# THERMOREGULATION

Spring 2020, Marie Nováková

Endothermic (warm-blooded) vs. ectothermic (cold-blooded) species

Arctic (20° - 40°C) vs. tropic (22° - 27°C water, 32° - 35°C) animals

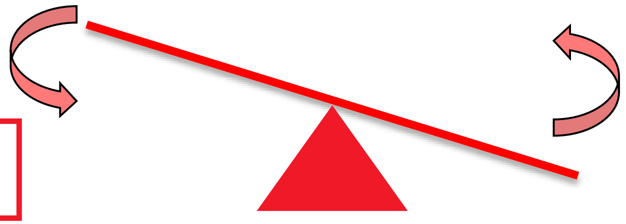
# THERMOREGULATION

All processes keeping body temperature within (relatively) narrow range

HEAT INTAKE

\+

HEAT PRODUCTION



HEAT LOSS

\+

HEAT OUTPUT

- Core temperature – homoeothermic regulation
- Peripheral temperature – poikilothermic regulation

**THERMOREGULATORY BEHAVIOUR**

Social thermoregulation

| Temperature (C) | Symptoms |
|---|---|
| 28 | muscle failure |
| 30 | loss of body temperature control |
| 33 | loss of consciousness |
| 37 | normal |
| 42 | central nervous system breakdown |
| 44 | death |

*Hypothermia*

*Hyperthermia*

# HEAT „CONVECTION“

- Inner heat convection (among inner organs and skin)
- Outer heat convection – heat output

## HEAT INTAKE/LOSS

- **Radiation** (irradiation, without touch, IR)
- **Convection** (temperature gradient, touch)

up to **36°C**

(+ Conduction - wind)

## HEAT OUTPUT

**Evaporation**

perspiratio sensibilis (sweat glands)

p. insensibilis (diffusion – skin and mucosae)

*1 litre of evaporated sweat – 2428 kJ*

## HEAT PRODUCTION

- Depends on energetic exchange (10% of BM - 1°C)
- Difference between rest and exercise (increases muscle rate – up to 90%)
- Shivering and nonshivering thermogenesis (voluntary and non-voluntary thermogenesis)
- Brown adipose tissue ($b_3$ adrenoreceptors, NA, lipolysis, expression of lipoproteinlipase and thermogenin, uncoupling of oxidative chain)

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# THERMOREGULATION CONTROL

Afferentation: TRP channels – 2 types

(TRPM8-cold, TRPV1-hot)

- Central thermoreceptors
- Peripheral thermoreceptors (skin – cold)

Mechanisms:

- Vegetative
- Somatic
- Endocrine (CA, thyroxin, TSH)
- Modification of behaviour

Thermoregulatory centres – CENTRAL THERMOSTAT:

Posterior hypothalamus – reaction to cold

Anterior hypothalamus – reaction to heat

(Upper part of middle brain - ?)

# THERMOREGULATORY MECHANISMS

| | |
|---|---|
| **COLD ACTIVATED** | **Decrease of heat output** |
| Skin vasoconstriction | + |
| Twisting | + |
| Horripilation | + |
| | **Increase of heat production** |
| Muscle shivering | + |
| Hunger | + |
| Increase of intentional movements | + |
| Increase of CA secretion | + |
| **HEAT ACTIVATED** | **Increase of heat output** |
| Skin vasodilatation | + |
| Sweating | + |
| Increase of ventilation | + |
| Loss of appetite, apathy, inactiveness | **Decrease of heat production** |

