BSS Altfragen

electrical Membrane properties

- good isolator —> low conductivity (1 mS/cm^2 oder =10^{-7} S/m)
- high capacity because of the lipid double layer (1µF/cm^2) like a condensator
- the lipid molecules act like flip flops
- affinity to positive ions (Na+, K+), because of negative charge of the outer membrane surface
- pores as channels → diffusion vs Electric forces
- passiv channels —> diffusion vs Electric forces
- active channels —> ion pumps
- gated channels → voltage, transmitter, stress, temperature gated
- U = □$_i$ - □$_e$ = -83 mV → □ potential

ECG signal analysis

power spectral density
principal component analysis
independent component analysis

Primary sensing cells

sensory neuron

Dendrites, nerve endings act as receptors for temperature, mechanical or chemical substances
branches of nerve axon acts as output of information, transmit action potential
a lot of ATP is needed to achieve information forwarding

Registration of impedance of the human body
Bestandteile: 4 electrodes, energy source, Amplifier, Bandpass, Demodulator
Bandpass: increases signal to noise ratio
Demodulator: inverts negative waveforms and (Low pass filter) smooths wave

more equipotential lines during inspiration (lower conductivity) and during late systole -> less blood, more isolating state

scattering of light & influence on total absorption

scattering of light happens in heterogeneous materials due to a vatiation in refractive index
this increases the pathlength of the photon & probability of absorption increases! -> major factor regarding total absorption
types of scattering:
isotropic: areas of scatterer experience same electrical field (ex. blue sky)
anisotropic: areas of scatter experience different electrical field

Relationship between arterial blood pressure and radius
radius r —> radius of blood vessel
The relationship is non linear so over expansion is avoided
bigger radius = lower blood pressure and the vessel is more elastic
smaller radius = higher blood pressure, vessel is more stiff
diastolic blood pressure is linked to impedance(Widerstand) of distant vessels and the peripheral impedance results in the state of the vessels.
if the vessel radius decreases, there is a vasoconstriction. the pressure rises shortly and the blood flows to vessels with lower impedance so that the pressure can decrease.
if the muscles around the vessels relax —> the vessels widen so the radius gets bigger and the pressure decreases

Blood flow reflected waves
waves spread from heart to periphery —> from thicker to thinner vessels
wave reflects when arteries branches and/or are stiff/ at arteriols
stiffer vessels reflect more than elastic ones
after some time the reflected waves and „new“ waves meet (überlappen) so there are second peaks in the waves (Blood pressure P is positively reflected) —> the wave that comes back pushes the blood „back in the heart“ so the heart needs more pressure to push blood through body
P_{ref} increases because of the reflected wave(backward wave) which increases because of stiffness of the vessels, the time (PTT) at which the waves meet decreases with stiffness

optical sensor penetration depth
is the depth at which the Intensity I_0 has fallen by 1/e (or 36%)
given by $1/\mu_a$
is important for the transmission of light (key issue)
μ_a —> absorption coefficient, absorption decreases with higher penetration depth

Thermal sensitivity of skin curvature sensors
Skin curvature sensors: captures any processes in body when it creates movement on the skin

<u>single magnetostrictive layer (ML)</u> —> in the middle neutral bending plate is there a tension or a compression on this layer, it changes its permeability (durchlässigkeit) —> changing magnetic attributes
tension: increases permeability (in upper area)
Compression: decreases permeability (in lower area)

<u>Double layer</u>
ML fixed on a non-magnetic carrier-layer(CL)
changes in permeability only on the down site (in the ML)
Coil used for producing electrical sensor signal (around the ML und CL layer)

temperature moves the plate itself (warm es dehnt sich, cold es zieht sich zusammen) so it creates inductivity without having an actual body signal
—> eliminate thermal sensitivity: use town coils (outer and inner) the inner one will be sensitive to temperature only, the outer one to temperature and bending

thermal sensitivity:
If there is a thermal difference the components bend and have a compression
There are two stress factors and therefore a tension, so the inductivity increases with temperature although the body does not give a signal

Acoustic sensor: Relation between membrane radius, bell volume and detected frequencies
auscultation on the chest: only lower frequencies can be heard, because they progress through soft tissue
high frequencies have higher damping so they only travel through the airways

The smaller the radius of the membrane the higher the frequency f
little membrane —> higher frequency can be heard

velocity of propagation (Ausbreitungsgeschw.) depends on stiffness
the stiffer the membrane the higher the frequency (higher velocity) —>
through pressures on stethoscope

bell: for resonance
the smaller the bell volume the higher the frequency

Respiratory pump, respiratory/cardiac interrelations
Systemic circulation: blood high with oxygen content goes into the body from the left atrium —> left ventricle —> aorta —> arteries —> arterioles —> capillaries
blood with low oxygen content goes back to the heart
venolen —> venes —> right narrow vene —> right atrium —> right ventricle

pulmonary circulation: blood with low oxygen goes from the heart to the lung
from the right ventricle -> pulmonary artery -> lung

blood with high oxygen goes to the heart
lung —> pulmonary vene -> left ventricle

80% of the blood in venes (blutspeicher funktion)

Respiratory pump:
<u>inspiration:</u>

- pressure in breast area decreases
- pressure gradient between peripheral venes and venes in thorax increases
- blood is drawn from peripheral venes in the thorax
- periphere volume decreases and the radius of the venes decreases
- left ventricle: reverse thoracic pump
    - pump volume of right ventricle increases
    - capacity of vessels in thorax increases
    - left shift of inter ventricular septum
    - stroke volume of left ventricle decreases
- heart rate: respiratory sinus arrhythmia
    - puls frequency increases

        - diastolic time to fill ventricles decreases
        - stroke volume of left ventricle decreases
- blood pressure
    - arteriell blood pressure decreases

<u>exhale:</u> same but opposite

reverse thoracic pump

- inspiration: decreased arterial blood due to decreased left ventricular stroke volume
- reduced pressure in breast area
- lower intracavitary left ventricular ejection pressure
- impeded left ventricular stroke volume

cross sensitivity of thermal sensors

elongation (dehnung) and tension have different coefficients of thermal expansion from ML and CL
If there is a thermal difference the components bend and have a compression but without a signal from the body
There are two stress factors and therefore a tension, so the inductivity increases with temperature although the body does not give a signal
—> with increasing temperature the inductivity increases because of bending

elimination of bending/thermal sensitivity

using 2 coils
inner coil: Sensitivite to Temp.
outer coil: sensitive to temp and beding
using trilayer
ML - CL - ML

PQ interval of the ECG

During the PQ Intervall the atria are fully stimulated/excited so there is no potential difference, it waits for the heart to stroke with the QRS complex
The ventricles are not erregt —> it shows the atrioventrikuläre Übergangszeit

QRS complex of ECG
propagation of excitation

ST interval of ECG
ventricles full excited, no potential difference

volume effects of sound attenuation
?

condition for closure of valves (pressure difference, blood flow = 0)
The valves open and close passively because of the pressure differences on either side of the valve. When the blood pressure is greater „behind“ the valve (presses against the valve) it is blown open and the blood goes through. The pressure adapts and then the pressure in front of the valves gets higher so ist pushes the valves back to close them.

auscultation of snoring sounds: small or large chest piece
snoring sounds are waves in the airways so they have a high frequency and have high losses over distance caused by damming through the tissue
so the membrane needs to have a smaller radius and a small bell volume
—> small chest piece because it can detect higher frequencies
bilayer sensor
ML (magnetostrictive Layer) is fixed on a non-magnetostrictive layer the CL.
If the sensor is bent —> tension is on the upside and compression on the downside
bilayer orientation within the earth magnetic fields but influence can be cancelled with calibration
ML is on the downside so the permeability is decreased on the downside and there is no changing on the upside.
This sensor needs a coil to create the electrical signals out of the tension difference
inductivity is proportional to the permeability and this is proportional to the Krümmung c=1/r
these sensors are bending and thermal sensitive

thermal sensitivity of bilayers
bilayers are sensitive to thermal changes due to a difference in *thermal expansion coefficient K* of the two materials

St = | Kml - Kcl |

Kml … thermal expansion coefficient of the magnetostrictive layer
Kcl … thermal expansion coefficient of the counterlayer (non-magn. layer)

bending sensitivity of bilayers

sigma > 0 for tension
sigma < 0 for compression
finite length bilayer -> strongly inhomogeneous stress distribution

active (ion pump) vs. passive (just pass through, pumping against the gradient) channels
Membrane of a cell is a good isolator
two surfaces —> electrical double layer = high capacity —> like a condensator
the inside of the cell wants positive Ions
cell Pores are channels for material transport, also pass through the Ions

passive channels: Diffusion —> just passes the ions through and pumping against the gradient —> K+ Ions back to inner cell after Action impulse

active channels: are ion pumps, voltage controlled, transmitter controlled, stress controlled and temperature controlled —> all these „signals“ activate the pump
transports K+ out and Na+ Ions in the cell against their gradient with the energy ATP

K+ channels —> only for small effective diameter
Na+ channels —> Na+ and H2O goes through, K+ with H2O shell is too large

cell behaviour in low/high frequency field (electrical field lines)
?

absolute refractory time (time between two openings of a channel)
The period from the initiation of the action potential to immediately after the peak, is referred to as the absolute refractory time. = time from depolarisation to repolarisation. It's the time between two openings of a channel.
Because the K+ ions go back in the cell (this takes time) there can't be another impulse during that time because the membrane voltage isn't reached yet. So the Na+ channels are temporarily inactivated → no new AI can be generated.
In this time another stimulus is given to the neuron will not lead to a second action potential —> just one at a time
→ about to 2ms, one way propagation
relative refractory time is the time from end of repolarisation to the end of the hyperpolarisation. also the delayed opening and closure if the K+ channels.

