory canal, tympanic membrane, and middle ear. The examination is suitable for identifying numerous abnormalities, such as acute otitis media and traumatic perforation of the tympanic membrane. Before beginning the examination, the examiner asks the patient to demonstrate facial muscle strength (smiling, furrowing the brow, closing eyes, puffing cheeks). Success in these indicates the integrity of the facial nerve (VII), which passes through the middle ear and may be affected in cases of acute otitis media.



Following this, otoscopy can begin, during which an appropriately sized ear speculum is attached to the otoscope equipped with a light source, causing no pain to the patient while providing proper visualization and maximum illumination of the ear's anatomy. To straighten the auditory canal, in adult patients, the auricle should be pulled up and back, while in children, it should be pulled down and back. The speculum is then slowly inserted into the auditory canal while confirming its health (inflammation, infection). The speculum should be inserted until the tympanic membrane becomes visible. On the tympanic membrane, we can examine its color, curvature, or presence of perforation. Additionally, we can verify the integrity of major anatomical structures, such as the pars flaccida (superior), pars tensa (posterior), and malleus (anterior). The physiological tympanic membrane is pearly in color, oval, 8-10 mm in diameter. The retracted part shows the adhesion of the malleus process.

2. Threshold

For precise hearing acuity (hearing threshold) examination, we use a threshold audiometer. The audiometer is a sound-generating device that can produce pure, sinusoidal sounds of specific frequencies (60-20000 Hz). For air conduction testing, the test sounds are delivered to both ears separately through headphones. The test sounds can be varied in 5-10 dB steps. For bone conduction testing, alongside the headphone, a special vibration-generating device is placed on the mastoid process, and the 50 dB masking sound is omitted.

The strength of sound used in audiometry is regulated on a decibel (dB) scale relative to the average hearing threshold of healthy adults. The Bel scale is a base-10 logarithmic scale, where dB should be interpreted as a ratio that displays the quotient of sound pressures (SPL) or intensities (SIL) on a logarithmic scale. Accordingly, 0 dB means that the ratio between the measured and reference value is equal. 0 dB corresponds to different sound pressures at different frequencies, which at 1000 Hz means a pressure of 20 µPa.

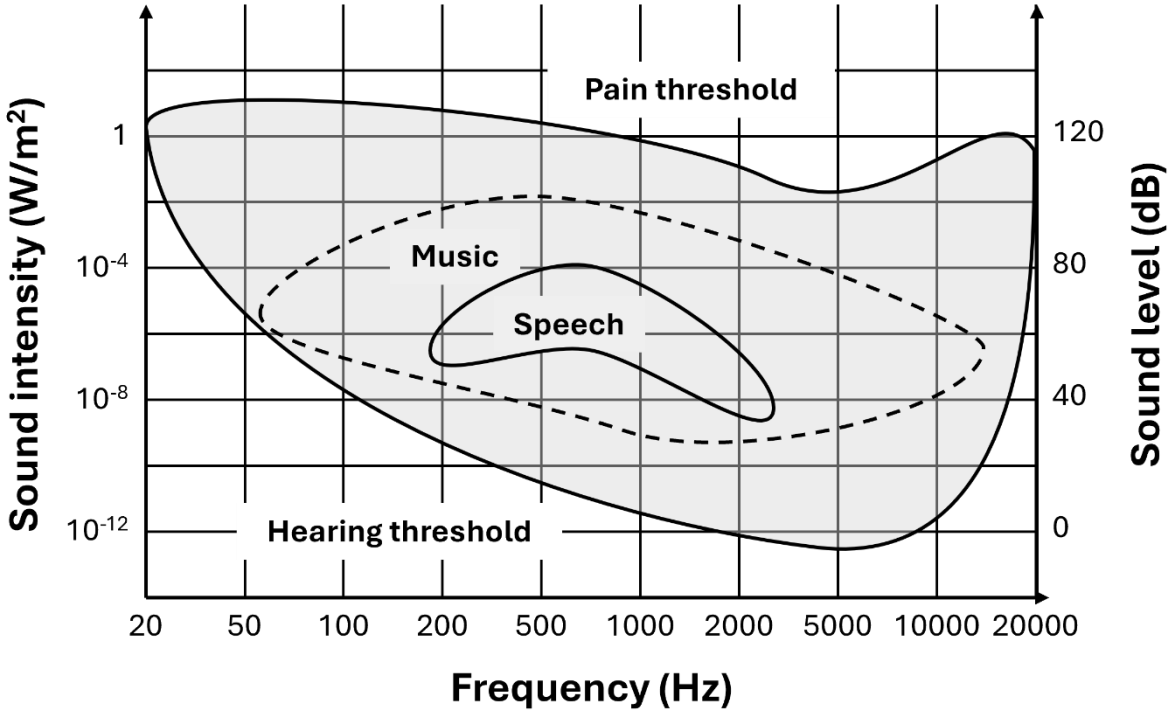
$$SPL\ (dB) = 20\ log\frac{P_n}{P_0} \qquad P_0 = 20\ \mu Pa$$

$$SIL\ (dB) = 10\ log\frac{I}{I_0} \qquad I_0 = 10^{-12}\ W/m^2$$

Audiometric testing should be performed in a room free from environmental noise (sound-insulated). The subject indicates hearing sounds by raising their hand or pressing a signal button. The hearing threshold values thus determined can be recorded at different frequencies (125, 250, 500, 1000, 2000, 4000, 6000, 8000 Hz). The hearing threshold values for each

frequency are marked on the evaluation sheet, according to international notation "x" for the left ear and "○" for the right ear, then the points are connected. A 10-15 dB deviation is still considered physiological. With normal air conduction, we get an almost straight line. In case of air conduction impairment, the threshold value for lower frequencies (<2000 Hz) increases.