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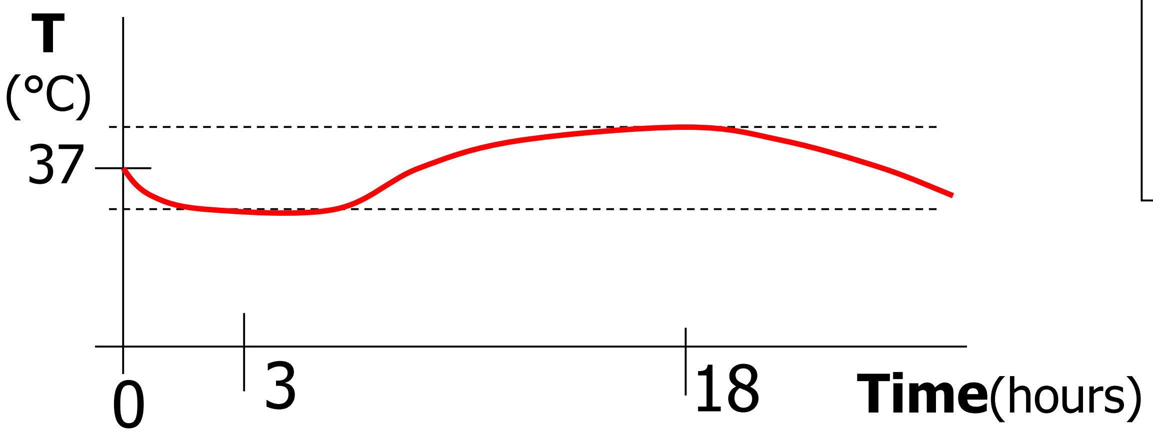
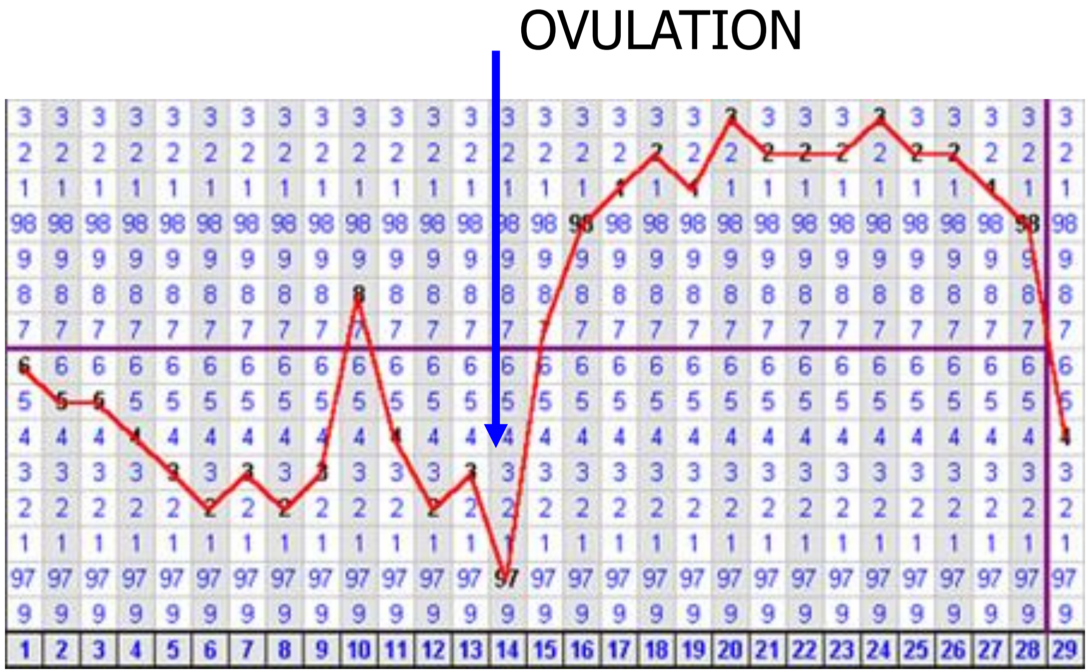
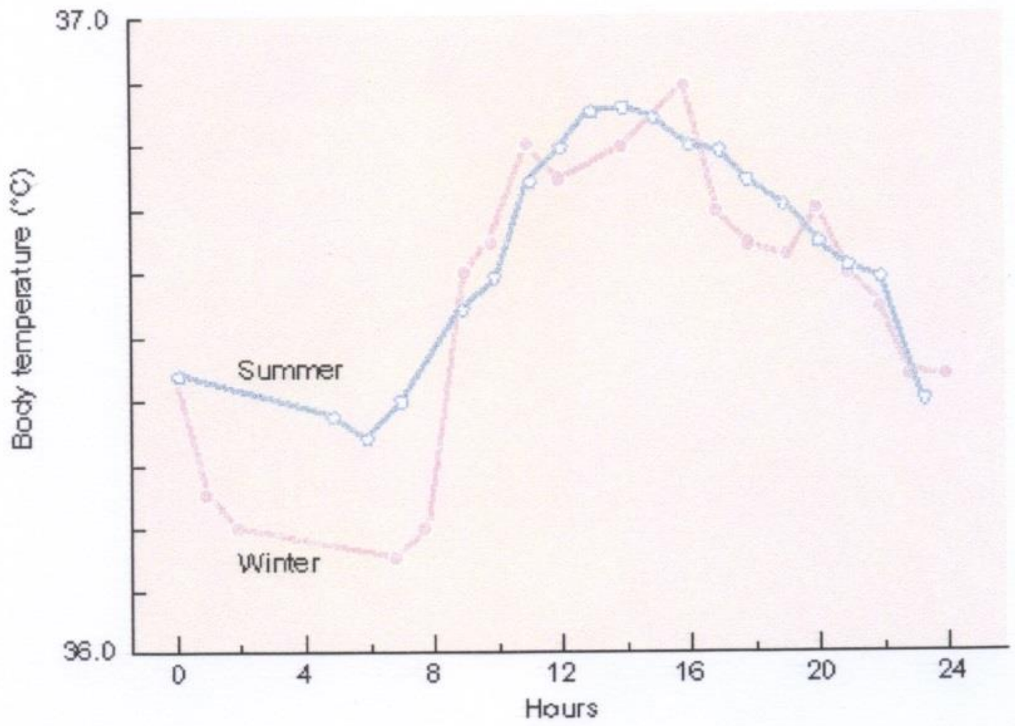



1. Circadian variation of body temperature
2. Cyclic variation in women (basal temperature)
3. Seasonal variation



# PHYSIOLOGY OF EXERCISE

Spring 2019, prof. MUDr. Marie Nováková, Ph.D.

