Response

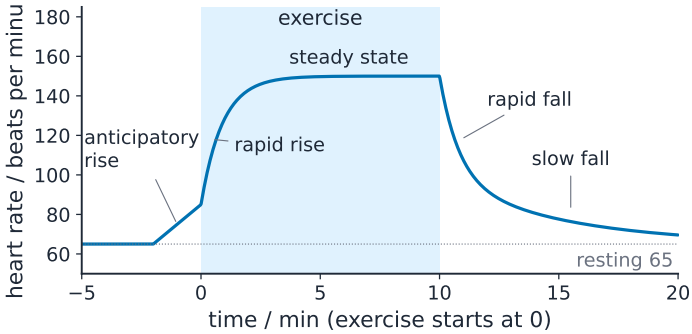
A.3 · SL and HL

Two hours under two

> Acute responses last one bout; training adaptations last.

- Kipchoge, Vienna 2019, 42.195 km in 1:59:40.
- Heart, lungs and muscles responded within seconds, and held steady.
- This unit: responses → **fatigue** → **recovery** → training → adaptations.

Heart rate during exercise



- Anticipatory rise from adrenaline, before the start.
- **Steady state** when oxygen supply meets demand.

Why stroke volume rises

A fuller, more stretched ventricle contracts more strongly (Frank–Starling).

- Muscle pump and breathing raise **venous return**.
- Levels off at about 40 to 60 % of maximal effort.

Blood pressure

Running

Systolic up, about 120 $\rightarrow$ 180.

Diastolic about the same.

Heavy lifting

Both rise sharply.

Worse when holding breath.

The Fick equation

1. **Rest.** $5 \times 50 = 250$ mL/min
2. **Hard run.** $20 \times 150 = 3000$ mL/min
3. **Change.** Twelve times; delivery $\times 4$, extraction $\times 3$

Decision

Oxygen uptake = cardiac output $\times$ a-vO_2 diff

Ventilation and heat

In the heat, heart rate drifts up as blood volume falls.

- Rapid rise from nerves, then a slower rise from chemoreceptors.
- Only 20 to 25 % of muscle energy becomes movement.

Types of fatigue

Cause	Typical event
PCr used up	100 m sprint
Acid builds up	400 m race
Glycogen used up	Marathon
Less drive from the brain	Long events in the heat

Lactic acid myths

> Hydrogen ions, not lactate, contribute to **fatigue**.

- Lactate is a fuel and clears within about an hour.
- Next-day soreness is DOMS, from eccentric muscle damage.

How long recovery takes

Store	Time to recover
Phosphocreatine	Half in 30 s; nearly all in 3 to 5 min
Lactate	About 1 hour
Muscle glycogen	24 to 48 hours
Muscle damage	Days

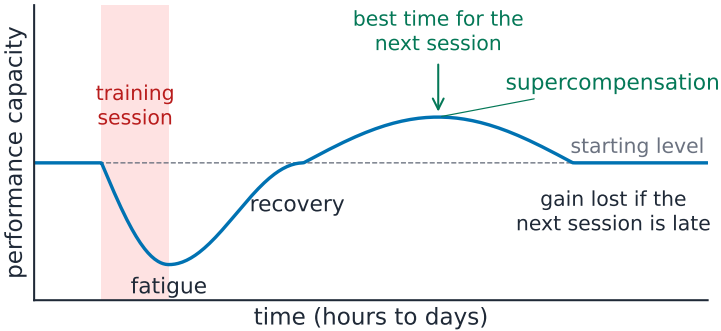
Refuelling after a run

1. **Fluid.** $1.5 \times 1.2 = 1.8$ L
2. **Carbohydrate.** $1.0 \times 60 = 60$ g per hour
3. **Protein.** About 20 to 25 g

Decision

Replace 125 to 150 % of the fluid lost

Supercompensation

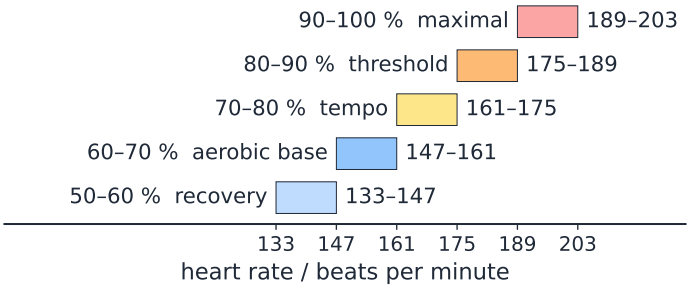


- **Fatigue**, then **recovery** above the starting level.
- Too soon, fatigue builds; too late, the gain fades.