Sound intensity (W/m^2)	Intensity change	Sound level (dB)	Sound pressure (μPa)	Pressure change
10^{-12}	1x	0	20	1x
10^{-10}	100x	20	200	10x
10^{-8}	10.000x	40	2000	100x
10^{-6}	1.000.000x	60	20000	1000x



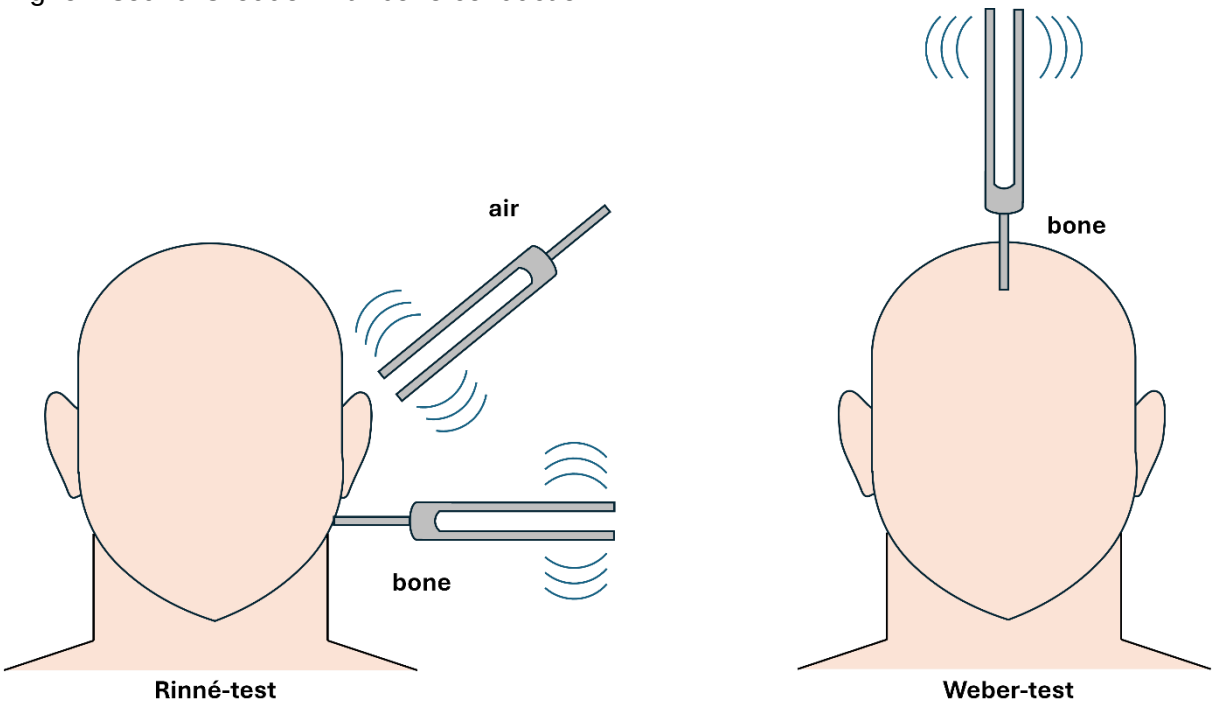
3. Tuning fork tests

We can also test differences in air conduction and bone conduction with tuning fork tests, which can determine whether the conductive or perceptive characteristics of conduction are impaired. The main types of tests are Weber, Rinne, and Schwabach tests.

Weber test: the vibrating tuning fork is placed on the midline of the head on the vertex or forehead, equidistant from both ears. In physiological cases, the sound reaches both ears equally. In unilateral hearing loss, the sound is heard more strongly on one side, which we call lateralization. It helps us detect unilateral conductive or unilateral sensorineural hearing loss. If Weber lateralizes toward the worse-hearing ear, then we can speak of conductive hearing loss, and if it lateralizes toward the better-hearing ear, then sensorineural hearing loss exists. The Weber test alone is not sufficient for identifying conductive and perceptive anomalies, therefore performing the Rinne test is also essential.

Rinne test: it allows us to compare bone and air conduction on the same side ear. The vibrating tuning fork is placed on the mastoid process, thus testing bone conduction. We keep the tuning fork there until the sound is no longer perceived. Then we hold the still vibrating tuning fork next to the patient's ear, making the sound audible again (air conduction). In physiological cases, air conduction is better than bone conduction, so if the tuning fork sound

is louder with air conduction, we evaluate it as Rinne-positive. In sensorineural hearing loss, we will also get a Rinne-positive result, so we can infer the type of impairment by considering lateralization. In conductive hearing loss, we will get a Rinne-negative result, meaning the tuning fork sound is louder with bone conduction.



		Weber		
		Left lateralization	**No lateralization**	**Right lateralization**
Rinné	**L + / R +**	R SN	**normal** (or both SN)	L SN
	L - / R +	L C	-	L SNC
	L + / R -	R SNC	-	R C
	L - / R -	L C + R SNC	Both C	L SNC + R C

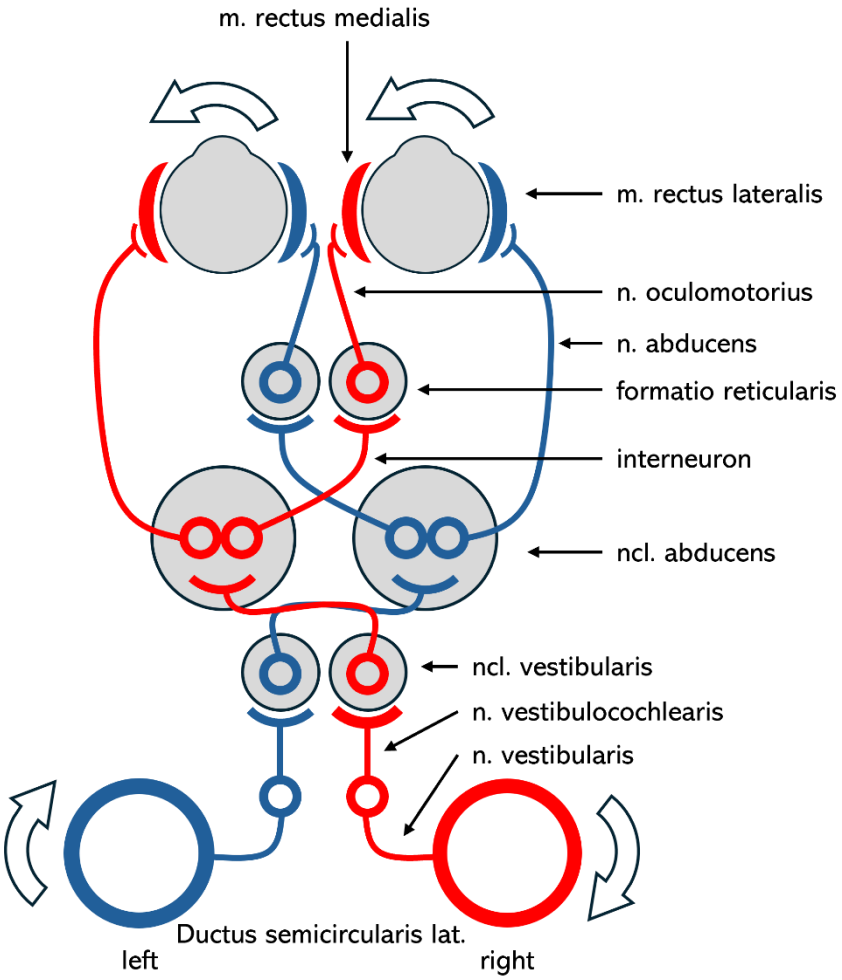
SN: sensorineural-, C: conductive-, SNC: combined sensorineural- and conductive hearing loss