nociceptors
bare Nerve cell endings that initiate the sensation of pain are nociceptors
When in pain they transduce receptor potentials which trigger action potentials
They react to thermal, mechanic, chemical stimuli
sense pain and are almost permanently activated

nociceptors → nerve fibres → dorsal horne of spine → up the spinal cord → thalamus as major relay station → cerebral cortex

- A delta-Faser for fast and sharp pain —> mechanical, mechanothermal stimuli (fast rising stimulus yields double pain experience
- C-Faser for slow and numb pain (not myelinisiert)

nociceptors respond to extremes of: (mostly all three of it)

- temperature
    - thermo sensitive channels
- pressure
    - mechano sensitive channels
- chemicals
    - acid sensitive channels (tissue damage → inflammation..)

why do we need secondary sensing cells (amplification)
to sense light and noises because they usually don't have the necessary energy for the membrane potential to create an action impulse. The stimulus of those are only a triggering event.
secondary sensing cells have intermediate amplification stages with v**ery high sensitivity**. Those amplify the signals so that an AI can be triggered. They work with ATP energy consumption.
the convert an amplitude-modulated membrane potential to a frequency-modulated signal.
synaptic cleft with following nerve cell act as output

plot changes of heart rate (respiration, sleep, stress, parasympathetic and sympathetic influence)
fluctuation of RR-Interval = heart rate through:

- SNS response during stress, mediated by hormones and nerves, heart rate increases → interrelated with LF band
- PNS system break and regeneration, mediated by nerve, heart race decreases → mainly interrelated with HF band at respiratory frequency

→ those two are complementary but not antagonistic systems

sleep: heart rate and blood pressure decrease with increasing sleep depth

what is rhodopsin
it is an light absorbing molecule
it isomerizates molecules through absorption of photons and makes a enzymatic reaction with a high amplification
when light irradiates, rhodopsin causes a deactivation of cGMP molecues

heart stroke volume
=the volume which the heart usually pumps in the body with one stroke
on average about 80 ml blood per stroke

blood flow
about 5 l/min

permittivity over frequency
frequency is permittivity dependent
the permittivity decreases with frequency
For the ranges of the frequencies, there are different dispersion mechanisms
gamma- Dispersion: f <30GHz is a orientation polarisation for bigger structures like molecules —> the molecules rearrange themselves along E
beta-dispersion: f<100Hz is a cell membrane polarisation —> the electric charge of
blood has about 3 stages of permittivity dropping with frequency, muscle has more

dispersion mechanisms
Dispersion is a specific change of biological tissue in limited frequency ranges. These changes give insight of the attributes of the tissue and the biggest frequency dependencies are with the permittivity

γ-Dispersion:

- microwave range (<30 GHz) —> orientational polarization with polar molecules
- range above 30 GHz but <100 GHz is on atomar level a displacement polarisation (upper bound for atomic nucleus movement)
- whith E!=0 the molecules align in direction of E

β-Dispersion:

- high-frequency range (1-100MHz) for cellular structures. Membranes are bypassed through displacement current so there is a cell membrane polarization
- with E!=0 the charge of the membrane aligns in direction of E

ON cells and OFF cells
ON cells: when there's light we want a action potential (e.g. light → hyperpolarisation → depolarisation → synaptic inverter) = sensing units

OFF cells: if there's light we don't want an action potential (e.g. light → hyperpolarisation → synaptic non-inverter)

so on takes a signal and makes an action potential
off takes a signal and does nothing

spatial resolution: convergence by adding outputs of rods, surround/lateral inhibition

penetration depth and its relation to μa
is the depth at which the Intensity I0 has fallen by 1/e (or 36%) given by $1/\mu_a$
is important for the transmission of light (key issue)
μ_a —> absorption coefficient, absorption decreases with higher penetration depth

explanation of ECG graph (what are the different parts --> PQRST)
p-wave: stimulus of the atriums
PQ-Intervall: atria fully stimulated —> no potential difference, blood flows to ventricles
QRS-complex: stimulation of the ventricles —> R zacke herzschlag
QRS is the highest spike
ST-Intervall: ventricles fully stimulated —> no potential difference
T-Wave: repolarisation of the ventricles (relaxation)

if the area of the QRS-complex is
>0 heart vector in direction of lead vector
=0 heart vector is normal to lead vector
<0 heart vector is the opposite direction of lead vector

EPSP = excitatory postsynaptic potential
is a local gradual difference of the membrane potential of cells which make an action potential. but is NOT an AI itself.
EPSP is the electrical positive difference of the membrane potential which is responsible for the action potential.
after the neurotransmitter bind to the membrane, Na+ Ion channels are opened and Na+ goes into the cell. then a depolarization of the dendrite is happening. The dendrite gives the stimuli to the axon hillock and there the EPSP are summed.
passing the stimuli as an action potential is only given when the threshold of all EPSP is higher than -50 mV.

vesicular sounds

- soft blowing or rustling sounds
- in the peripheral lung area (thorax) because of air swirls when inhaling
- the sources are distributed
- they are lower pitched and softer than bronchial breathing.
- There is no pause between inspiration and expiration
- normal 100-500 Hz, abnormal -1000 Hz

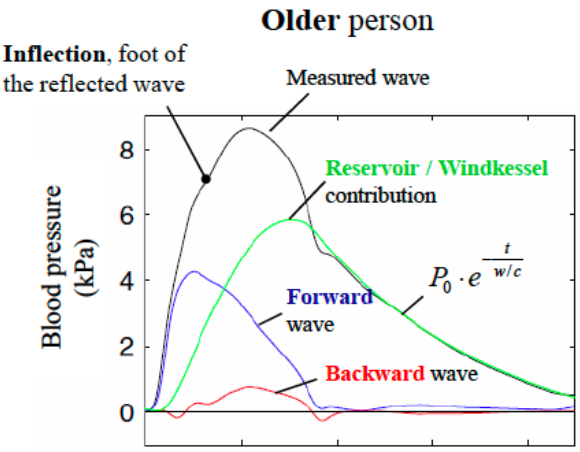
Windkessel

is a single compliant compartment just outside the left ventricle at the beginning of the aorta.

it is an elastic reservoir yielding space under high blood pressure (during systole) and returns to original shape and size during low blood pressure (during diastole)

it is to create a more even blood flow —> hold back blood during systole so that not too much at once is pushed through vessels —> takes away the pulsing

with advancing age, arteries and the Windkessel stiffen, the effect lessens -> increased systolic blood pressure. the increased bp indicates risk for myocardial infarction, strokes, heart failure, cardiovascular diseases in general



Hypertension caused by arterial stiffness!!

Goldmann-Gleichung

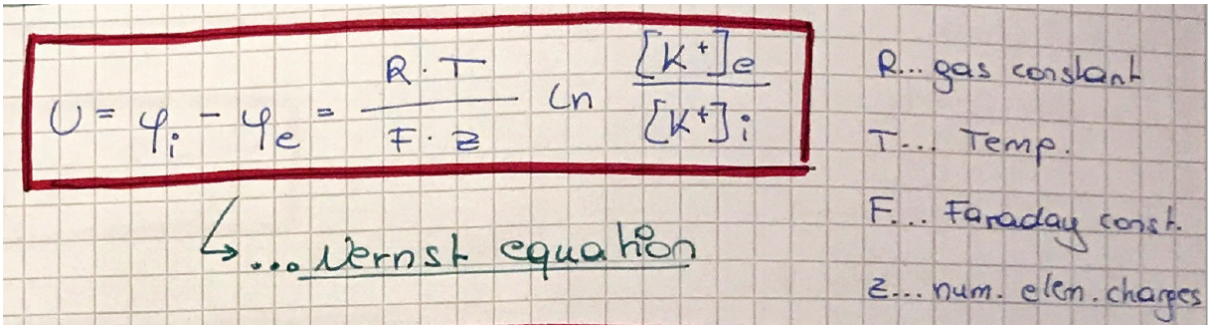
used to the membrane potential of cells, according to the concentration of ions and their membrane permeability

gK:gNa:gCL = 40:1:0 ratio

$$U = 58mV \cdot lg \frac{g_K \cdot [K^+]_e + g_K \cdot [Na^+]_e + g_K \cdot [Cl^-]_i}{g_K \cdot [K^+]_i + g_K \cdot [Na^+]_i + g_K \cdot [Cl^-]_e}$$

U ~-70mV, so its slightly higher than the -83mV which is measured. the consideration of the positive Na+ ions rise the absolute U value.

Nernst equation



Physiological issues for alternating signal in EFPG

electric field plethysmography
active procedure
—> procedure for measuring volume fluctuation of a body or organ
currency is given to the body, the voltage of the fluctuation is measured and therefore the impedance is calculated
—> applied alternating electric field, because the electrical field of the body alternates too
e.g. when inhaling the impedance increases (more air more impedance) when there is an currency the voltage rises

<u>signal components:</u> nearly constant component U_0 (>90% of u) and alternating component u_ (<10% of u) → because of respiratory and cardiac activity, displacement of organs etc.

alternating components —> störung ca 10%

- respiratory & cardiac activity
- displacement of organs
- displacement of liquids
- blood volume changes, flow velocity changes

- blood has a higher conductivity —> diastole = more blood in heart so the voltage is lower and the impedance is lower (more currency)

higher speed of blood means higher impedance (because blood cells align along blood vessels, pathway for current is longer)

Geometrical/Medium damping factors for acoustic signals
acoustic Signals lose energy when they are switching mediums
e.g. loses energy when going from skin to air because more than 99% of the acoustic pressure is reflected ($n_{body} > n_{air}$) —> high reflection factor

<u>damping with:</u>
geometrical distance 1/r (reverse square law) —> the wave loses energy over distance so its damped
Intensity I is proportional to 1/r^2
medium e^(-alpha*r), alpha= absorption coefficient of medium —> switching mediums takes energy, its frequency dependent in which medium a signal is damped

Absorption coefficient alpha depends on 3 phenomena:
inner friction —> different local particle speed = energy loss
heat conduction —> temperature adaptation takes energy from sound wave
molecular relaxation —> vibration of the molecules is delayed, that takes energy