# What is it work???


MUSCLE TYPES

- Skeletal
- Heart
- Smooth

EXERCISE:

1. **Dynamic** (positive/negative)
2. **Static**

**CHANGES DURING EXERCISE:**

1. Cardiovascular
2. Respiratory
3. Metabolic

# HOMEOSTASIS

**THERMOREGULATION**

**Ergotropic system – sympathetic nervous system**

**ANTICIPATION OF EXERCISE**

„Fight or flight“ – EVOLUTIONARY ASPECT

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# CARDIOVASCULAR REACTIONS DURING EXERCISE

1. Heart reactions
2. Circulation reactions

1. Increase of cardiac output (heart reserve !)
2. Increase in coronary blood flow
3. Hyperaemia in lung circulation
4. Hyperaemia in muscles (difference between contraction and relaxation!!!)
5. Higher supply of $O_2$ and metabolites, higher removal of $CO_2$ and catabolites

## METABOLIC AUTOREGULATION OF BLOOD FLOW

Decreased pH, decreased $pO_2$, increased $pCO_2$, increased $K^+$, increased body temperature

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**CARDIAC RESERVE** = maximal CO / resting CO **4 - 7**

**CORONARY RESERVE** = maximal CF / resting CF **3.5**

**CHRONOTROPIC RESERVE** = maximal HR / resting HR **3 - 5**

**VOLUME RESERVE** = maximal SV / resting SV **1.5**

CO – cardiac output (l/min), CF – coronary flow (l/min/100gr), HR – heart rate (min-1), SV – stroke volume (ml)

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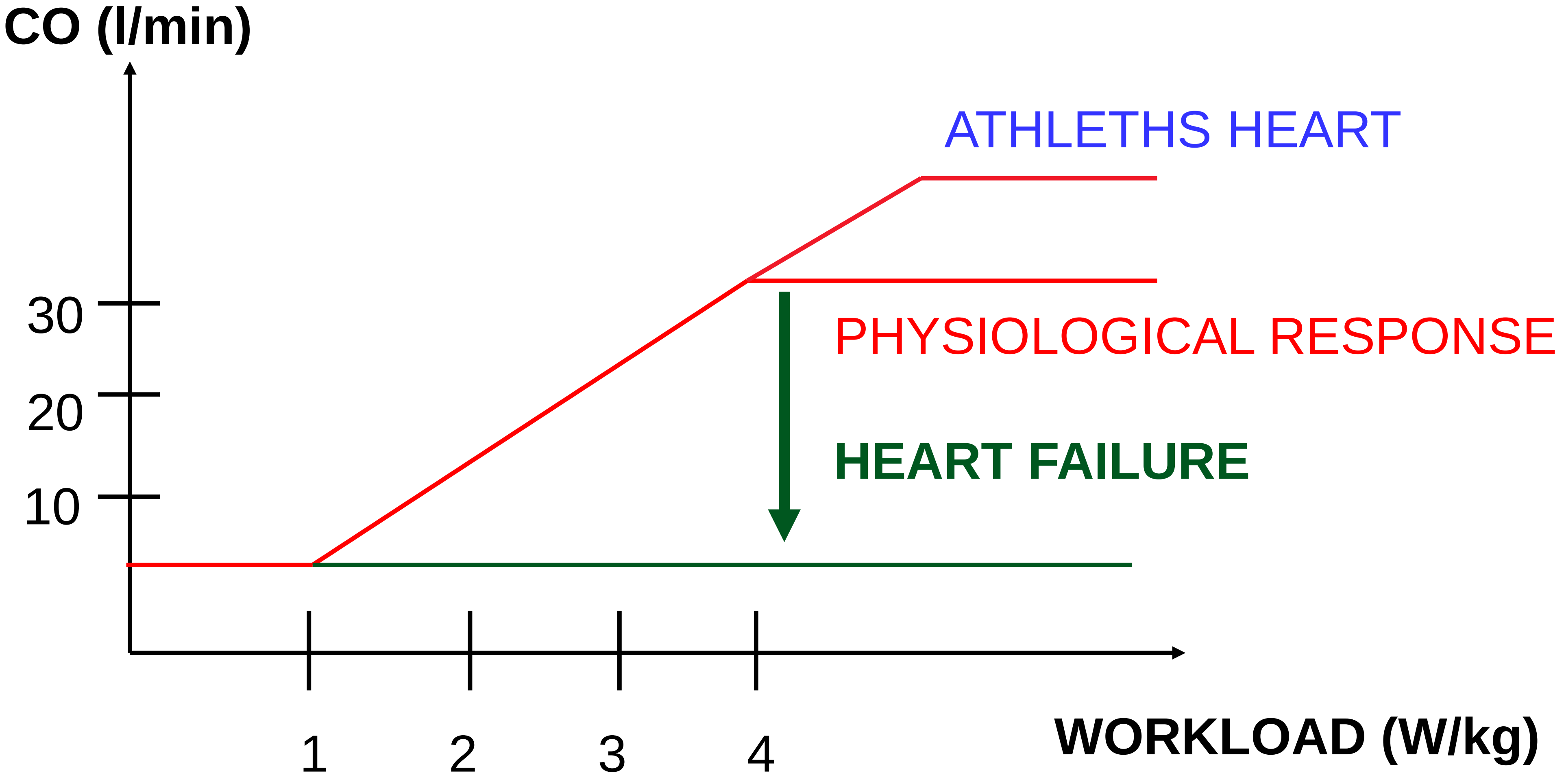
# CARDIAC RESERVE in healthy and diseased heart