Vestibulo-ocular reflex (VOR)

The vestibulo-ocular reflex is a mechanism that ensures the stability of the eye, and the image projected on the retina during head movement by activating the appropriate extraocular muscles. The reflex has 3 main elements: 1. peripheral sensory apparatus (vestibulum, semicircular canals), 2. central processing system (nuclei, cranial nerves), 3. motor output (extraocular muscles). The vestibulum can detect linear acceleration of the head, corresponding to the position relative to gravity and head movement. The semicircular canals can detect angular acceleration (head rotation). When we move our head, the canals move relative to the fluid (inertia), which triggers movement of the hair cells. Each canal (through cranial nerve VIII) has excitatory and inhibitory innervation with both eyes' eye movement muscles (motor nuclei of cranial nerves III, IV, VI). Movement of the canals in a given direction

triggers conjugate opposite movement of the eyes. The movement is not saccadic but consists of slower and continuously following movements. To examine the reflex, we place the patient's head in our hands, then determine the free state of the neck by gently moving the head right and left. Then we ask the patient to look into our eyes and without warning make a quick, small movement to rotate the head right, then left (10-15°). With intact VOR, the patient maintains their gaze on the examining physician. In case of reflex arc injury, the so-called doll's head sign appears, during which head rotation is not compensated in the eye and the patient cannot maintain their gaze on a focal point during sudden movement.

During prolonged, unidirectional vestibular stimulation, slow movement is followed by saccadic correction. The alternation of slow following and saccadic movements is nystagmus. Experimentally, we can induce post-rotational nystagmus by rotation in a Bárány chair. In another experimental setup, we create a temperature gradient using cold or warm water introduced into the auditory canal. With an intact brainstem, cold water triggers contralateral eye movement, while warm water triggers ipsilateral eye movement. We call this phenomenon caloric nystagmus. We can also differentiate nystagmus based on their direction. In this case, they get their names from the fast, saccadic component. The appearance and direction of nystagmus can help us in the differential diagnosis of vertigo conditions, for example. Post-rotational nystagmus can be induced using the Bárány chair. For this, we seat the patient in the chair and ask them to bend their head forward approximately 45°. Then we rotate them in the chair for 15-20 s at relatively high speed, then suddenly stop. We then ask them to look into our eyes. Due to the sudden stop, the endolymph continues to circulate in the semicircular canals due to its inertia. This flow triggers compensatory nystagmus in the eye.



04 Hearing task sheet

name: date:
group: evaluation:

Otoscopy results

Auditory canal patency:
Tympanic membrane integrity:
Tympanic membrane color:
Light reflection:

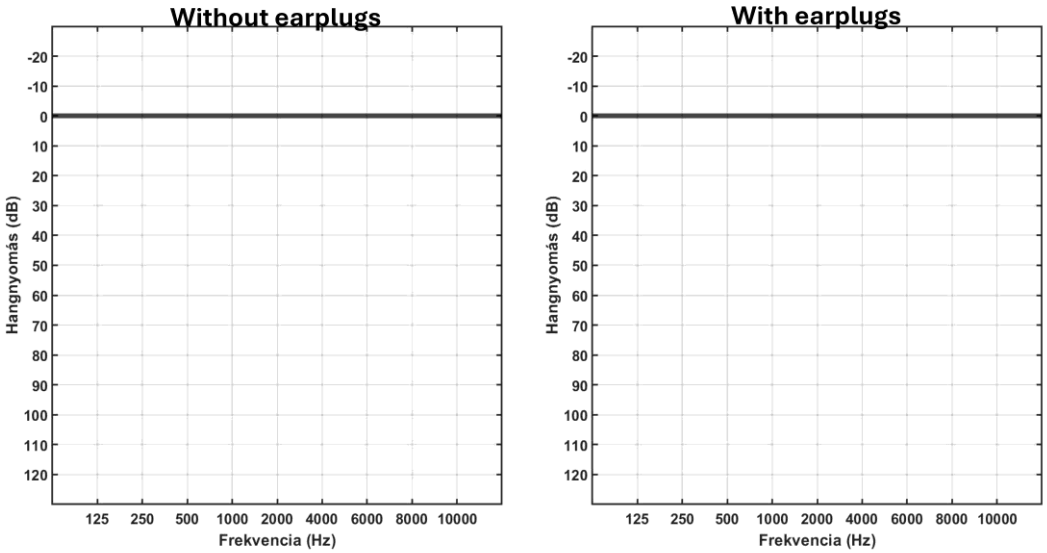
Tuning Fork test results

	Without earplugs		With earplug	
Weber				
Rinne	R:	L:	R:	L:
Result				

Audiometry

Determine the hearing threshold for both ears, first without an earplug, then with an earplug in one ear!

Instructions: The examiner sends sound stimuli of given frequencies to the left and then the right ear. The subject sits with their back to the examiner and signals with a hand movement when they hear the sound. Starting from 0 dB, we regulate the sound pressure using the following method: if they heard it, decrease the sound pressure by 10 dB; if they did not hear it, increase it by 5 dB. This way we cross the hearing threshold multiple times, and we record the value on the audiogram where the subject responded correctly in 50% of cases (O: right ear, X: left ear). We perform this at 250, 500, 1000, 2000, 4000, and 8000 Hz.



Vestibular system

Evaluate the vestibulo-ocular reflex! _____

Evaluate the nystagmus!

Direction of rotation: _____

Direction of nystagmus: _____

Vision

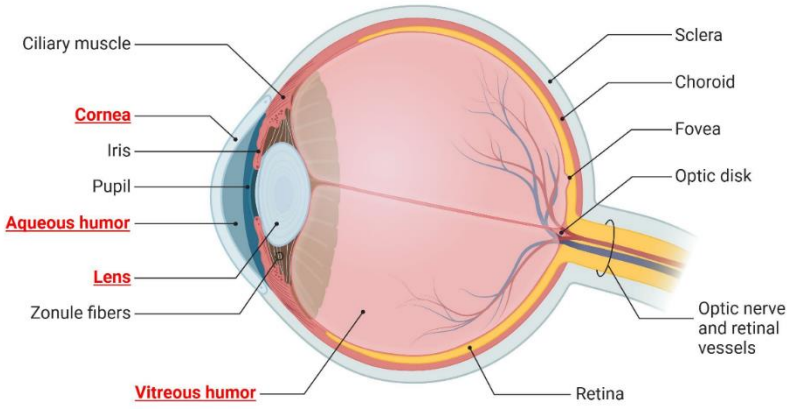
In this practical session, we discuss the most fundamental examinations related to vision, supplemented with the examination of eye movements. More detailed theoretical material is contained in the lectures and textbooks; here we present only the minimal theoretical knowledge necessary for understanding the practical work.