$alpha = alpha_{innerf} + alpha_{heatc} + alpha_{molecularr}$
$alpha_{innerf}$ → medium viscosity
$alpha_{heatc}$ → difference of specific heat capacities at const pressure and volume
$alpha_{molecularr}$ → difference difference of sound velocities before/after relaxation

high frequencies travel through stiff materials (airways) damping is higher, listening must be close to source

low frequencies travel through soft tissue, sources are hard to locate, less damping

Mie Scattering

- light scattering = dispersion of light due to chaotic variation in refractive index
- only when size s of structure is in the range of the wavelength ƛ of the photon (600-900nm)
- the smaller the wavelength, the bigger the scattering
- the tissue is not homogen so there are a lot of transitions and a lot of refractive indices
- longer pathway of photons also increases possibility of absorption

if s >= ƛ
mie anisotropic scattering

- on molecule structures
- protein aggregation (Mitochondrien 1µm)
- collagen fibre bundle (3 µm)
- the scattering magnitude scales with s/ƛ

augmentation index

is based on blood pulse-wave reflection and is a measure of arterial stiffness and risk factor for cardiovascular disease.
with increasing age the vessels get stiffer and the reflections of the waves are earlier —> the blood pressure increases with age and so does the AI
the AI increases about 60-80%
AI is measured as the ratio of the central pulse Pressure cPP

When vessels are stiff, a reflected wave is formed where arteries split or the vessel is too stiff —> this wave goes back to the heart und increase the pressure at which the heart has to pump (gegen diese wellen)

increase of pressure P_ref because of reflected/backwards wave
P_{ref} increases with increasing distal stiffness, Δt decreases with higher distal stiffness, systolic pressure increases
--> together, AI and myocardial contractility increase to overcome increased P
-> load on heart increases

$AI = P_{ref} / P_{inc}$

optic respiratory changes
the breathing is visualized as a sinus-curve
inhaling: positive peak, exhaling negative peak

during inspiration

- the arterial diameter decreases and so does the left ventricular stroke volume
- the peripheral venous blood volume decreases and the venous diameter too

—> therefore transmitted light intensity increases during inspiration because the vessels and the blood can't absorb that much light

expiration —> opposite and μ_a*d increases

attenuation (dämpfung) of acoustic signals
acoustic Signals lose energy when they are switching mediums
e.g. loses energy when going from skin to air because more than 99% of the acoustic pressure is reflected ($n_{body} > n_{air}$) —> high reflection factor
sources of sound can be distributed or concentrated
distributed= vesicular sounds
concentrated = bronchial sounds

<u>damping with:</u>
geometrical factor 1/r (reverse square law) —> the wave loses energy over distance so its damped
medium e^(-alpha*r), alpha= absorption coefficient of medium —> switching mediums takes energy, its frequency dependent in which medium a signal is damped

Attenuation alpha depends on three "sub-alphas", they are summed up:

- alpha_inner friction: due to differences in local sound particle velocity, there is friction between the moving particles —> energy loss = damping
- alpha_thermal conduction: propagation linked with local variations of temperature, balancing of which withdraws energy from soundwave

- alpha_molecular relaxation: pressure translates to vibration of molecules (with a bit of delay) at the expense of rotational energy (of atoms) and translational energies (gas pressure)

$alpha_{innerf}$ → medium viscosity
$alpha_{heatc}$ → difference of specific heat capacities at const pressure and volume
$alpha_{molecularr}$ → difference difference of sound velocities before/after relaxation

efpg principles
Efpg is an active approach —> apply current and measure the medium impedance of human body to interpret the results
for registration of volume and/or conductivity changes of organs
—> applied alternating electric field, because the electrical field of the body alternates too
separate voltage and current electrodes

<u>signal components:</u> nearly constant component U_0 (>90% of u) and alternating component u_ (<10% of u) → because of respiratory and cardiac activity, displacement of organs etc.

<u>Values:</u>
- frequency is 20-100 kHz (below 20 nerves are stimulated, over 100 = dispersion), flat course of ε and γ

- current is 1mA (thermal effects increase with higher I)
    - probability of neural stimulation increase with increasing I and decreasing f
    - signal-to-nose ratio of u_ (=information carrier) increase with increasing I
    - avoid thermal effects
- difference amplifier → bandpass → demodulator → highpass → anti aliasing filter

recording technique:
- Recording with 2 electrodes:
    - measure contact and electrode impedance
    - Disadvantage: varying contact and electrode impedance, movement artefacts affect impedances

- Recording with 4 electrodes:
    - no contact impedance and if I is constant or voltmeter is ideal

<u>apply current instead of voltage</u>:

- current allows local assessment of conductivity changes and yields higher sensitivity
- when applying voltage “local no blood” leads to changes in the voltage drop that are misleading

<u>body correlations</u>
e.g inhalation:
more air —> more impedance —> more equipotential lines —> higher voltage outputs are measured

e.g. systole/diastole:
change of the impedance/ equipotential lines only around the heart (local occurrence) —> heart filled with blood during diastole —> less potential difference (cause blood leitet gut) —> less voltage output

definition of diastolic blood pressure
during diastole:
Phase 1 - relaxation
pressure in ventricles decreased —> Aortic valve closes
Phase 2: filling
pressure in ventricles decreases to pressure in atrium, mitral valve opens
blood streams from atrium in ventricles —> ventricle volume increases

<u>diastolic blood pressure</u>
average pressure about 80 mmHg
is a proportional function of the total peripheral Impedanz R
R = pressure ratio / blood flow
the smaller the radius the higher the peripheral impedance —> non linear, it increases to the exponent of 4
during diastole the vessel radius decreases so the pressure increases
during inhalation the diastolic blood pressure decreases
when the heart frequency decreases the diastolic pressure decreases

frequency behavior of acoustic signals on the air-tissue interface
in stiff materials (airways) the signals propagate with high frequencies and the sources are concentrated
in soft materials (tissue) the signals propagate with low frequencies and the sources are distributed and hard to locate

- low frequencies spread in tissue, low losses over distance
- high frequencies spread in the air(ways), high losses over distance (when changing to tissue)

acoustic Signals lose energy when they are switching mediums air to tissue
e.g. loses energy when going from skin to air because more than 99% of the acoustic pressure is reflected ($n_{body} > n_{air}$) —> high reflection factor
—> wavelength and size of reflected object have to be about the same size

signals which travel through the airways:

- low-freq (<300Hz): are absorbed from the airways tissue, which are soft tissues and so there are high losses of the low frequencies of a signal
- high-freq: sounds propagate along airways, travelling into branching structures

relation between wavelength and scattering
light scattering = dispersion of light due to chaotic variation in refractive index
only when size s of structure matches the wavelength ƛ of the photon (600-900nm)
the smaller the wavelength, the bigger the scattering

- Scattering = dispersion of light because of chaotic variations of the refractive index
- the tissue is not homogen so there are a lot of transitions
- longer pathway of photons also increases possibility of absorption
- the smaller the wavelength the bigger the scattering

when the structure (where its scattered) is < ƛ
—> Rayleigh isotropic scattering —> lipid-water (about 9 nm)
when the structure is >= ƛ
—> mie anisotropic scattering —> kollagenfaserbündel (3 µm)

Laplace Law
LV wall stress = (excess pressure * radius) / (2* LV wall thickness)

Left ventricular (LV) wall stress is the force acting against the myocardial cells. Its directly proportional to the left ventricular pressure and radius and indirect proportional to the wall thickness.

The law describes the left ventricular wall stress, which is important for determination of myocardial oxygen demand. (wie viel sauerstoff der Herzmuskel braucht)

Wall stress is also called after load = the load that the heart must eject blood against.

Selectivity for Na+ and K+ ions
ion channels are based on their selectivity of K+ and Na+ Ions
—> with H2O molecules
- ions are always surrounded by water molecules
- K+ ions have a bigger radius than Na+ ions
- the bigger the radius the smaller the mantle

K+ channel is only penetrable by small radius (with the small mantle K+ is small insgesamt)
Na+ channels for ions which are bind with a H2O molecule, but K+ bind with H2O would be too big for this channel —> so only Na+

Physiological Interpretation of QT Section in EKG
its the time from the beginning of the QRS-complex to the end of the T wave
QRS-complex: stimulation of the ventricles —> depolarization of the ventricles
T-Wave: repolarisation of the ventricles

the QT section depends on the heart rate. It presents the period of the ventricle stimulation.
If the QT section is longer than usual, it could be a cardiac arrhythmia and lead to kammer flimmern
Long QT-Syndrom is mostly triggered through medicine.

Relation between blood pressure and pulse transit time (PTT)
Pulse transit time refers to the time it takes a pulse wave to travel between two arterial sites. The speed at which this arterial pressure wave travels is directly proportional to blood pressure. An acute rise in blood pressure causes vascular tone to increase and hence the arterial wall becomes stiffer causing the PTT to shorten. When blood pressure falls, vascular tone decreases and PTT increases.

PTT = time a pulse wave takes to travel to a certain distance within a blood vessel.
measure can allow deductions considering blood pressure and elasticity of vessels. —> systolic-diastolic deflection
The reference blood pressure P_ref increases when the PTT decreases and that can lead to a hypertonie (bluthochdruck)

Permittivity in tissue
=the ability of a material to store electrical potential energy under the influence of an electric field
In the body the impedance is inhomogeneously distributed
conductibility (Leitfähigkeit) depends on the Frequency
conductibility increases with increasing frequency
the frequency depends on the permittivity
because conductibility = frequency * permittivity
<u>if the frequency increases, the conductibility increases and the permittivity decreases</u>

<u>Dispersion mechanismus</u> —> important for permittivity because the better the two mediums can mix the better permittivity there is

3 mechanisms:
displacement polarisation —> atoms, high frequencies, E-feld displaces ladung -> f < 100 000 GHz

gamma-Disperiosn —> bigger structures (molecules), orientational polarisation -> f < 30 GHz

beta - dispersion —> even bigger structures (cells), cell membrane polarisation -> f < 100 MHz

Secondary sensing cells
Special epithelial cells as receptors
they are connected via a synaptic gap to the nerve cell as output
—> for sensing lights, sound, acceleration, etc
requires less activation energy than primary sensing cells, because light etc do not have enough energy to change the membrane potential —> so the secondary sensing cells have intermediate amplification stages with very high sensitivity. Those amplify the signals so that an AI can be triggered. They work wird ATP energy consumption.
they convert an amlitude-modulated membrane potential to a frequency-modulated signal.