| PARAMETER | REST | EXERCISE | INCREASE (x) |
|---|---|---|---|
| **Cardiac output** (l/min) | 5-6 | 25 (35) | 4-5 (7) *Cardiac reserve* |
| **Heart rate** (t/min) | 70 | 210 (250-190) ***depends on age*** | 3-5 *Chronotropic reserve* |
| **Stroke volume** (ml) | 75 | 115 | 1.5 *Volume reserve* |
| **Systolic BP** (mmHg) | 120 | ↑ ? | - |
| **Diastolic BP** (mmHg) | 70 | ↓↑ ? | - |
| **Pulse BP** (mmHg) | 50 | 70-100 | 1.5-2 |
| **Mean BP** (mmHg) | - | - | minor increase |
| **Muscle perfusion** (ml/min/100g) | 2-4 | 60-120 | 30 (10% $MV_{max}$) |

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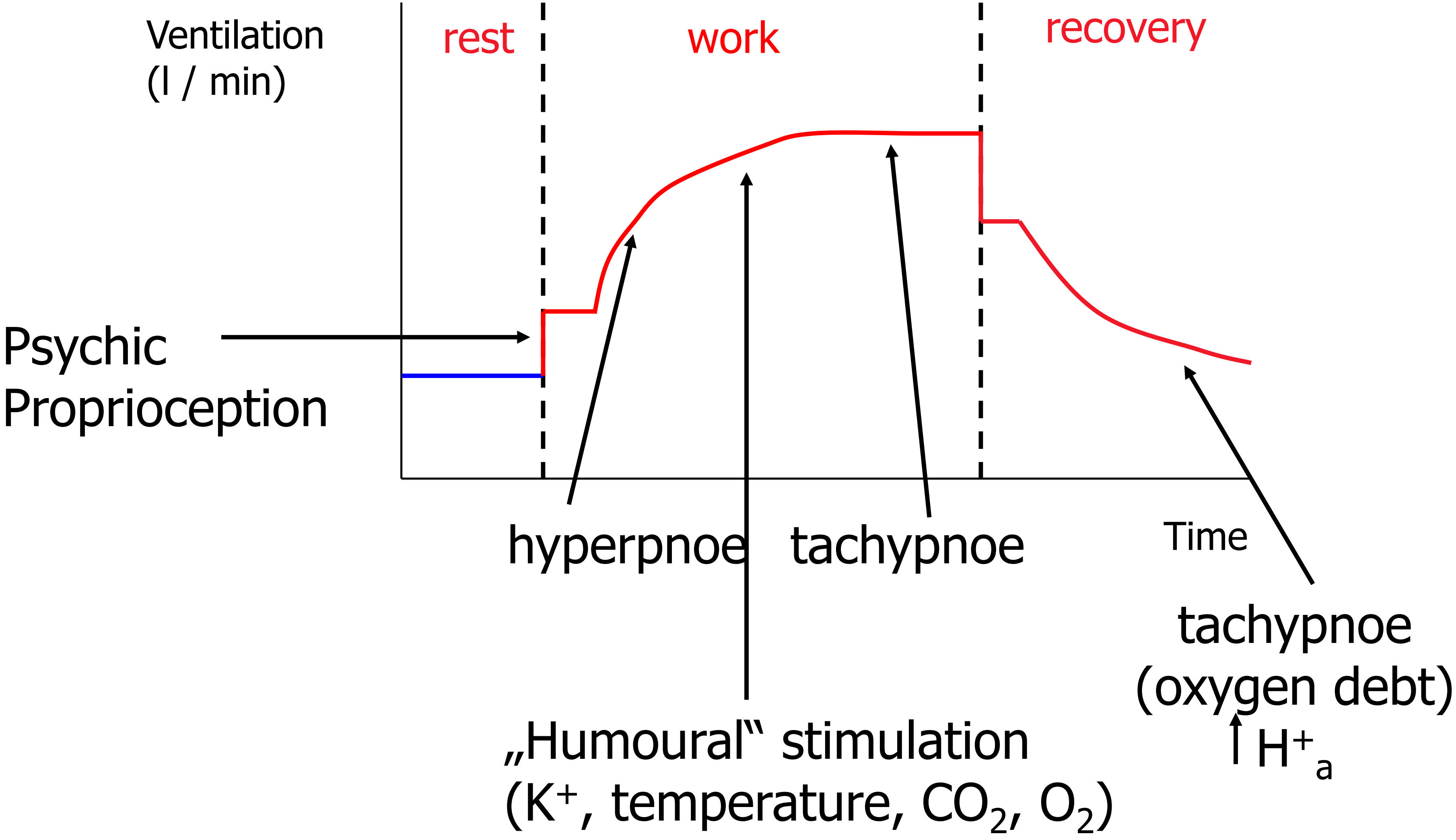
# RESPIRATORY REACTIONS DURING EXERCISE