The Optical System of the Eye

The optical system of the eye is the totality of structures that enable (but are not sufficient for) vision, which transforms incoming light rays through refraction so that they can converge on the retina. We speak of refraction when light passes from a medium with one refractive index to a medium with another refractive index (e.g., air-water interface). The unit of refraction is the diopter (D), which is the reciprocal of the focal length (f) expressed in meters:

$$D = \frac{1}{f}$$

In the case of the eye, there are four refracting media, from outside to inside: cornea, aqueous humor, lens, and vitreous body. It is important to note that refraction occurs at the boundaries between these media, with the most significant refraction occurring at the air-cornea boundary (approximately 40-43 diopters) and the aqueous humor-lens boundary (17-20 diopters when looking into the distance). The total refraction of an eye looking into the distance is approximately 60 diopters; when looking at nearby objects, an additional maximum of +12 diopters is added due to the curvature of the lens.



Visual Acuity Examination

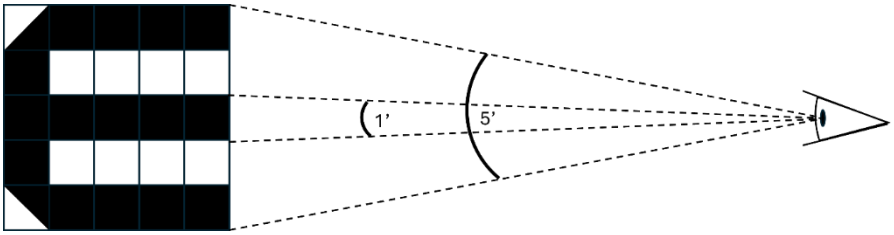
During image focusing, the eye's optical system adjusts so that the focal point of light rays coming from the image falls exactly onto the central part of the macula (fovea centralis) of the retina, which is the site of sharp vision. While looking at a distant point, in a healthy (emmetropic) eye, the ciliary body muscles (m. ciliaris) relax, causing the lens suspensory fibers to tighten and flatten the lens (thus reducing its refractive power). To have near objects' images focus sharply on the retina, the eye's refractive power must increase. The only structure whose refractive power can change is the lens.

When looking at near objects (near adaptation or accommodation), the ciliary muscle contracts, causing the suspensory fibers of the lens to relax and the lens becomes more convex due to its own elasticity (increasing its refractive power). This process is accompanied

by convergence of the eye axes and pupillary constriction (miosis). Together, this is called the accommodation triad.

Visual acuity is determined using a vision chart. The chart displays figures (Snellen letters, numbers, or Landolt rings) in decreasing size from top to bottom, which, when viewed from the distance indicated next to them, appear at exactly 5' visual angle, with the details of the images appearing at 1' visual angle. The topmost figure's detail gives a 1' visual angle from 50 m, while the second-to-last row's figures give this from 5 m (the last black row below the line is used for testing hyperacuity). The letters on the chart are drawn in a square that can be divided into 25 small squares; each small square appears at a 1' visual angle, and the large square at a 5' visual angle.

The examination is performed with a well-illuminated chart. The person being examined sits 5 meters away from the chart hung at eye level on the wall, covering one eye with their hand on the same side. We ask them to read the letters and numbers, proceeding from top to bottom. We find the smallest symbol that they can still reliably recognize.



Visual acuity (visus) can be described with a fraction: V=d/D, where d is the distance in meters from which the reading is made and D is the distance from which the recognized figure appears at a 5' visual angle, and its details at a 1' visual angle. The normal value is V = 5m/5m (= 1). If an individual can only recognize symbols from 5 m that should be visible at a 5' visual angle from 15 m, then their visual acuity is V = 5/15. If the person being examined cannot see even the topmost figure, we bring the chart closer. If reading the chart is unsuccessful, we perform finger counting from various distances. In such cases, instead of visus, we specify the distance from which the examined person can reliably count the number of fingers shown against a dark background.

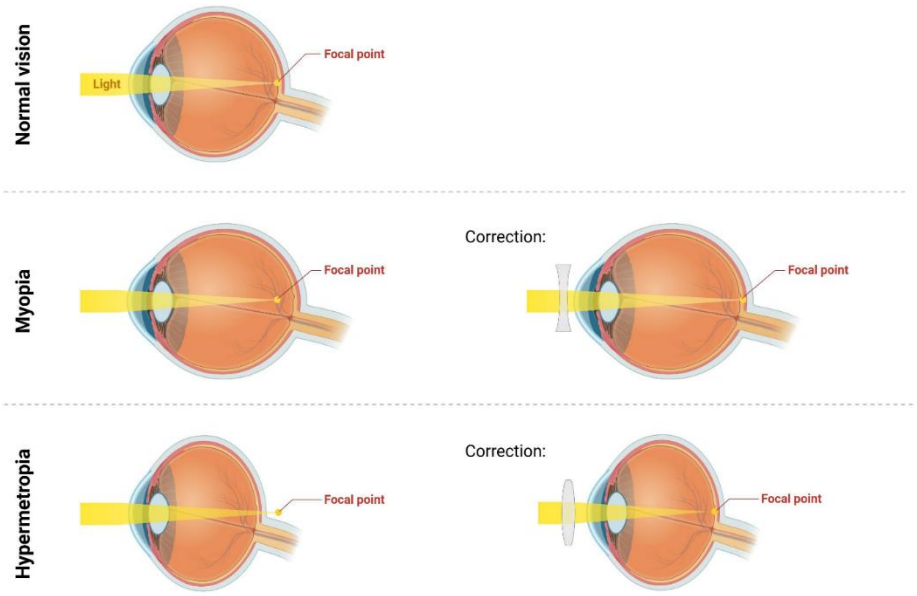
Near visual acuity can be examined using charts (Csapody chart) containing texts written in different sizes held 30-35 cm from the eye. The visus value is indicated next to the texts.

The closest point from which we are still able to focus incoming light rays on the macula is called the **near point** of vision. As the lens loses its elasticity with age, this distance increases. To determine the near point, fix your gaze with one eye on the tip of your upward-pointing thumb held at arm's length, and bring it closer until you can still see it clearly. Measure the distance between your thumb and eye (you can also use a pen instead of your thumb).

If the visus differs from normal, we place different lenses in front of the examined person's eye and correct the deviation with the appropriate lens. We correct the refraction of only one eye at a time.