Stimulation of the sensing cells (noises..) is just a trigger like a switch not the real signal

Osmoreceptor
for volume and salt concentration regulation

osmosis —> water diffuses through a membrane in direction of the higher concentrated solution (osmotic pressure >0) because water tries to equalize these solutions
when the concentrations of the impermeable substances (Na+, Cl-) are equal —> osmotic pressure =0

osmotic pressure >0
-> H2O flows into cell
-> the cell swells
-> mechanic channels for K+ and Cl- are opened
> salt concentration in the cell decreases
-> H2O stops - > osmotic pressure =0

adaptive filtering
When using adaptive filtering on a component from a given signal, the threshold is being adapted to changes in other components - different to fixed threshold that cannot respond to e.g. changes in heart rate

= adaptive cutoff
for respiratory activity

to cancel out noise, feedback, cancellation
→ filter cardiologic signals out of respiratory signal
e.g. when monitoring the breathing the heart rate has to be filtered out

Relation between P_O2 and blood oxygen saturation
Oxygen saturation (SaO2) is a measurement of the percentage of how much hemoglobin is saturated with oxygen.
oxygen is mainly carried by hemoglobin
Oxygen is transported in two ways:
oxygen dissolved in blood plasma about 1-3%
oxygen bound to hemoglobin (SaO2) about 97-99%

the oxygen is delivered into tissue by diffusion driven by pO2 between the plasma and the tissue cell

the oxygen saturation in the blood is on average 97-99%
during apnea it is 80%

The higher the PO2 the higher the oxygen saturation in the blood. The relation is non linear

the oxygen goes into the tissue from the red blood cells via diffusion in the plasma and then diffusion from the plasma in the tissue. all that with the force of the pO2 pressure

exogenous clock (= solar and social clocks)
e.g. light, length of day
is partly responsible for the regulation of the body temperature
because the highest temp. is around 6 o clock p.m.
the lowest temp around 3 a.m.
The exogenous clock tells the body (together with the indigenous) what time it is and so the temperature can be adapted

ST-Interval and what it means
Is the time between the S-peak of the QRS complex and the T-Wave from an ecg.
During the ST Interval the ventricles are fully stimulated, so there should be no peak. At the end of this interval, the repolarization of the ventricles start.
changes of this line (higher or lower) indicate a bad myocardial perfusion.

rods & cones - which is larger, and what does it mean?
they are photoreceptors on the back of the retina and are there to difference brightness and color of light—> they are secondary sensing cells

rods (stäbchen) are very sensitive for light and brightness but do not „see“ color, in the dark only rods are active

cones (zäpfchen) are less sensitive and recognize color.

- 3 different types for the 3 colors red, green, blue
- the most cones are in the fovea
- the cones have the highest resolution because of the 1:1 connection between receptors and neurons

there are less cones than rods in the eye and the rods are larger than the cones so the rods are more sensitive

dark: depolarization because of Na+ inflow through transmitter controlled channels and synaptic transmission
bright: cGMP concentration reduces, synaptic transmission stops
→ no action potential

sleep apnea - what is it? types?
sleep apnea is a sleeping disorder, caused by abnormal pauses of the breathing. This pause is at least 10 seconds long and is usually accompanied by snoring.
apnea described by respiratory disturbance index, RDI >5
during apnea:

- hypoxic stimulation of chemoreceptors
- oxygen is saved → vessels restrict
- systolic and diastolic pressure rise

there are 3 different types:

obstructive sleep apnea:
it is caused by a physical block of the airflow because of reduced muscle tone, high body mass or narrowing of the upper airways.
—> the airflow as an sinus curve is very flattened almost no visible peaks

central sleep apnea:
caused by the central nervous system, like the brain forgets to breathe
—> normal sinus curve but with longer parts that are zero

mixed apnea:
include both of the above

ECG function
the ecg is a passive method via electrodes on the body —> they are measuring a potential difference which is caused by the electric signals of the heart
the ecg measures the propagation of the electrical signals inside the heart muscle. also the heart position and heart rate.
more equipotential lines in the front than the back

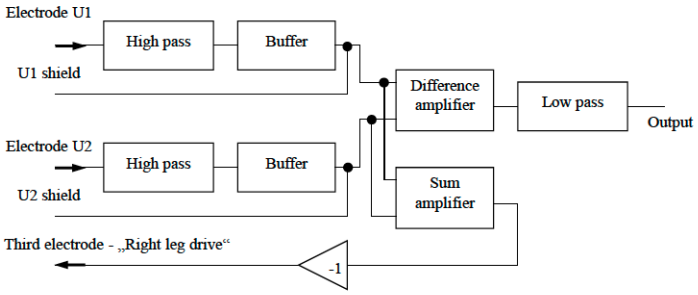
- two electrodes to measure the potential difference
- a high-pass-filter to filter low frequencies (movement artifacts)
- a puffer for an active shield
- a Third electrode on the foot to avoid interferences
- a differential amplifier to compare and amplify the inputs from the electrodes
- low pass filter to filter the high frequencies

depolarisation of the heart:
registration of the electrical stimuli of the heart muscle —> with potential difference on the body surface
if there is no stimuli —> cells internal negative, cells outside positive
if stimulated there is a current in the cell —> current dipole

heart is stimulated through the sinus node —> stimulation goes from atrium to ventricles so there is a summed up current dipole

the cells have an equalizing current outside and there is the potential difference

Einthoven: 2 electrodes on the hands, 1 on the foot
wilson derivation: 6 electrodes on chest, 2 on hands, 2 on foot



heart rate - how is it connected with the autonomous nervous system
the heart rate is mainly independent from the brain. It is the interval between two R peaks of an ecg.
The autonomous nervous system regulates key functions of the body, e.g heart-rate

heart rate is controlled by two branches of the ans —> the sympathetic nervous system and the parasympathetic nervous system
these two are complementary but not antagonistic systems

- sns releases the hormones to accelerate the heart rate and force a contraction
- sns triggered e.g. through stress —> increases heart rate e.g. during inhalation
- sns through hormones and nerves
- sns relatively slow
- pns is a system break and regeneration
- pns through vagusnerv —> decreases the heart rate e.g during exhalation
- pns relatively fast

so the ans has sns and pns to maintain the balance of the heart rate

HEART RATE. describe the heart rate dependent to the breathing cycle
inhaling increases the heart rate, breathing out decreases the heart rate
when breathing in there is less space for the heart because the lung volume gets bigger —> so the stress level increases and the sns is activated to force more contractions
during exhalation the space gets bigger, there is a relaxation and the pns kicks in to slower the heart rate

sleep stages
REM (rapid eye movement) : paradox sleep, high mental activity and inhibition from muscle movement, dreams to overcome the impacts of the day, implicit memory tasks (motoric skills)

NREM —> for revitalising the body
has 4 stages, there for explicit memory tasks (learning vocabulary)
stage 1: start of sleep, slow eye movement, partly conscious
stage 2: unconsciousness, but easily awaken
stage 3+4: deep sleep

classification of the stages through eeg

heart rate & blood pressure decrease, respiratory frequency reduced while NREM & respiratory volume increase

PROBING DEPTH. describe the probing depth
describes depth Z to which the incident light penetrates the tissue, where changes of optical characteristics at this depth Z within the tissue lead to change the intensity I_0 by at least 5%
—> key issue for the reflection of light
—> measured with a source photodetector and its parameters: d_r, μ_A, μ_s'

- low probing depth → increases the absorption or scattering
- depth z is non-linear dependent from ƛ and S, and dependent from blood volume
- more blood locally = higher absorption, decreasing probing depth

salt receptors
secondary sensing cell for primary taste salty
NaCl → Depolarisation --> Opening of Ca2+ channel → synaptic propagation
Na+ concentration in extra cellular space increases - more Na+ ions enter the cell, causing depolarisation. Ca2+ channels open, causing a synaptic signal

sour receptors
secondary sensing cell for primary taste sour

detection of pH-level via H+ channels, blocked K+ channels, activated Na+ channels

low pH level (e.g. signal for spoilt food) means more H+ ions overall and inside the cell -> membrane potential increases

bitter receptors

secondary sensing cell for primary taste bitter
numerous taste receptors → activation of enzymes → opening cation and Ca2+ channels
signal for potential danger

sweet receptors
secondary sensing cell for primary taste sweet
numerous taste receptors → activation of enzymes → opening cation and Ca2+ channels
signal for intaking food rich with calories (partly digestion in mouth)

umami receptors
secondary sensing cell for primary taste umami
numerous taste receptors → activation of enzymes → opening cation and Ca2+ channels
signal for protein intake

Tonic-phasic receptor
is a sensing organ

- like a phasic receptor but adaptive
    - takes care of the change = adaption
    - amplitude and parts of duration of the signal are codes