Demands on respiratory system:

1. Higher gases exchange – higher diffusion
2. Higher ventilation
3. Higher perfusion (hyperaemia in lung circulation)

| PARAMETER | REST | EXERCISE | INCREASE (x) |
|---|---|---|---|
| **Minute ventilation** (l/min) | 6-12 | 90-120 | 15-20 |
| **Respiratory frequency** (d/min) | 12-16 | 40-60 | 4-5 |
| **Tidal volume** (ml) | 0,5-0,75 | 2 | 3-4 |
| **Blood flow** (l/min) | 5,5 | 20 – 35 | 4-6 |
| **$O_2$ intake** (ml/min) -$V_{O2}$ | 250-300 | 3000 | 10-12 |
| **Total $CO_2$** (ml/min) | 200 | 8000 | 40 |
| **$pO_2$** (Torr) | 40 | 25 | |
| **$O_2$ extraction** (%) | + | + | ++ |

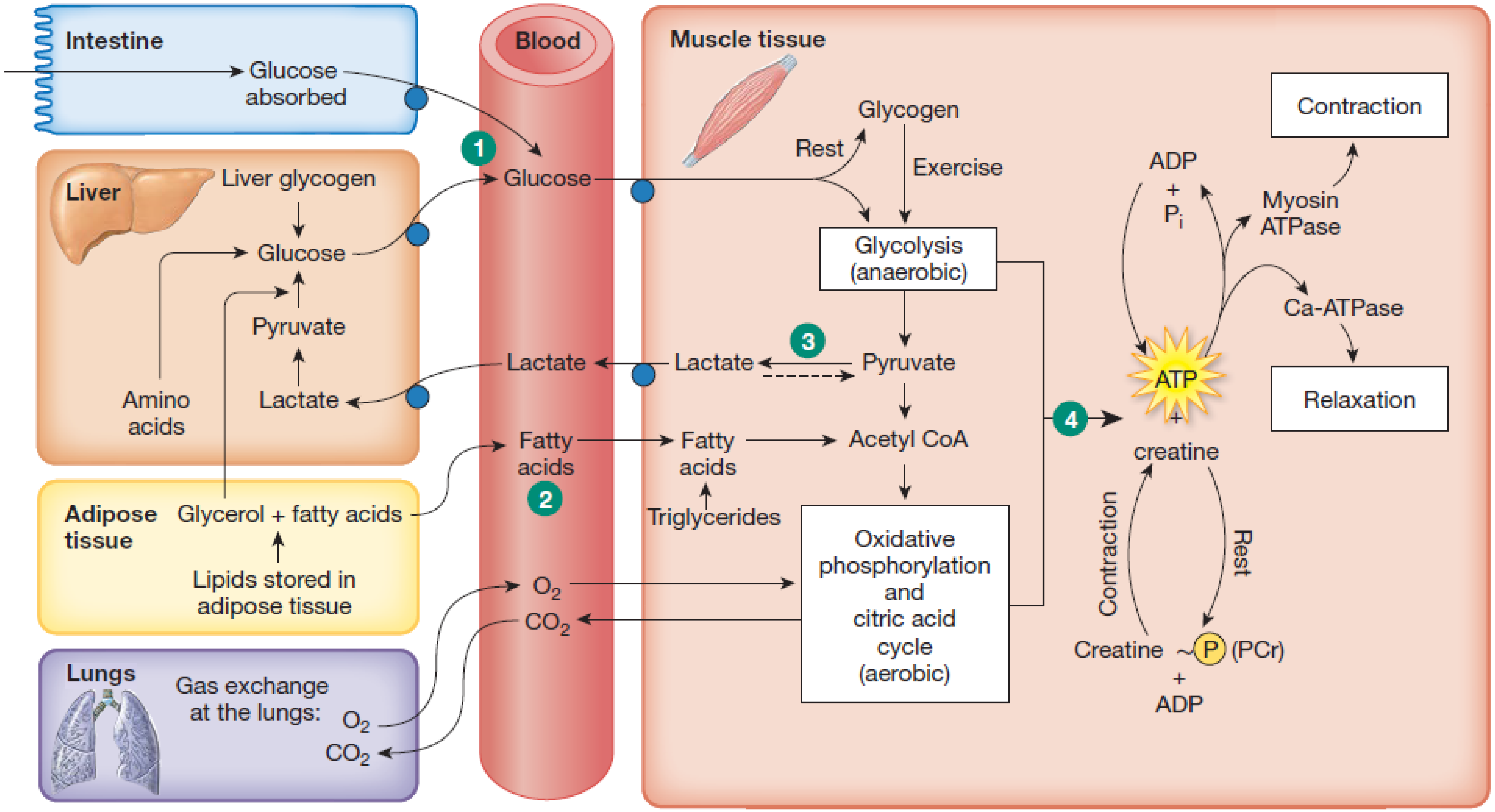

Ventilation
(l / min)
rest
work
recovery
Psychic
Proprioception
hyperpnoe
tachypnoe
Time
tachypnoe
(oxygen debt)
↑ $H^+_a$
„Humoural" stimulation
($K^+$, temperature, $CO_2$, $O_2$)

R = 1.5 – 2.0

R = 0.5

## OVERVIEW OF MUSCLE METABOLISM

ATP for muscle contraction is continuously produced by aerobic metabolism of glucose and fatty acids. During short bursts of activity, when ATP demand exceeds the rate of aerobic ATP production, aerobic glycolysis produces ATP, lactate, and $H^+$.