In **nearsightedness (myopia)**, the eye's longitudinal axis is longer than normal, or the refractive power is too strong relative to the bulb length, causing the focal point to fall in front of the retina. It is corrected with concave (diverging, negative diopter) lenses.

In **farsightedness (hypermetropia)**, the eye's longitudinal axis is shorter than normal, or the refractive power is small relative to the bulb length, causing the focal point to fall behind the retina. It is corrected with convex (converging or positive diopter) lenses.

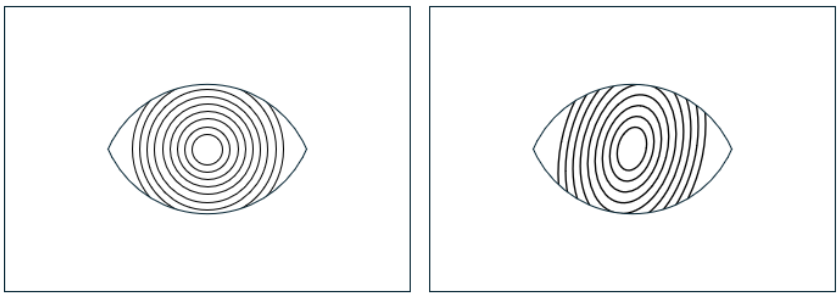


Astigmatism Examination

The cornea is normally an almost regular hemispherical structure. If the curvature of the corneal surface is not uniform but differs along different meridians (more convex in one direction, flatter in another), we speak of astigmatism. This causes the focal points of individual light beams to fall in different places. This often results in blurred vision whether looking near or far. The cornea physiologically has a slight astigmatism: its refractive power is 0.5 D stronger in the vertical direction (this is called physiological astigmatism).

Non-physiological astigmatism is corrected with cylindrical lenses, where the lens has a basic (symmetric) diopter value and a cylindrical diopter component in a specific direction.

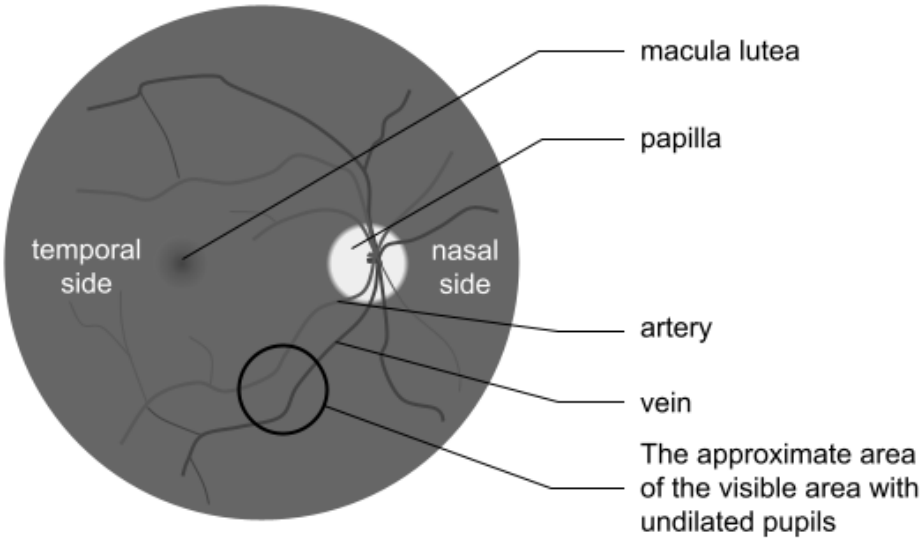
Astigmatism can be most simply examined with the Plácido keratoscope. This is a disc approximately 25 cm in diameter with a handle, featuring concentric circles and a round opening in the center. The person being examined stands with their back to the light source, and we hold the device in front of our eye so that the lamp's light falls on the disc and from there onto the eye, then examine the reflection of the concentric circles on the patient's cornea through the round opening. If the radii of curvature differ along different meridians, the concentric circles will appear distorted.



In clinical practice, qualitative measurement of astigmatism (the difference in refractive power between meridians) is performed using refraction testing and keratometry (automated ophthalmometer). In the former case, the patient must read symbols on a vision chart while different lenses are applied, while the latter provides direct information about corneal curvature.

Ophthalmoscopy

This is among the most commonly used ophthalmological examinations. The examination is performed with an ophthalmoscope, which has a built-in light source and adjustable lens series for correction. Using this device, we can see the structures on the fundus by illuminating through the pupil into the eye. The examination is performed in a dark room. We ask the patient to focus on a distant object. If we are examining the patient's right eye, we take the ophthalmoscope in our right hand and stabilize the patient's head with our left hand. We place the ophthalmoscope in front of our right eye and position ourselves about 15 cm from the patient's eye. Looking through the ophthalmoscope, we search for the "red reflex" in the patient's eye (light rays reflecting back through the pupil from the retina). Once we find this, we move closer to the patient until the fundus and its structures come into focus. Due to the strong light source, the pupil will constrict and only a small segment of the fundus will be visible. We can change the fundus field of view by tilting the ophthalmoscope. The built-in lenses should be adjusted based on the sum of the uncorrected refractive errors of both the subject and examiner. On the fundus, we examine the papilla (optic nerve exit point), the macula lutea (site of sharp vision), and the condition of the blood vessels on the fundus. Normally, the optic nerve head has sharp contours and a light color (it is advisable to follow the course of the vessels during fundus orientation).



Color vision testing

Three types of cones (red, green, blue) are responsible for color vision. We speak of color blindness when color perception is completely absent. It can be hereditary or acquired (e.g., due to diabetes). In dichromats, one type of cone is missing (protanopia = red color blindness; deuteranopia = green color blindness; tritanopia = blue color blindness). Monochromats have only one type of cone in their eyes. In complete color blindness, all three receptors are missing (including the macula lutea), but this is rare.

If the perception of a particular color is reduced, or the patient has difficulty distinguishing between two colors, we speak of color vision deficiency. This can occur because the quantity of receptors is reduced, they do not function properly, or their light absorption spectra are too close to each other. Red-green color vision deficiency is most common and is more frequent among males as it is inherited in an X-linked manner.

Color vision deficiency is most commonly tested using pseudo-isochromatic plates (e.g., Ishihara). These plates show numbers, letters, or lines in a color different from the background but with matching luminance. Both the symbol and background consist of dots, which eliminates contours. The average size, saturation, and brightness of the dots are the same for both the symbol and background, so these factors do not help in recognizing the symbol. Only individuals with normal color vision can recognize the symbol, while those with color vision deficiency either cannot see it or see a different number. For testing children who do not yet know numbers, the task is to trace their finger along the line visible on the plate.