        - Generates an AI only at the beginning of an excitement alternating current
- adaption through
    - ional mechanisms: activation of voltage-gated K+ channels and deactivation of voltage gated Na+ channels —> decreasing receptor potentail
    - mechanical structure: filters DC component out of stimulus → only sharp changes
- the action impulses are as long as the membrane potential is above the threshold
- intervals between the action potentials are getting bigger, even tough the potential difference is above the threshold
- number and order of action potentials give information about the intensity of the stimulus
- quick adaptation, moderately rapid

structure of membrane
lipid double layer!
lipid molecules as basic substance —> hydrophilic heads, hydrophobe tails
lipid double layer (liquid structure) —> high capacity (works like condensator)
receptors, enzyme, antigenes and ion channels on the outside of the cell
saturation of stray electric fields inside and outside

extracellular space —> polar binding between heads and water (hydrophil) and polar binding between heads

intracellular space —> hydrophobic binding between tails

Frequency dependent sound transmission
wavelength (space) * frequency(time) = velocity

lower frequency (<300Hz) sounds propagate along tissue (softer tissue resonates to lower frequency, can't align to too high freqs)
so the lower frequencies absorbing from the airways to the tissue, airways are non-rigid resonating tubes and absorbing sound and energy

higher frequency propagates along stiffer media e.g bones and through airways

sound travels through the air into the branching structures = longer way

vessels with rising pressure stiffen —> so pulse waves increase the frequency

low frequency sounds are hard to locate, distributed source
high frequency sounds —> damping is higher and the source must be closer to listening location

pacemaker of the heart
there for the propagation of the activation

- sinoatrial node: primary pacemaker, about 70 signals per minute, generates action pulses
- AV-node: 50 signals per minute
- bundle of His: 30 signals per minute

sinoatrial node gives the signals (and overwrites the others, because there would be an uneven mix) but all 3 are always active for safety

Ion channels
are on the outer side of the membrane
ion channels are based on their selectivity of K+ and Na+ Ions
—> with H_2O molecules
    ions are always surrounded by water molecules
    K+ ions have a bigger radius than Na+ ions
    the bigger the radius the smaller the mantle
K+ channel is only penetrable by small radius (with the small mantle K+ is small insgesamt)
Na+ channels for ions which are bind with a H_2O molecule, but K+ bind with H_2O would be too big for this channel —> so only Na+

those channels can be voltage-, transmitter-, temperature and stress-gated

dispersion mechanisms in the tissue
Dispersion is a specific change of biological tissue in limited frequency ranges. These changes give insight of the attributes of the tissue and the biggest frequency dependencies are with the permittivity

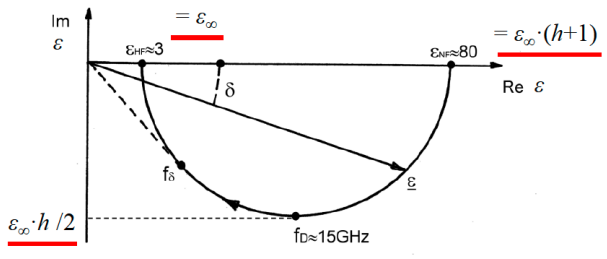
γ-Dispersion:

- microwave range (<30 GHz) —> orientational polarization with polar molecules
- range above 30 GHz but <100 GHz is on atomar level a displacement polarisation of the nucleus (upper bound for atomic nucleus movement)
- with E!=0 the polar water molecules align in direction of E (or the nucleus displaces)

β-Dispersion:

- high-frequency range (1-100MHz) for cellular structures. Membranes are bypassed through displacement current so there is a cell membrane polarization
- with E!=0 the charge of the membrane aligns in direction of E

decrease of permittivity over frequency
increase of conductivity with increasing frequency
larger structures need more time to align, can only handle lower frequencies! (also true for sound!)
water dispersion:



pumping of venous blood
parallel arrangement of veins and arteries -> the arterial blood is pumped into arteries, therefore indirect pumping of venous blood, support by venous valves to stop the backflow
The arteriell blood is pumped, but indirectly also the venous blood
"respiratory pump": blood volume and vein umfang decrease during inspiration, "sucking" blood back towards heart from the peripheral vein system so the blood volume in the veins in thorax increases

electrical axis of the heart
important parameter —> direction of electric stimulation
= mean direction of the total dipole during QRS complex (major electrical activity); R-peaks are not concurrent in the leads.
QRS —> biggest peak

determination by the net area of QRS complex.

- area > 0 = heart vector in direction of lead vector
- area ~ 0 = heart vector perpendicular to lead vector
- area < 0 = heart vector opposite to lead vector

blood pressure and respiration
Inspiration:
intrathoracic pressure decreases, stroke volume of left ventricle decreases, right ventricular stroke volume increases, leftward displacement of interventricular septum, the systolic blood pressure decreases, mean pressure decreases

apnea:
reduction of arterial baroreflex, diastolic and systolic pressure increases, mean pressure increases

blood pressure in general
heart pumps blood in circular flow with every stroke —> pulse waves

average blood pressure = stroke volume * total periphere impedance
stroke volume= 70-80 ml
periphere impedance —> the bigger the vessels the smaller the impedance
arteroils reduce the pressure the most
the average blood pressure should be over 60 mmHg, otherwise ischemic situation

<u>systolic blood pressure:</u>

- about 120 mmHg
- proportional to stroke volume and aortic impedance (depends on stretchability of arteries) ~1/compliance

- illness: arteriosclerosis = limited distention and pressure rises

<u>diastolic blood pressure:</u>

- about 80 mmHg
- proportional to the total peripheral resistance R → ΔP = Q*R
- R mainly determined by arterioles (responsible for most of pressure)
- if the vessel radius decreases, the diastolic pressure increases = vasoconstriction
- if the heart rate decreases, the pressure decreases because the blood has more time to flow

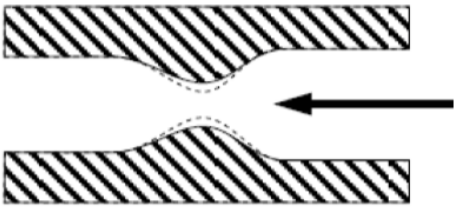
during the systole the heart cannot provide itself with blood, only during diastole

<u>vessel tissue control the blood pressure:</u>
stiff collagen —> more distal arteries, higher pressure
complaint elastin —> more in proximal arteries, more elasticity = lower pressure
smooth muscle —> more elastic = lower pressure, for local blood supply

Charge and shape complementarity
membrane structure has charge and shape complementarity
there is a key and lock principle for shapes and also for minus and plus charge (- and + attract eachother)
the ion channels on the outside can be transmitter gated,
transmitter bind to the channel through complementary conformation and charge between channel control molecule → therefore it opens
there is a charge between channel control molecule and transmitter

<u>in general:</u> way of binding molecules together, is used with transmitter gated channels, charge and shape of molecules must be complementary in order to bind to each other

Origin/model of continuous lung sounds
=lung sounds developed because of air swirls



- there are vesicular sounds —> auscultation in the peripheral lung area, swirls while inhaling, distributed sources, air tubulences during inspiration
- bronchial sounds —> auscultation on bigger airways, turbulent air flow induces vibration on the walls of the airway, during in and exhalation, central source, caused by oscillation of larger airways

continuous sounds are sounds that are normal or pathologic. Mostly through constriction of the airways. These constrictions are „always“ there, they don’t open up quickly
e.g. wheezing 100-500 Hz

discontinuous sounds: pathological only, explosive reopening of small airways, fine and course crackling up to 1kHz

Gamma-dispersion
γ-Dispersion:
Dispersion is a specific change of biological tissue in limited frequency ranges. These changes give insight of the attributes of the tissue and the biggest frequency dependencies are with the permittivity

- microwave range (<30 GHz) —> orientational polarization with polar molecules, molecules rearrange themselves along E
- range above 30 GHz but <100 GHz is on atomar level a displacement polarisation of the nucleus (upper bound for atomic nucleus movement)
- with E!=0 the molecules align in direction of E, yields the orientation along the electric field gradient

Voltage versus current application in electrical field plethysmography
efpg is an active procedure
its an measurement for volume fluctuation from the body or organs
application of current —> a voltage can be measured and the impedance is calculated

—> applied alternating electric field, because the electrical field of the body alternates too
the current should have an amplitude of 1 mA, the possibility of a neuronal stimulation increases with increasing current

current application has more advantages over voltage application
measured is the difference between the potentials of the electrodes with a differential amplifier

<u>apply current instead of voltage</u>:

- current allows local assessment of conductivity/impedance changes
- higher sensitivity
- when applying voltage “local no blood”(nearby areas) leads to changes in the measurement

HRV - heart rate variability
hrv is the ability to change the time interval between two heart strokes —> to adapt to different situations
it's a measurement for the general adaptability of an organism
responsible for the acceleration or slower of the heart rate is the autonomous nervous system
the more variable the the heart stroke the healthier the organism, e.g survival after myocardial infarct
fluctuation of RR-Interval through:

- SNS response during stress, mediated by hormones and nerves, heart rate increases → interrelated with LF band
- PNS system break and regeneration, mediated by nerve, heart race decreases → mainly interrelated with HF band at respiratory frequency

→ those two are complementary but not antagonistic systems

<u>calculation</u>: with the ecg the R-peaks are measured and the intervals of each two R-peaks are looked at
HRV index = number of all RR intervals divided by the height of the histogram of RR intervals

types of gate controlled channels
VO:

- voltage gated ion channels:
  - opens in dependency to the membrane potential. —> in every nerve cell
  - in resting state: extremely high electrical field, channel closed by protein.
  - reduction of E to the threshold value E_S by voltage -> opening of Na+ gate (protein re-aligns to the changed electrical field)
- Transmitter gated channels:
  - if specific transmitters bind to the channel it opens
  - transmitter bind to the channel through complementary conformation and charge between channel control molecule → therefore it opens
- stress controlled channels:
  - membrane proteins response to mechanical stimuli (due to stress)
- temperature controlled channels:
  - receptors for heat and cold activate opening/closing?
  - warmth: channels react to rising temperature (and cross-sensitivity to capsaicin ["scharf"]). more Na+ inflow, action potential ensues
  - cold: channels open for lower temperature (and cross-sensitivity to menthol). less K+ leaving the cell - action potential ensues

Internet:

- voltage controlled ion channels:

  opens in dependency to the membrane potential. —> in every nerve cell

- chemical controlled ion channels:

  opens when a specific molecule (ligand) bind to them. in synapsis or sensing cells