Principles of training

Principle	Meaning
Specificity	Adaptations match the training
Progressive overload	Load rises gradually
Reversibility	Unused fitness is lost
Individual differences	People respond differently

Karvonen training zones



- **Heart rate reserve** = maximum − resting.
- Target = resting + percentage × reserve.

Target heart rate

1. **Maximum.** $220 - 17 = 203$
2. **Reserve.** $203 - 63 = 140$
3. **Target.** $63 + 0.70 \times 140 = 161$

Decision

70 % of maximum gives only 142, so name the method

Resistance training

Aim	**Repetitions and load**
Strength	1 to 6 at 85 % of 1RM or more
Hypertrophy	6 to 12 at 67 to 85 %
Muscular endurance	12 or more below 67 %

Interval training

ATP–PC intervals

10 s sprint, 50 s rest.

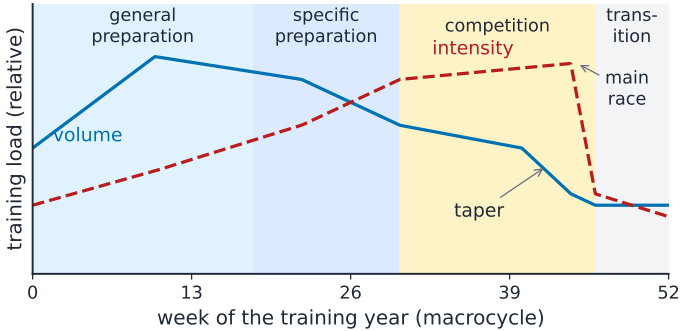
1 to 5, PCr rebuilt.

Aerobic intervals

3 min hard, 2 min jog.

Short rests.

A periodised year



- **Macrocycle**, mesocycles of 3 to 6 weeks, weekly microcycles.
- **Taper** cuts volume 40 to 60 %, keeps intensity.

The trained heart

1. **Untrained.** 70×70 mL $= 4.9$ L/min
2. **Trained.** 45×110 mL ≈ 5.0 L/min
3. **Difference.** Fewer beats, bigger **stroke volume**

Decision

Training **bradycardia** saves the heart work

Muscle adaptations

Endurance

More **mitochondria**, **myoglobin**, enzymes.

More fat used; glycogen spared.

Resistance

Larger type II fibres.

More PCr; better buffering.

The lactate threshold

1. **Before.** $0.60 \times 45 = 27$
2. **After.** $0.75 \times 52 = 39$
3. **Change.** Up 44 %

Decision

The threshold improves more than VO_2max

Overtraining

Stage	Performance drop lasts
Functional overreaching	Days to 2 weeks
Non-functional overreaching	Weeks to months
Overtraining syndrome	Months or longer

Altitude

> Live high to gain red blood cells; train low to keep intensity.

- Lower **partial pressure of oxygen**; about 75 % at 2500 m.
- EPO raises red blood cells over 3 to 4 weeks.

Check: heat acclimatisation

Your turn

Which change happens with heat acclimatisation?

A. Sweat becomes saltier
B. Plasma volume rises
C. Heart rate rises at the same workload
D. Sweating starts later

Exam tips

> Say whether a change is an **acute response** or a **training adaptation**.

- Describe heart rate graphs in phases.
- Do not blame lactic acid for **fatigue** or soreness.
- Link each adaptation to performance.

Check yourself

Try these

A 16-year-old has a resting heart rate of 68. Find the target heart rate at 75 % of heart rate reserve.

Explain why stroke volume rises during exercise.

Compare muscular adaptations to endurance and resistance training.