Pupillary Reflex Testing

The pupillary reflex is a brainstem reflex that plays a role in the eye's adaptation to light. The pupils constrict (miosis) in response to light and dilate (mydriasis) in darkness. The pupillary reflex is tested with a low or medium-intensity light (pupil lamp, pupilloscope). Shining it into one eye (passing the light across rather than holding it steadily), we first observe the ipsilateral eye's reflex (direct pupillary reflex) then the contralateral eye's. The pupil on the opposite side also constricts, despite not being directly exposed to light. This is called the indirect (consensual) pupillary reflex. This occurs because information from the same sides (nasal or temporal) of both eyes from the optic nerve reaches the ipsilateral pretectal area, but fibers from here innervate both the ipsi- and contralateral Edinger-Westphal (nucleus oculomotorius accessorius) nuclei, which innervate the m. sphincter pupillae through cranial nerve III (oculomotor nerve).

Optokinetic Nystagmus

Nystagmus refers to conjugate eye movements with equal deviation where slow and fast phases alternate. The slow component is of labyrinthine origin (see: vestibulo-ocular reflex), while the latter is a central, corrective movement. By convention, the direction of nystagmus is identified by the direction of the fast component.

Nystagmus can be induced by stimulating the vestibular system, but also by movement/moving of the visual field (e.g., looking at roadside trees from a moving vehicle). The latter is called optokinetic nystagmus. First, a slow following eye movement can be observed, followed by a fast saccade in the opposite direction, with which the eye returns to the middle position and sets on a new fixation point.

During the practical, we induce nystagmus by having subjects view a black and white grid pattern on the computer screen.

Eye Movement Examination

First, we observe the position of the bulbs at rest, the width of the palpebral fissures, and the presence of nystagmus. We ask the patient if they experience double vision. Then we can examine commanded (voluntary) eye movements by asking the patient to look left, right, up, and down. For testing guided eye movements, we ask the patient to follow our index finger or pen held about 60 cm in front of their eyes, which we move in an "H" pattern (horizontally and vertically). We observe whether eye movement is free and conjugate, and if double vision occurs. Then we ask the patient to fixate on our finger or pen at about 50 cm distance, which we then bring closer to the nasal bridge, observing the convergence of the eye axes, which is part of the accommodation reaction. During the examination, we can test the integrity of the gaze centers and pathways, the nerves responsible for eye movement, and their nuclei (III, IV, and VI).

In a negative status, the palpebral fissures are equally wide, the bulbs look forward in parallel, the patient has no nystagmus or double vision, and the eyes move conjugately and freely in all directions.

Confrontational Visual Field Testing

The visual field is the area of the environment from which we gather visual information at a given moment. A vertical imaginary line passing through the pupil divides the visual field into nasal and temporal fields, while a horizontal line divides it into upper and lower visual fields. Based on these, we divide the visual field into quadrants (upper and lower nasal quadrants, upper and lower temporal quadrants). Although we see images projected onto the macula clearly, we also perceive objects projected onto peripheral areas.

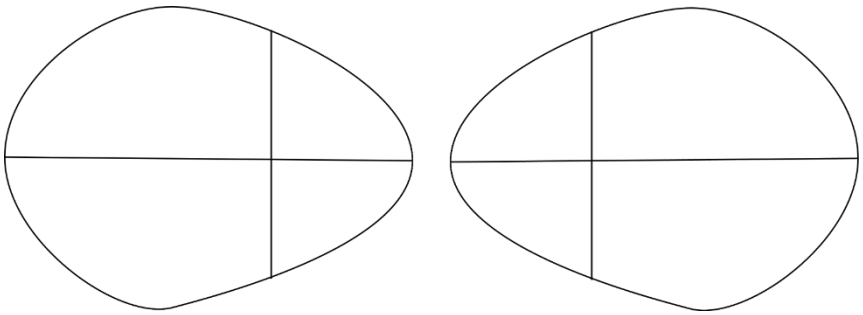
The simplest method (binocular visual field testing) involves the examiner sitting or standing opposite the patient, moving their fingers at the periphery of their own visual field at an equal distance from both the patient's and examiner's face along an imaginary plane. We ask the patient to look at the center of our forehead and not move their eyes. The patient verbally indicates on which side the examiner is moving their fingers (right, left, both), or we can ask them to grab the examiner's hands when they notice the moving fingers.

Another method (monocular examination) involves asking the patient to cover one eye, while the examiner covers their opposite eye (so if the patient covered their right eye, the examiner covers their left). Then the examiner tests the patient's visual field temporally, nasally, above, and below by moving fingers at the periphery of their own visual field. Visual field defects can occur due to lesions in specific parts of the visual pathways and occipital lobe.

05 Vision task sheet

name: date:
group: evaluation:

Evaluate the following parameters:

	Right eye	**Left eye**
Distance vision acuity		
Near point		
Astigmatism		
Fundus		
Color vision		
Pupillary reflex	Direct:	Direct:
	Consensual:	Consensual:
Commanded eye movements		
Guided eye movements		
Accommodation		
Optokinetic nystagmus	Direct of movement: Direct of nystagmus:	
Confrontal visual field		

Neurological Examination

A neurological examination aims to assess the function of the central and peripheral nervous systems. This includes examining the state of consciousness, cranial nerve function, and the sensory and motor functions of the nervous system.

Examination of Consciousness

The neurological examination includes the assessment of both the vigilance and the content of the consciousness. A detailed description of this is covered in Practice Session 3.

Neck Examination

One of the first steps in a neurological examination is examining the neck. Possible causes of nuchal rigidity include meningitis and subarachnoid hemorrhage, as these conditions limit spinal mobility by irritating the meninges. Evaluation and exclusion of these conditions are essential.

Three clinical tests are used to examine nuchal rigidity in a supine patient:

- Brudzinski's sign: with legs extended, we flex the patient's head forward. In pathological cases, knee flexion occurs
- Kernig's sign I: we raise the patient's extended leg. In pathological cases, head nodding occurs
- Kernig's sign II: we extend the patient's raised, flexed leg. In pathological cases, head nodding is also observed

Examination of Cranial Nerves

Smell (I): To evaluate the function of the olfactory nerve, we usually ask patients about their self-assessment of their sense of smell and any related complaints. Instrumental examination of smell is possible using an olfactometer.

Vision (II, III, IV, VI): The neurological examination also includes the evaluation of the visual system. This involves examining the patient's visual acuity. This step is important because reduced visual acuity can be caused by numerous conditions (neurological and internal medicine), not just ophthalmological problems. Vision examination also includes evaluation of the fundus, the visual fields, and the assessment of the eye movements. Two reflexes are typically evaluated concerning the visual system. One is the pupillary reflex. Normally, pupils are round, moderately dilated, equal in diameter, and light sensitive. Additionally, we examine the corneal reflex, which tests cranial nerves V and VII. The absence of the corneal reflex, especially bilaterally, indicates brainstem lesions. During the test, we very gently touch the cornea at the corner of the patient's eye with a gauze corner, to which the patient normally responds by blinking. These are discussed in detail in Practice Session 5.