1. Glucose comes from liver glycogen or dietary intake.
2. Fatty acids can be used only in aerobic metabolism.
3. Lactate from anaerobic metabolism can be converted to glucose by the liver.
4. Both aerobic and anaerobic metabolism provide ATP for muscle contraction.

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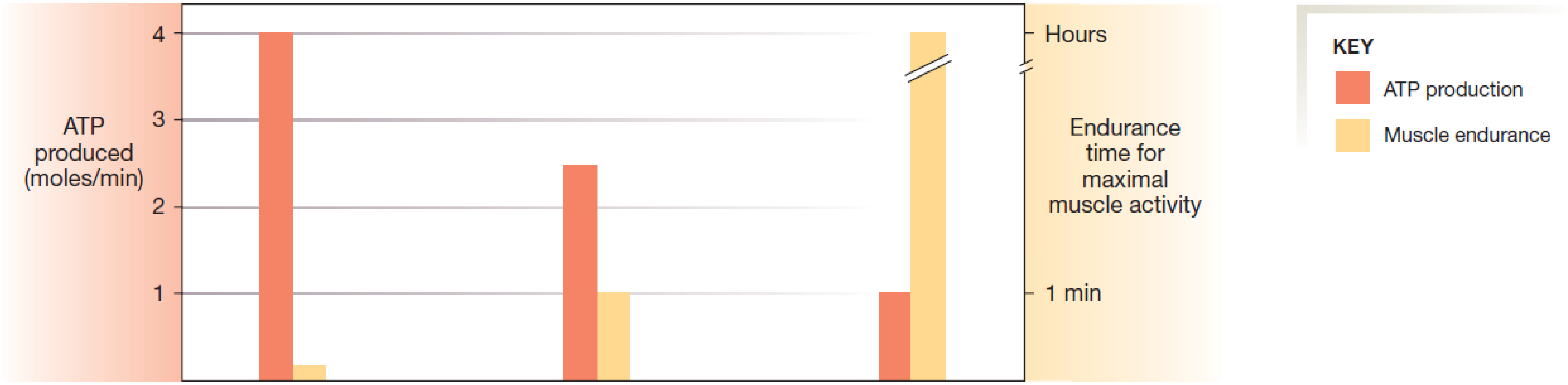
## AEROBIC VERSUS ANAEROBIC METABOLISM

Anaerobic metabolism produces ATP 2.5 times faster than aerobic metabolism, but aerobic metabolism can support exercise for hours.




**Phosphocreatine** can sustain only 10 seconds of maximal exercise.

**Anaerobic metabolism** produces ATP 2.5 times faster than aerobic metabolism but can support only 1 minute of maximal exercise.

**Aerobic metabolism** supports exercise for hours.

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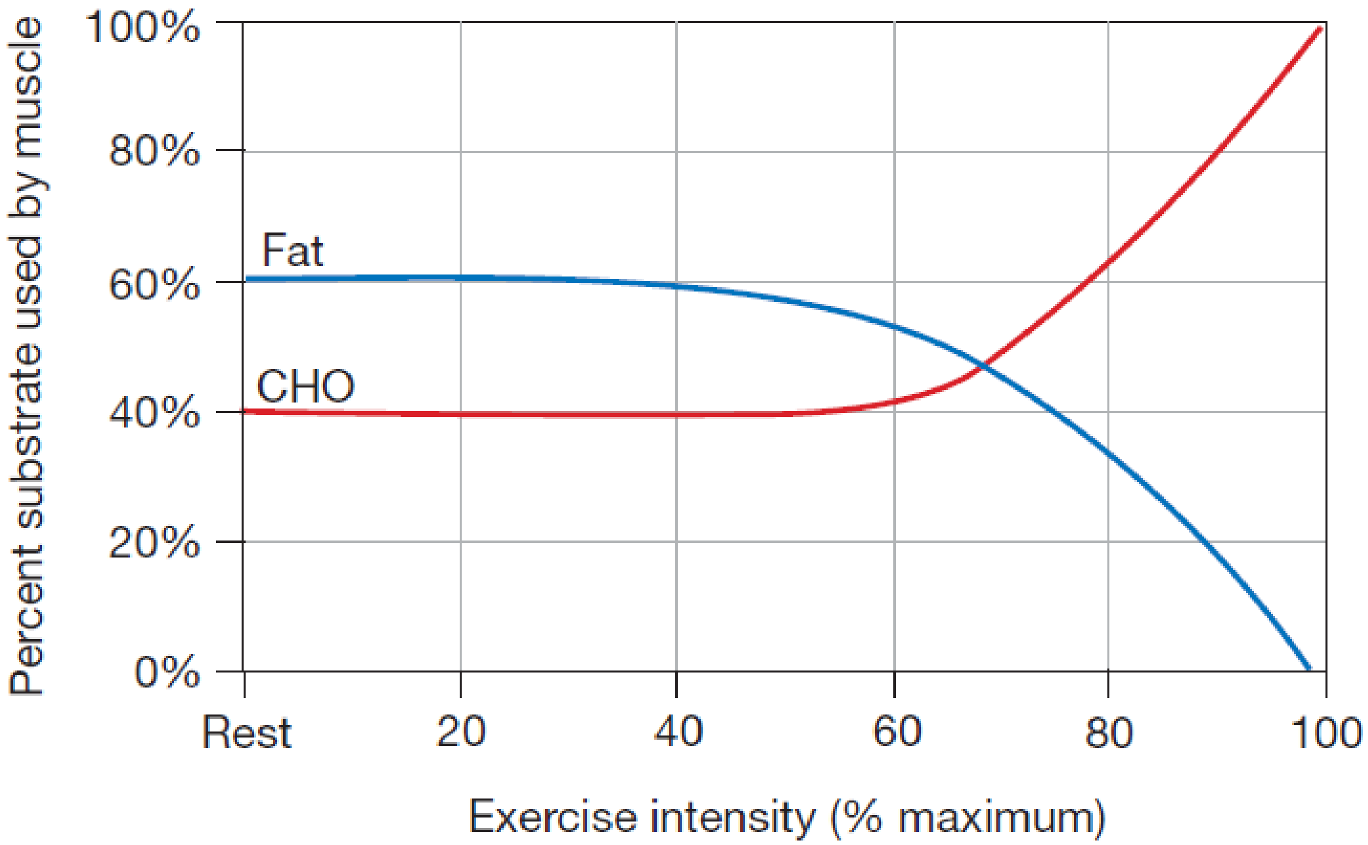
## ENERGY SUBSTRATE USE DURING EXERCISE

