Qualification Round

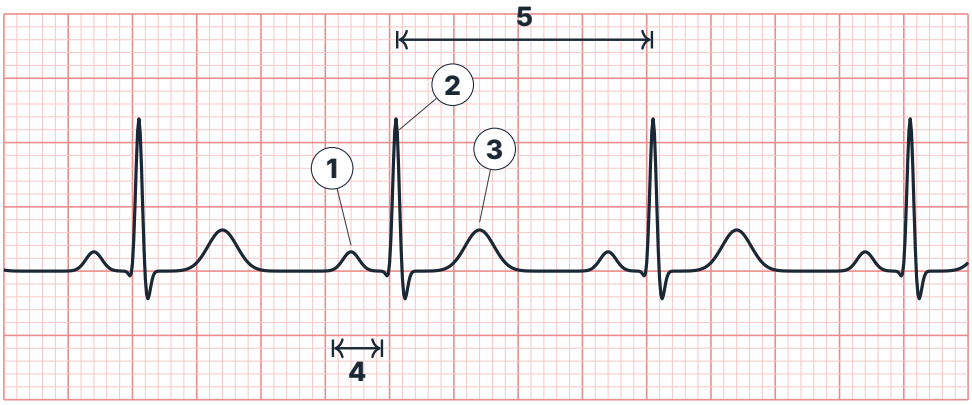
Problem A: Reading a Heartbeat

Every heartbeat starts with a small electrical signal that spreads through the heart muscle. An electrocardiogram (ECG) records these signals with electrodes placed on the skin.

Below is a section of the ECG of a healthy 16-year-old at rest. The paper moves at 25 mm per second, so one small square (1 mm) corresponds to 0.04 s.

Task: Match each number 1 to 5 in the ECG with the correct name from the list below. Each name is used exactly once.

Names: P wave (activation of the atria), PR interval, QRS complex (activation of the ventricles), T wave (recovery of the ventricles), time between two heartbeats (RR interval).



paper speed 25 mm/s; 10 mm = 1 mV; one small square = 1 mm

Problem B: The Tireless Pump

Your heart beats about 100,000 times every day, without ever taking a break. At rest, the heart of a healthy adult beats about 70 times per minute, and with every beat it pumps about 70 mL of blood into the body (the stroke volume).

During hard exercise, the heart of a trained athlete beats up to 150 times per minute and pumps about 110 mL with every beat. The volume of blood pumped per minute is called the cardiac output:

$$\text{cardiac output} = \text{heart rate} \times \text{stroke volume}.$$

(a) Calculate the cardiac output at rest in litres per minute, and the volume of blood the heart pumps in one day.

(b) How many litres of blood does the heart pump during a life of 80 years (use the resting values)? An Olympic swimming pool holds about 2.5 million litres. How many pools could you fill?

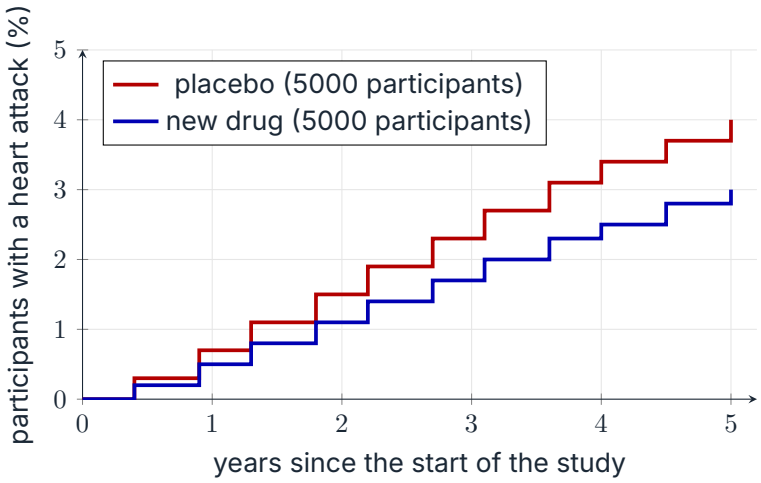
(c) Calculate the cardiac output of the athlete during hard exercise. Why does the body need so much more blood flow during exercise?