Trigeminal Nerve (V): The trigeminal nerve consists of motor and sensory fibers. The motor branches are responsible for innervating the masticatory muscles; to examine these, we ask the patient to clench their jaw. In pathological cases, asymmetry may appear in the jaw, and the tone of the two masseters may not be equal upon palpation. When examining sensory innervation, we primarily test fine touch sensation; for this, we touch the patient's face. Since the nerve has three main branches, all three nerves must be tested, so this touch should be performed symmetrically on the forehead, face, and along the jawline. In pathological conditions, the patient perceives symmetric touch differently on the two sides.

Facial Nerve (VII): The facial nerve has motor, sensory, and autonomic branches. Damage to the sensory and autonomic fibers involved in taste and salivation is usually not examined with separate clinical tests. Motor fibers innervate the facial mimetic muscles, and examination of these muscles is essential. We ask the patient to raise and then furrow their eyebrows. Then

we ask them to pucker their lips and show their teeth (grin). Finally, we ask them to puff out their cheeks and resist our attempt to push the air out. In facial nerve paresis, asymmetry appears in the strength of mimetic muscles and thus in the face.

Vestibulocochlear Nerve (VIII): The patient's hearing can be examined using the previously discussed Weber and Rinne tests, or more precisely with audiometry (see Practice Session 4). If these are not available, we can roughly assess the patient's hearing with very small clicks near their ear. To test further function of the vestibulocochlear nerve, we examine whether the patient experiences dizziness (vertigo) or has nystagmus. Another option is observing the vestibulo-ocular reflex (VOR), also known as the "doll's eye" maneuver, which we also describe in Practice Session 4.

Glossopharyngeal Nerve (IX): In case of glossopharyngeal nerve injury, due to motor fiber damage, we can observe asymmetry of the pharyngeal arch, soft palate, and uvula, so it's important to look inside the patient's mouth. Additionally, disorders of taste, salivation, and swallowing (dysphagia) may occur. To test cranial nerve IX, we can elicit the gag reflex, which becomes sluggish if the nerve is damaged. For this, we gently touch the patient's pharynx with a spatula, which normally causes the patient to gag.

Vagus Nerve (X): In the case of vagus nerve injury, we can also observe pharyngeal asymmetry and dysphagia. Other important symptoms include voice changes (dysphonia) or loss (aphonia), and digestive difficulties due to gastrointestinal system sluggishness (gastroparesis). Additional important symptoms include fluctuating heart rate and blood pressure and associated loss of consciousness (syncope).

Accessory Nerve (XI): The accessory nerve is responsible for innervating the muscles around the neck. To test this, we ask the patient to raise their shoulder and resist our attempt to push it down.

Hypoglossal Nerve (XII): The hypoglossal nerve innervates the tongue muscles. During the examination, we ask the patient to stick out their tongue. The tongue should be symmetric, with its tip in the midline. Then we ask the patient to move their tongue right and left.

Examination of the Sensory System

While examining the sensory system, we primarily look for sensory losses in the extremities. It's important to examine the integrity of both protopathic and epicritic sensations in both the proximal and distal parts of the limb.

Epicritic perception includes fine touch and vibration. Fine touch is tested by symmetrically and gently touching the patient's upper and then lower extremities. Moving from top to bottom, we stroke the patient's upper arms, forearms, and hands, and similarly on the lower extremity. It's important to observe whether the patient feels the stimulus, feels it everywhere, and if the sensation occurs symmetrically. For vibration testing, we place the base of a vibrating tuning fork on a bony surface, which is the wrist for the upper extremities and the ankle for the lower extremities. We ask the patient to indicate when they no longer feel the vibration (if they feel it at all). Then we place the tuning fork base on our own wrist, thus comparing the patient's vibration sensation with our own.

Protopathic sensation is primarily tested through temperature sensation. For this, we use the metal and rubber parts of the reflex hammer, where the metal parts elicit a cold sensation while the rubber or plastic parts elicit a warmer sensation. With intact temperature sensation, the patient can distinguish between touches from the two parts of the hammer. We touch the patient with a specific part of the hammer while their eyes are closed and ask whether they feel colder or warmer part. If temperature sensation is not preserved, pain testing is also possible. During this, we make small pricks with a not-too-sharp instrument without breaking the patient's skin and observe the reaction.

There is also the possibility to test higher-level integrative functions of the sensory system. One such higher-level function is stereognosis. For this examination, we ask the patient to

close their eyes and then place an object in their hand (key, pen, etc.). With preserved stereognosis, the patient should be able to name the object without visual information. Another such function is graphesthesia, where again with the patient's eyes closed, we draw simple shapes (e.g., numbers) on the patient's palm with our finger, and the patient must name the shape. Finally, we can test two-point discrimination ability, which is the smallest distance between two-point stimuli that the nervous system can recognize as separate stimuli. Regarding two-point discrimination, it's important to note that it shows great variance even within skin surfaces. This distance is smallest on the hand and fingers, while it can be several times larger on the neck and back. This function is based on the density of receptors and the size of receptive fields in the given skin area. To test this, we can use Weber's compass.

Examination of the Motor System

In the motor system, we evaluate three things: muscle tone, muscle strength, and reflexes.

For examining **muscle tone**, we ask the patient to relax the given limb and then evaluate muscle tone by passively moving the joints. Evaluation can be hypo-, normotonic, or spastic tone. Muscle tone is important in distinguishing between central and peripheral paralysis. In central paresis, spastic tone primarily occurs (spastic paresis), while in peripheral paralysis, hypotonia occurs.

When examining **muscle strength**, we test the strength of major limb muscle groups against resistance. In practice, we ask the patient to resist force applied by us, e.g., don't let us push down their upper arm, don't let us open their elbow, etc. In muscle strength examination, we symmetrically examine the major joints of the upper limb (shoulder, elbow, wrist), and then the lower limb (hip, knee, ankle). Additionally, finger strength is typically tested by asking the patient to form rings with their fingers one by one, while we try to separate them. Muscle strength is evaluated on a 0-5 scale:

- 0: no muscle response to active movement attempt (complete paralysis)
- 1: fasciculation (muscle twitching) in response to active movement attempt, but no joint movement
- 2: active movement is only possible with gravity eliminated (in the horizontal plane)
- 3: the limb can just be maintained against gravity
- 4: stronger than 3 but not full muscle strength (active movement against small resistance)
- 5: full muscle strength

Muscle strength examination includes testing for latent paresis (usually unilaterally occurring reduced muscle strength), for which we use the Mingazzini test. During this, we ask the lying patient to raise their hand at 45° palm up, close their eyes, and maintain their arms. With reduced muscle strength and without visual information, the paretic limb rotates and sinks. The test can be performed similarly on the lower limb.