At low-intensity exercise, muscles get more energy from fats than from glucose (CHO). During high-intensity exercise (levels greater than 70% of maximum), glucose becomes the main energy source.

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Data from G. A. Brooks and J. Mercier, *J App Physiol* 76: 2253–2261, 1994

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# OXYGEN CONSUMPTION AND EXERCISE

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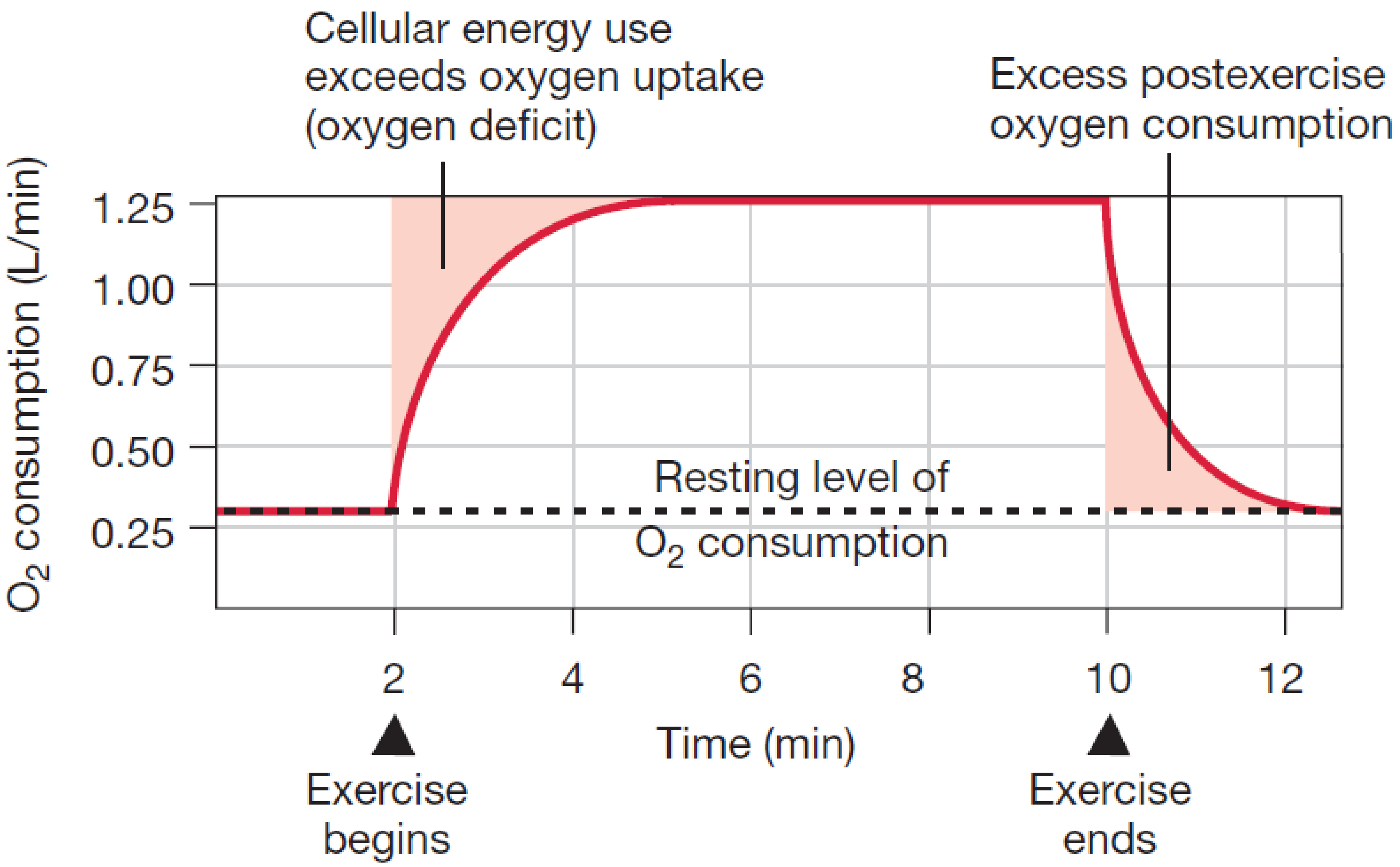
Oxygen supply to exercising cells lags behind energy use, creating an oxygen deficit. Excess postexercise oxygen consumption compensates for the oxygen deficit.