- mechanical controlled channels:

  opens dependent on mechanical tension of the surface of the cell —> in mechanical sensing cells

- thermal controlled ion channels:

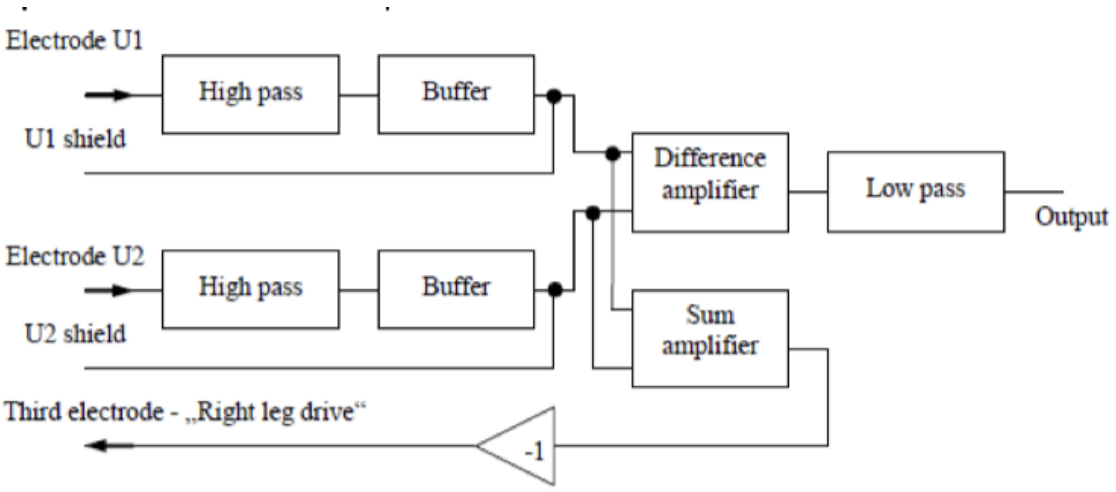
opens with impact of thermal fluctuation

- light controlled ion channels:

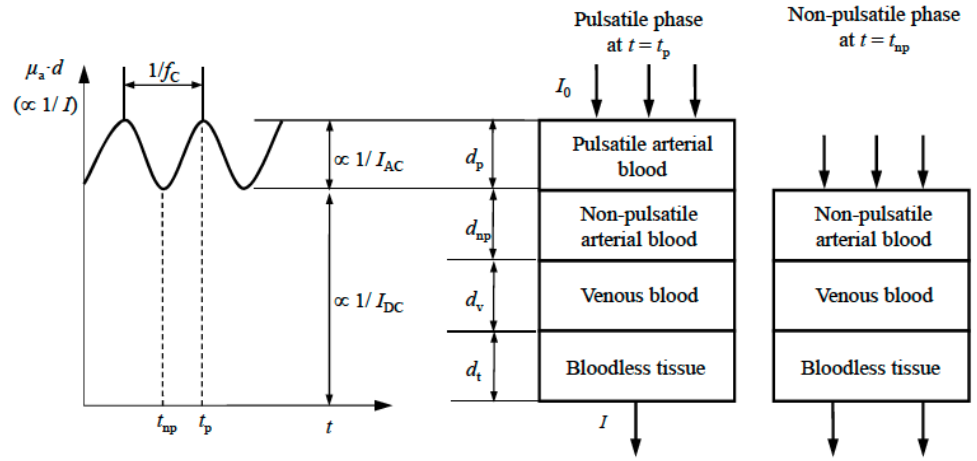
  change their conformity under irradiation of a specific wave length —> rhodopsin

Right leg drive
for the ecg with 2 measuring electrodes (for the potential difference) there is a third electrode placed on the foot.
its there to

- avoid interferences, because humans can absorb interferences from the surrounding and those can interfere with the measurement
- Third electrode measures those interferences and inverts them, than adds them to the output signal of the two electrodes which come out of the puffer —> therefore the interference is „deleted“



compartment model of the tissue
for registration of arterial blood oxygen S and the absorption
End of systole = pulsatile phase, end of diastole = non-pulsatile phase



Lipid Struktur

- the membrane structure is a lipid double layer (liquid structure)
- receptors, enzymes, antigenes, ion channels are all on the outside of the cell
- this double layer works as an isolator, so the membrane has a high capacity (like a condi)
- lipid molecules as a base substance —> have hydrophobic tails and hydrophilic heads
- the lipid molecules act like flip flops
- extracellular space: polar binding between the heads and water molecules and polar binding between the heads
- intracellular space: hydrophobe binding between the tails

—> leads to saturation of the electric dispersion fields inside and outside

Effect of Respiration for optical biosignals
blood absorbs light better than the surrounding tissue. —> more blood = higher absorption
during inspiration the blood volume decreases because the blood is drawn to the thorax —> when an optical signal is put in the body (light source measured by a photodetector) the measured intensity of the light increases because there is less blood and therefore less absorption of the light, which is also dependent on the red light particles in the blood
for expiration its the opposite

dependence of bending sensitivity of a bilayer on material properties dime

$\sigma > 0 \rightarrow$ for tension and $\sigma < 0$ for compression
finite length bilayer -> strongly inhomogeneous stress distribution
mechanical factor of sensitivity depends on material properties and dimensions
sensitivity is higher with stiffer/thicker materials and with an ideal bilayer. alsp not bad with glued bilayer

bending sensitivity $s = k_e * k_m \rightarrow$ product of magnetoelastic factor and mechanical factor
quantitative assessment of bending sensitivity

composition of arteries

3 layers

- 1 layer: outside layer, strengthened with stiff collagen —> the bigger the vessel the stiffer
- 2 layer: conform elastin —> provides an elastic artery and a continuous blood flow (takes away the pulsing)
- 3 layer: smooth muscle —> contraction of the vessel with this muscle

heart sounds

heart sounds develop through closing of the heart-valves (spectogramm)

1. sound: at start of the systole
    - closure of the mitral valves and tricuspid valve
    - the loudest and longest noise 140ms, with low frequency

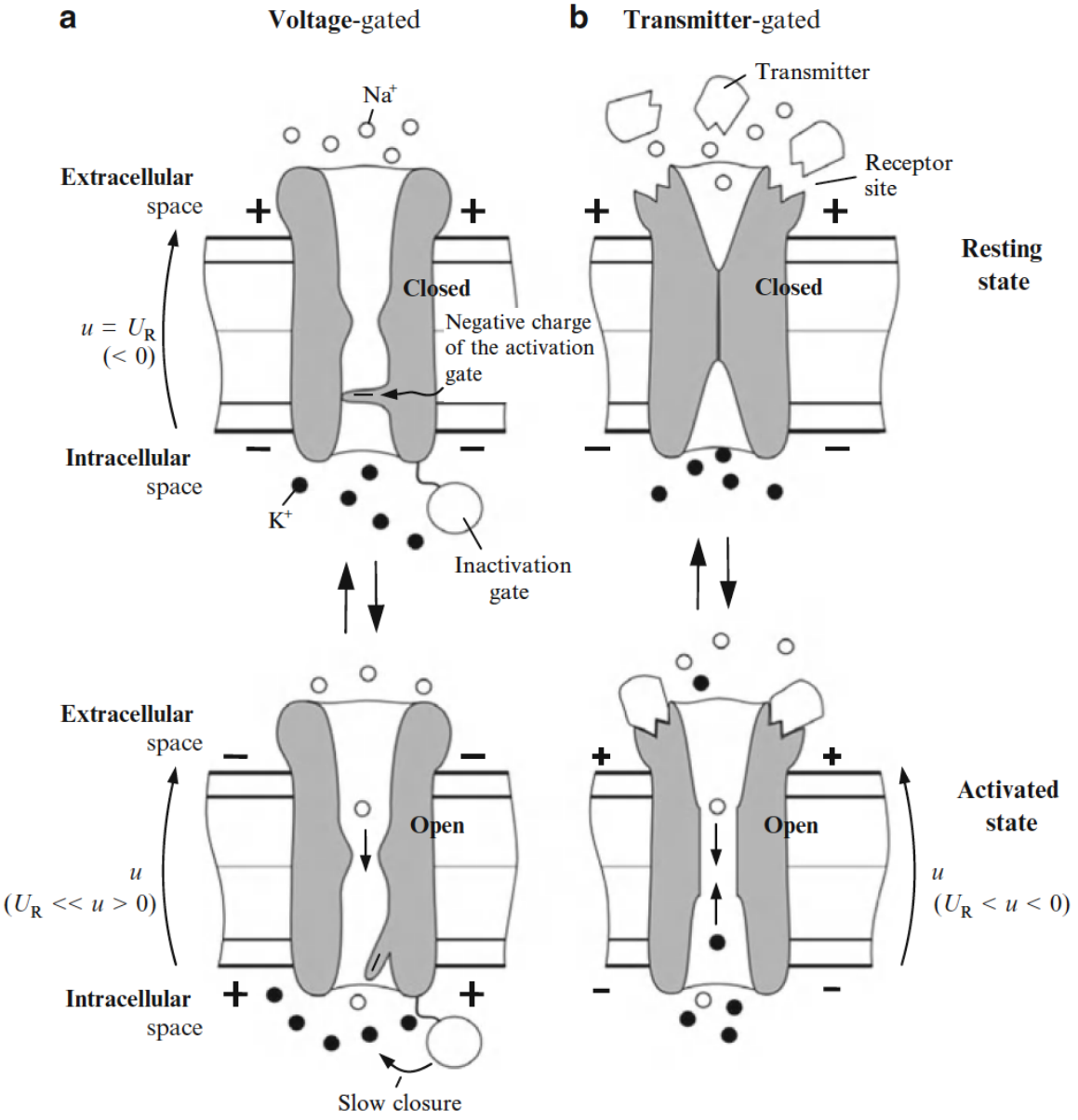
2. sound: at end of the systole

    - closure of the stiff aortic and pulmonary valves
    - also vibration of the atriums and ventricles
    - weaker intensity and sounds like a click, 110ms