Problem D: What Does the Trial Really Mean?

A pharmaceutical company tests a new drug that is meant to prevent heart attacks. In a randomised, double-blind, placebo-controlled trial, 10,000 adults with a high risk of heart disease were randomly assigned to take either the new drug or a placebo (an identical-looking tablet without an active substance) every day for 5 years. Neither the participants nor their doctors knew who received which tablet.

The graph shows the percentage of participants in each group who had a heart attack. After 5 years, 150 of the 5,000 participants in the drug group and 200 of the 5,000 participants in the placebo group had had a heart attack.

With the risk of an event in each group, the relative risk is $\mathrm{RR} = \dfrac{\mathrm{risk}_{\mathrm{drug}}}{\mathrm{risk}_{\mathrm{placebo}}}$, the relative risk reduction is $\mathrm{RRR} = 1 - \mathrm{RR}$, the absolute risk reduction is $\mathrm{ARR} = \mathrm{risk}_{\mathrm{placebo}} - \mathrm{risk}_{\mathrm{drug}}$, and the number needed to treat is $\mathrm{NNT} = 1/\mathrm{ARR}$.



(a) Calculate the risk of a heart attack in each group, the relative risk, the relative risk reduction, the absolute risk reduction and the number needed to treat.

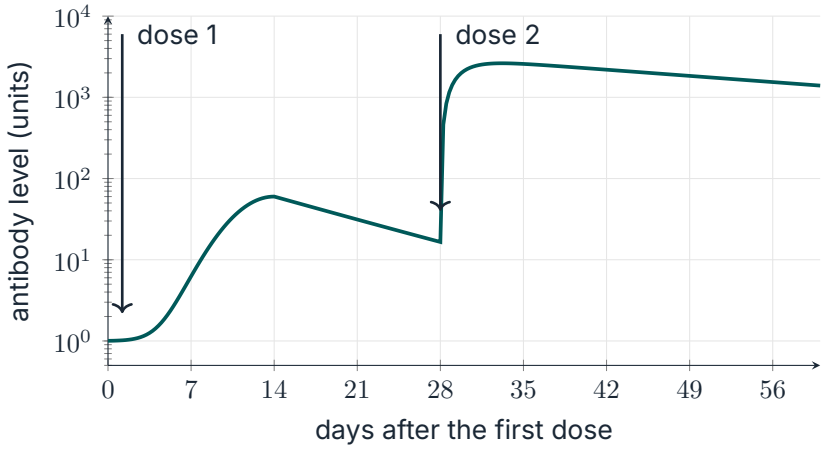
(b) A newspaper writes: *New pill cuts heart attacks by 25 %!* Is this correct? Explain why the absolute numbers give a different impression, and which number is more useful for a person deciding whether to take the drug for five years.

(c) The 95 % confidence interval of the relative risk is 0.61 to 0.92. Explain what this means and whether the effect is likely to be real or due to chance.

Problem C: Why a Second Dose?

Many vaccines are given in two doses a few weeks apart. In a vaccine study, the level of antibodies against the vaccine antigen was measured in the blood of volunteers after a first dose on day 0 and a second dose on day 28.

The graph shows the average results. Note that the vertical axis is logarithmic: each step corresponds to a factor of 10.



(a) Read from the graph the highest antibody level after the first and after the second dose, and how many days after each dose this maximum was reached. By about what factor is the maximum after the second dose higher?

(b) Explain which cells of the immune system make the response after the second dose so much faster and stronger.

(c) Why do people often need another booster dose years later?

Problem E: Jet Lag

Mei flies from Shanghai to Paris, where the local time is seven hours behind Shanghai. After arriving, she lies awake at night and feels tired and hungry at strange times during the day. This lasts for several days.

Deep inside the brain, a tiny group of nerve cells works as a master clock that keeps sleep, hormones, body temperature and digestion in step with day and night. One of the signals it controls is the hormone melatonin. The graph shows how the melatonin level in the blood normally changes over 24 hours.

Task: Explain how the body's internal clock is normally kept in step with day and night, why Mei suffers from jet lag after the flight, and why the problem slowly disappears after a few days.