When examining reflexes, we evaluate deep reflexes, skin reflexes, and pathological reflexes. Reflex evaluation can be: areflexia, hyporeflexia, normoreflexia, hyperreflexia, or clonus. In areflexia, muscle response is completely absent to adequate stimulus; in hyporeflexia, the muscle response is less than expected (particularly noticeable unilaterally). In hyperreflexia, an enhanced muscle response appears to be an adequate or even smaller triggering stimulus. Hyperreflexia can appear as an extended reflex area, meaning the muscle response can be elicited from a larger surface. We speak of clonus when a rhythmic muscle response appears to the triggering stimulus.

Deep reflexes are examined in the limb joints. Diminishment of these reflexes most often occurs due to peripheral paralysis, while hyperreflexia occurs during central paresis.

Additionally, the presence and absence of different **reflexes** help in localizing spinal cord lesions, so it's important to know the synaptic segment of each reflex.

In the upper limb, we examine three deep reflexes: biceps, triceps, and radial reflexes.

- The biceps reflex synapses in the C5-C6 segment. To elicit it, we find the biceps tendon in the patient's slightly flexed elbow, which we press down with our thumb to tense the muscle. Then we strike our finger with the reflex hammer, causing the biceps to contract and flexion to occur at the elbow.
- For the triceps reflex (C6-C7 segment), we strike the triceps tendon above the olecranon with the hammer with the elbow flexed at right angles. This causes triceps contraction and elbow extension.
- The radial reflex (C5-C6 segment) can be elicited by striking the radius head on the flexed forearm, causing flexion in the forearm.

In the lower limb, we examine the patellar reflex and the Achilles reflex.

- For the patellar reflex (L4), we strike the quadriceps tendon below the patella with the hammer on the suspended, flexed lower limb. The reflex response will be knee extension.
- For the Achilles reflex (L5-L6), we raise the lying patient's foot with knee flexed. Keeping the sole in dorsiflexion, we strike the slightly tensed Achilles tendon with the hammer, causing plantar flexion in the foot. The Achilles reflex can also be elicited by striking the sole.

Among superficial reflexes, we examine the abdominal reflex and plantar reflex.

- For the abdominal reflex, we can test spinal cord segment integrity at three levels (Th7-Th8, Th9-Th10, Th11-Th12). We gently scratch the abdominal skin from the outside toward the navel on the same side at the upper, middle, and lower levels using the reflex hammer. In normal reflex response, the navel moves toward the scratch because the abdominal muscles tense on that side.
- For the plantar reflex (L5-S2), we gently scratch the lateral arch of the sole from the heel to the base of the hallux in an 'L' shape using the reflex hammer. The physiological response is plantar flexion of the toes.

As the final step, we examine pathological reflexes. As their name suggests, the presence of these reflexes is pathological, most commonly appearing in cases of descending pathway injury and central paresis. We look for three pathological reflexes: Hoffman, Trömner, and Babinski reflexes.

- To elicit the Hoffman reflex, we hold the patient's hand in ours and flick the middle finger's nail downward. Physiologically there is no reflex response, while in pathological cases, adduction/flexion of the thumb can be observed.
- The Trömner sign is similar to the previous one. To elicit the reflex, we flick the patient's fingers from below, which in pathological cases also triggers thumb flexion.
- The Babinski sign is a pathological response to the plantar reflex. When scratching the lateral arch of the sole, instead of plantar flexion, dorsiflexion occurs in the hallux. Under one year of age, dorsiflexion is the physiological response.

Cerebellar and Balance Tests

Cerebellar tests examine cerebellar function. During these, we observe limb coordination and movement.

In the finger-to-nose test, we ask the patient to extend their arm, then touch their nose with their index finger and repeat this with eyes closed. In cerebellar damage, the movement is not smooth and continuous, and the patient misses the target. If the patient only has problems with eyes closed, proprioception disorder should be considered, as in this case, the lack of visual information causes the problem.

The heel-to-shin test is the equivalent of the finger-to-nose test. We ask the patient to touch one knee with their opposite heel, then slide the heel down along their shin.

Cerebellar functions can be well examined through diadochokinesia, which means executing rapidly alternating movements. In practice, we ask the patient to clap their hands alternating between palm and back of hand. With impaired cerebellar functions, alternating movements become jerky, resulting in dysdiadochokinesia.

For maintaining balance, visual, proprioceptive, and vestibular information is available, and at least two of these are needed. This ability is tested by the Romberg test. In the Romberg test, we ask the patient to stand with feet together, and if successful, to close their eyes. By eliminating visual information, we test vestibular and proprioceptive sensing. In the enhanced Romberg test, the patient must stand not with feet together but with one foot in front of the other.

At the end of the examination, we ask the patient to walk to the other end of the room and back. During this, we observe the patient's gait. Normal gait requires intact pyramidal, extrapyramidal, cerebellar, peripheral, and sensory nervous systems. As a result, numerous diseases can cause gait problems.

06 Neurological examination task sheet

name: date:
group: evaluation:

Evaluate the following parameters based on examination:

Consciousness: _____

Neck: _____

Cranial nerves

Smell		
Vision		
Trigeminal nerve (L/R)		
Facial nerve (L/R)		
Vestibulocochlear nerve		
Glossopharyngeal nerve		
Vagus nerve		
Accessory nerve		
Hypoglossal nerve		

Sensory system

	Touch (L/R)		Vibration (L/R)		Temperature (L/R)		Graphaesthesia (L/R)		2 point disc. (L/R)	
Upper limb										
Lower limb										
Torso										

Motor system

	Muscle tone (L/R)		Muscle strength (L/R)	
Prox. upper limb				
Dist. upper limb				
Prox. lower limb				
Dist. lower limb				

Upper limb	biceps reflex (L/R)		
	triceps reflex (L/R)		
	radial reflex (L/R)		
Lower limb	patellar reflex (L/R)		
	Achilles reflex (L/R)		
	talp reflex (L/R)		
Pathological reflexes	Hoffman sign (L/R)		
	Trömner sign (L/R)		
	Babinski sign (L/R)		

Coordination and balance

Finger-to-nose test (L/R)		
Hell-to-shin test (L/R)		
Diadochokinesia (L/R)		
Romberg test		
Gait test		