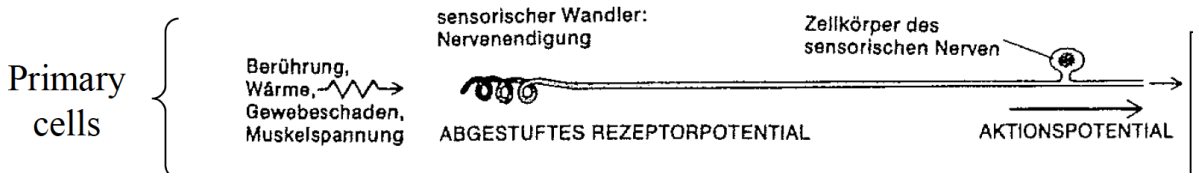
other sounds coming from the heart are mostly pathological
e.g opening of the valves
up to 100 Hz
$f_1 < f_2$

Effective tissue conductivity and its relationship to f (frequency)
the conductivity of tissue increases with increasing frequency
the conductivity is dependent on the frequency (local Merkmal)

transmitter controlled channel
transmitter bind to the channel through complementary conformation and charge between channel control molecule → therefore it opens
there is a charge between channel control molecule and transmitter
Na+ gated channels open 10x faster than K+ channels
Na+ are involved in building of action potential



primary sensing cells
bare nerve endings = dendrites, as receptors
nerve axons as output
i.e. for touching, warmth, tissue damage, etc.
→ generates an action potential and gives that to the central nervous system



they make an conversion of an amplitude-modulated membrane/receptor potential into a frequency-modulated signal = impulse train
so the membrane potential which comes from the receptor voltage is converted into an action potential.

Rayleigh scattering
light scattering = dispersion of light due to chaotic variation in refractive index
only when size s of structure is in the range of the wavelength ƛ of the photon (600-900nm)
the smaller the wavelength, the bigger the scattering

rayleigh **isotropic** scattering: (ex. blue sky)
when s < ƛ
lipid water membran ca. 9nm
Water protein periodicity of collagen fibrils, 70 nm
the scattering magnitude scales with s/ƛ^4

acoustic signals

heart sounds (closing of valves), lung sounds (air turbulence), snoring sounds (vibration of soft palate or uvula), apneaical sounds (no breathing, followed by gasping for air)

- heart sounds: ~ 100Hz
- lung sounds: ~ 100-500Hz
- snoring sounds: up to 800Hz
- obstructive snoring: 2000Hz

probing depth vs penetration depth
both describe depths to which the incident light penetrates the tissue

<u>probing:</u>
describes depth to which the incident light penetrates the tissue,
where changes of optical characteristics at a depth Z within the tissue lead to change the intensity I_0 by at least 5%
—> key issue for the reflection of light
—> measured with a source photodetector and its parameters: d_r, μ_A, μ_s'

- low probing depth → increases the absorption or scattering
- depth z is non-linear dependent from ƛ and S, and dependent from blood volume

non linear dependance of scattering coefficient on wavelength and absorption
more blood locally = higher absorption, decreasing probing depth
absorption law: $I = I_0 * e^{-\mu a * d}$ e-term= probability of survival of photon after d

<u>penetration:</u>
is the depth at which the Intensity I_0 has fallen by 1/e (or 36%)
given by $1/\mu_a$
is important for the transmission of light (key issue)
μ_a —> absorption coefficient, absorption decreases with higher penetration depth

forward vs. inverse problem

- forward problem: we want to know what the source does to the signal, e.g. impedance - this is easy, we measure it.
- inverse problem: determine what happens based on the signal, e.g. out of the ECG, determine if the heart is healthy (more complicated)

stethoscope and frequencies
stethoscope: auscultation on the chest, coupling of sounds, chestpiece as amplifier → consists out of bell and membrane

auscultation on the chest: only low frequencies can be heard, because they progress through soft tissue, high frequencies have higher damping so they

only travel through the airways and are damped or reflected by the tissue if they wanna “get out”

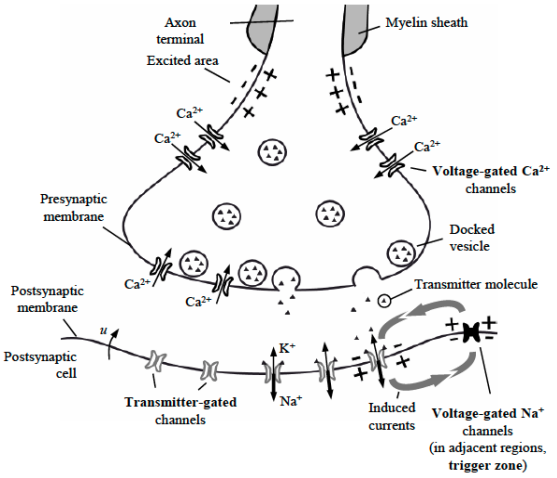
The smaller the radius of the membrane the higher the frequency f
little membrane radius —> higher frequency can be heard
the stiffer the membrane the higher f can be heard

bell: for resonance
the smaller the bell volume the higher the frequency
small bell volume → higher f can be heard

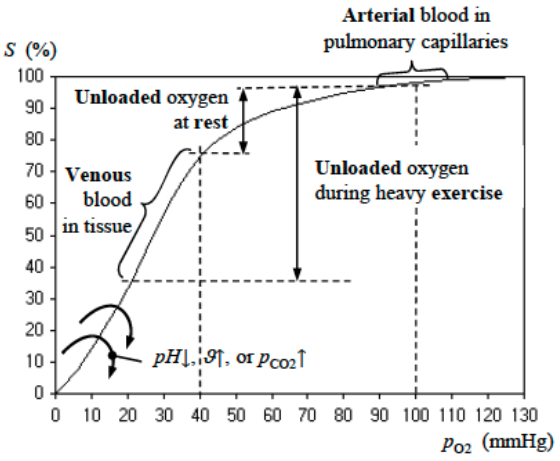
synaptic propagation

1) synaptic bouton has vesicles with transmitters
2) the signal (presynaptic AI) reaches the end of the axon membrane → voltage change
3) voltage dependent Ca^{2+} channels open
4) Ca^{2+} ions flow in the bouton → it gets “positive” → depolarisation of the membrane
5) vesicles filled with neurotransmitters go intracellular to the presynapsis and fuse with the membrane. Their content is laid off into the synaptic gap
6) the neurotransmitter diffuse through the synaptic gap to the postsynapsis and bind onto the receptors of its membrane to induce a special effect. → opening of transmitter-gated channels for Na+ and K+
7) Na+ inflow stronger than K+ outflow → depolarisation of postsynaptic membrane = epsp bauen sich auf
8) AI to the right and to the left where the Na+ channels reside

in a network of cells the propagation goes from one cell to another
e.g. patellar reflex → propagation from nerve cell to muscle



functionality of blood oxygenation
hemoglobin oxygen saturation SaO2
Oxygen saturation (SaO2) is a measurement of the percentage of how much hemoglobin is saturated with oxygen. average 97-99%



Oxygen is transported in two ways:
oxygen dissolved in blood plasma (pO2) about 1-3%
oxygen bound to hemoglobin (SaO2) about 97-99%

- O2 mainly carried by hemoglobin (=protein molecule)
- the O2 is delivered to the tissue by diffusion which is driven by the p_{o2} (sauerstoff partial druck)
- this diffusion is between the plasma and the tissue cell
- oxyhemoglobin is like a local oxygen storage to maintain p_{o2}

red blood cell → plasma → tissue cell
there to provide the organs and cells with oxygen

arterial saturation shows oxygen supply to tissues
venous saturation shows oxygen uptake by tissue

body temperature
core temperature about 37°C
circadian variation +- 0,6°C (min 3 am, max 6pm)
the target value is readjusted according to the inner clock → endogenous and exogenous
at the surface of the extremities the temperature is about 28°C, but it depends on the surrounding temperature

regulatory mechanisms:
- physical work
  - temperature goes up
  - activation of warmth receptors in the skin → vessels dilate and have reduced heat exchange → perspiration → heat loss
- freezing

    - temperature goes down
    - activation of cold receptors → vessels restrict → muscle tremor (zittern) → heat generation and normalization
- fever
    - temperature goes up
    - reduced heat dissipation and blood circulation in skin → vessels restrict
    - increased heat production because of shivering → sensation of cold
    - **or**
    - temperature goes down
    - sensation of cold

pain perception
pain = tissue under stress or damaged
the nociceptors (=primary sensing cells with bare nerve endings as receptors) sense pain and are almost permanently activated

nociceptors → nerve fibres → dorsal horne of spine → up the spinal cord → thalamus as major relay station → cerebral cortex

- Adelta fibres: quick & sharp pain
- C-fibres: slow & dull pain

nociceptors respond to extremes of: (mostly all three of it - polymodal)

- temperature
    - thermo sensitive channels
- pressure
    - mechano sensitive channels
- chemicals
    - acid sensitive channels (tissue damage → inflammation..)

- pain = resolved in central nervous system as ratio between nociceptor input and thermo input?
- temporal ignorance of pain can be accomplished due to release of endorphins in the brain
- slow and dull pain can hardly be adapted and lasts much longer, quick and sharp pain is faster gone

there are three types of pain:

- referred pain = convergence of neurons, pain from organs felt in skin area
- phantom pain = severed intermediate spinal nerves still send pain signals
- chronic pain = origin is long gone but still pain persistence (trauma)

sense of light and vision

secondary sensing cells
visible light is mix of different wavelengths
color: mix of absorbing and reflecting certain wavelengths
Black: total absorption
White: total reflection

- Light enters cornea -> passing pupil -> lens (bending) -> retina photoreceptors

Rods: highly sensitive to light, black and white
Cones: detect color, low sensitivity, concentrated in fovea region of retina (low blood vessels)

Photoreceptors: dark(transmitter cGMP gated channels open for Na, transmission) vs bright (reduced cGMP concentration, no synaptic transmission)

sense of hearing

- secondary sensing cell with hair cells as mechanical receptors (sensory hairs)
- sound is a mechanical vibration, it has to go through passage to create a signal = through ear
- pinna → auditory channel → eardrum → middle ear (3 bones) → oval window → cochlear duct (fluid filled) → vibration of basilar membrane → bending of sandwiched sensory hairs → nerve impulses → round window of tympanic channel
- the hearable frequency range is 20 - 16 kHz with no direct coding
- the generated action potential from the spatial information is up to 500 Hz
- coding
    - high pitched sounds vibrate basilar membrane at thinner end 16kHz

    - low pitched sounds vibrate thicker end 20 Hz
- higher pressure bends the basilar membrane downwards
- maximum deflection amplitude depends on frequency and loudness
- place of maximum vibration depends logarithmically on frequency

hair cells mechanical receptor
organ of Corti, 16k Hair cells, high sensitivity
hair moves distances less than its diameter
3 rows outer hair cells - motor
inner hair cells - secondary sensing cells, frequency coding

sense of smell
- =primary sensing cells with phasic receptors = no sent after a while because of the quick adaptation
- receptors for smellable chemicals (e.g. scent/pheromones)
- close to sense of taste (head cold clogs nasal passages → food tastes different)
- $5*10^6$ olfactory receptors as neurons with 10^3 different receptors
- neurons build direct line to brain
- low specificity
- ex. ZigZag flight moth

sense of taste
- =secondary sensing cells
- each taste = combination of 5 primary tastes
    - sweet (sugar, amino acids)
    - sour (type if acide)
    - bitter (caffeine, nicotine, rotten)
    - salty (salt NaCl)
    - umami (amino acids, meat, cheese)
- taste = survival and secretion of digestive enzymes that break down food into nutrients (rotten food)
- chemical receptors with regional distribution on tongue and throat - no topographical information
- 10k taste buds
- Aufbau: Papillen -> Geschmacksknospen -> Geschmackszellen
- Ex.: Salty: NaCl, Depolarisation, Ca Channels open yields synaptic propagation

sense of balance
secondary sensing cells

- from inner ear, vestibular apparatus → acceleration sensors for *rotation* and *linear* movement
- rotational movement:
    - three semicircular fluid filled canals (one per axis), closed by cupula (jelly like mass)
    - sensory hairs inside are bent and therefore action impulses are generated
- linear movement:
    - translational acceleration of head + gravitational acceleration
    - two macula organs: *utricle* for tilting of head, *saccule* for linear movement in the vertical plane (up and down movement)

sense of touch

- primary sensing cells and biggest receptor unit
- receptors in dermis and epidermis
- 3 receptors:
    - mechanical receptor: stress/stretch sensitive ion channels
    - thermal receptors: warm sensors → channels open for higher temperature and capsaicin, cold sensors → channels open for lower energy and menthol
      both have a certain cross sensitivity
    - chemical receptors: complimentary conformation and charge between channel protein and transmitter molecule & cold/heat sensor
- touch for pain perception

touching - Mechanical receptors

- Merkels discs: slow adaptation, Intensity
- Meissner corpuscle: rapid adaptation, velocity
- Ruffini endings: slow adaptation, Intensity
- Pacinian corpuscle: rapid adaptation, acceleration

heart vs lung sounds - frequency & propagation
ƛ = v/f
frequency dependent sound pathway & attenuation
highly inhomogeneous propagation medium

low frequency < 300 Hz -> coupling from airways into parenchyma
high frequency -> sound remains within airways

heart: 7 - 9 Hz

- caused by closing of the heart valves
- first sound → closure of mitral and tricuspid valves, loudest 140ms
- second sound → closure of aortic and pulmonic valves, lower intensity, 110 ms
- other sounds → pathologic, opening valves, leaking
- normal heart sounds are drawn in blood
- concentrated sound sources

lung: normal 100-500 Hz, abnormal -1000 Hz

- caused by air turbulences
- based on location
- vesicular sounds → peripheral lung fields, air turbulences, inspiration, distributed sources
- bronchial sounds → large airways, turbulent airflow, induce vibrations of airways, central source, inspiration
- continuous sounds (normal and pathologic) → constriction of airways
- discontinuous sounds (pathological) → explosive reopening of airways, crackles
- distributed sound sources

snoring sounds

- based on origin
    - nasal snoring (uvula oscillations)
    - oral snoring (soft palate oscillations)
- based on type of origin
    - normal snoring → narrowing of airways during inspiration, reduced musle tone
    - obstructive snoring → temporal occlusions of airways, obstruction
- based on distinct signal waveform
    - simple waveform→ sinus, without closure
    - complex waveform → train structures, temporal colliding of airways
- based on properties
    - normal: 100-800 Hz
    - obstructive: up to 2000 Hz

photon diffusion theory
for light scattering, or scattering and absorption effects at once

single scattering event: $I = I_0 * e^{-\mu s * d}$

multiple scattering and absorption media (μs > μa and low anisotropy)

$$\frac{I}{I_0} = k \cdot \frac{e^{-d \cdot \alpha}}{4 \cdot \pi \cdot D \cdot d}$$

$$D = \frac{1}{3 \cdot (\mu_a + \mu'_s)}$$

$$\alpha = \sqrt{3 \cdot \mu_a \cdot (\mu_a + \mu'_s)}$$

$$\mu'_s = \mu_s \cdot (1 - g)$$

μs' desbrices effective isotropic scattering
g describes asymmetrie of scattering
forward → g=1
isotropic → g=0
backward → g=-1

cardiac/respiratory sensitivity with optical signals
the light of optical sensors is absorbed with $I = I_0 * e^{-\mu a * d}$

cardiac:

- local systole → μa * d increases → absorption increases
    - because μa_blood >> μa_tissue and d_p increases in the light path
- local diastole → μa *d decreases

respiratory:

- inspiration → μa *d decreases
    - arterial blood → left ventricular stroke volume decreases and peripheral arterial d decreases
    - venous blood → peripheral venous blood volume decreases, peripheral venous d decreases
    - increase of the transmitted light intensity I during inspiration

structure of the cell
consist out of organelles, which execute specific functions
6 organelles:

- **ribosome**: moleculare conversion of the genes outside the cell nucleus
- **mitochondria**: powerhouse of the cell, store specific energy
- **golgi apparatus**: cell metabolism, depo function
- **vacuoles**: build up inner cell pressure

- **endoplastic reticulum**: binds extra cellular space with nucleus, signal propagation
- **nucleus**: during cell division it produces ribosomes for the doubling of the genetic material

nucleus has the DNA → 46 Chromosomes in total, length 2m

action potential
a current is applied, so the membrane voltage changes. This current impulse leads to a hyperpolarization of the membrane potential -83 mV in the distance x. This hyperpolarization decreases with x. After reaching the threshold of -60 mV there is a very sharp depolarization (=opening of Na+ channels) followed by a short overspill (Überschuss) of positive voltage = action impulse. This happens because Na+ ions flow into the cell.
After the overspill there is a sharp repolarisation. (=closure of Na+ channels) this is assisted by longer opening of K+ channels. Because of this long outflow of K+ the membrane is refractare after an AI. there are afterpontentails of the AI. During this time the ion pumps bring back the ions to the right place.

the depolarization is answered by an AI after reaching the threshold. The AI "turns around" at location x and looks to the inside. there are new compensational currents which look to the outside and propagate away from x and the reach a point where a new depolarisation begins.

muscle activation
1. action potential spreads through muscle fibres network → the presynaptic impulse leads to inflow of Ca2+ which leads to activation of vesicles → transmitters go in synaptic gap.
2. the transmitters bind to the receptors with charge & shape complimentary and the channels open → Na+ inflow K+ outflow
3. following the ion currents is a EPSP and they sum up to AI's in the muscle fibres.
4. the impulses spread through the fibres and make an active contraction → shortening of fibres

circadian changes
24 hour cycle of physiological process

- physiological functions: blood pressure, heart rate, body temperature = minimum in the morning, maximum late afternoon
- hormonal processes: melatonin maximum 3 a.m., cortisol maximum 7 a.m.
- mental processes: reaction time shortest late afternoon
- physical processes: physical work capacity highest 3 a.m.

extern timers: light, food intake, social field, season
intern timers: hormones, body temperature

sensing organs - receptors
<u>tonic receptor</u>

- transmitter is there for basic level of stimulation (constant level)
- receptor generates Action Impulse as long as the stimulation is there
- DC transmission and no adaption
- amplitude and duration of signal are codes
- not often in nature

<u>phasic receptor</u>

- is there for the change of a stimulation
- generates an AI only at the beginning of a stimulation (a long as potential difference is over threshold)
- AC transmission and fast adaptation
- differential behavior or stimulus slope coded

<u>phasic tonic receptor</u>

- like a phasic receptor but adaptive
    - takes care of the change = adaption
    - amplitude and parts of duration of the signal are codes
    - Generates an AI only at the beginning of an excitement alternating current
- adoption through
    - ional mechanisms: activation of voltage-gated K+ channels and deactivation of voltage gated Na+ channels —> decreasing receptor potential
    - mechanical structure: filters DC component out of stimulus → only sharp changes

- the action impulses are as long as the membrane potential is above the threshold
- intervals between the action potentials are getting bigger, even tough the potential difference is above the threshold
- number and order of action potentials give information about the intensity of the stimulus
- quick adaptation, moderately rapid

skin curvature sensor - monitoring on the neck

- for cardiac activity, respiratory activity and blood pressure
- blood pressure:
    - during systole the vessel radius increases, sensor bends → conductivity
    - during diastole the vessel radius decreases, sensor in “normal” position
- a lot of störungen → it needs adaptive filtering with estimated frequency

linear filtering: fixed cutoff value
adaptive filtering: adaptive cutoff value