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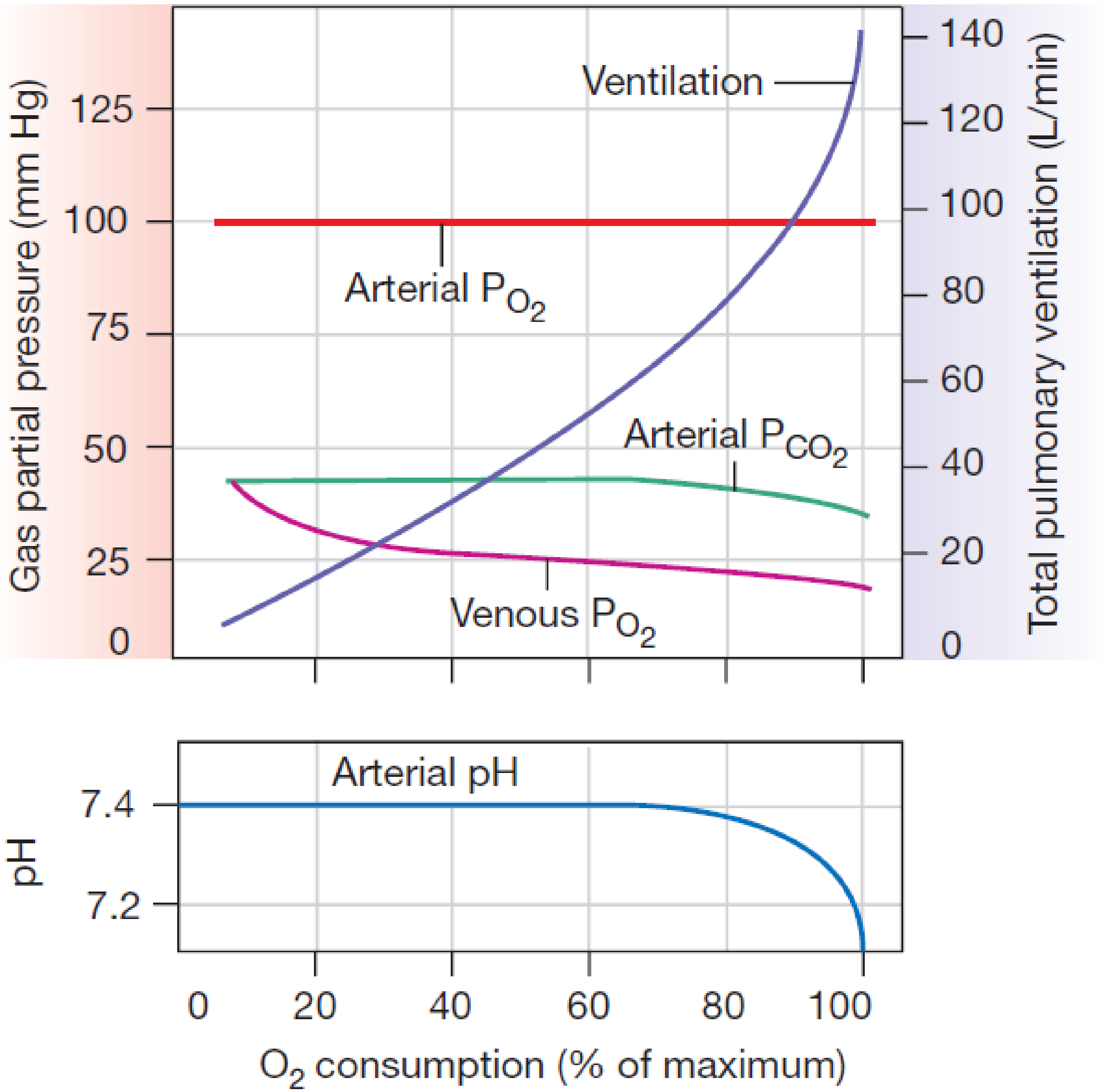
## BLOOD GASES AND EXERCISE

Arterial blood gases and pH remain steady with submaximal exercise.

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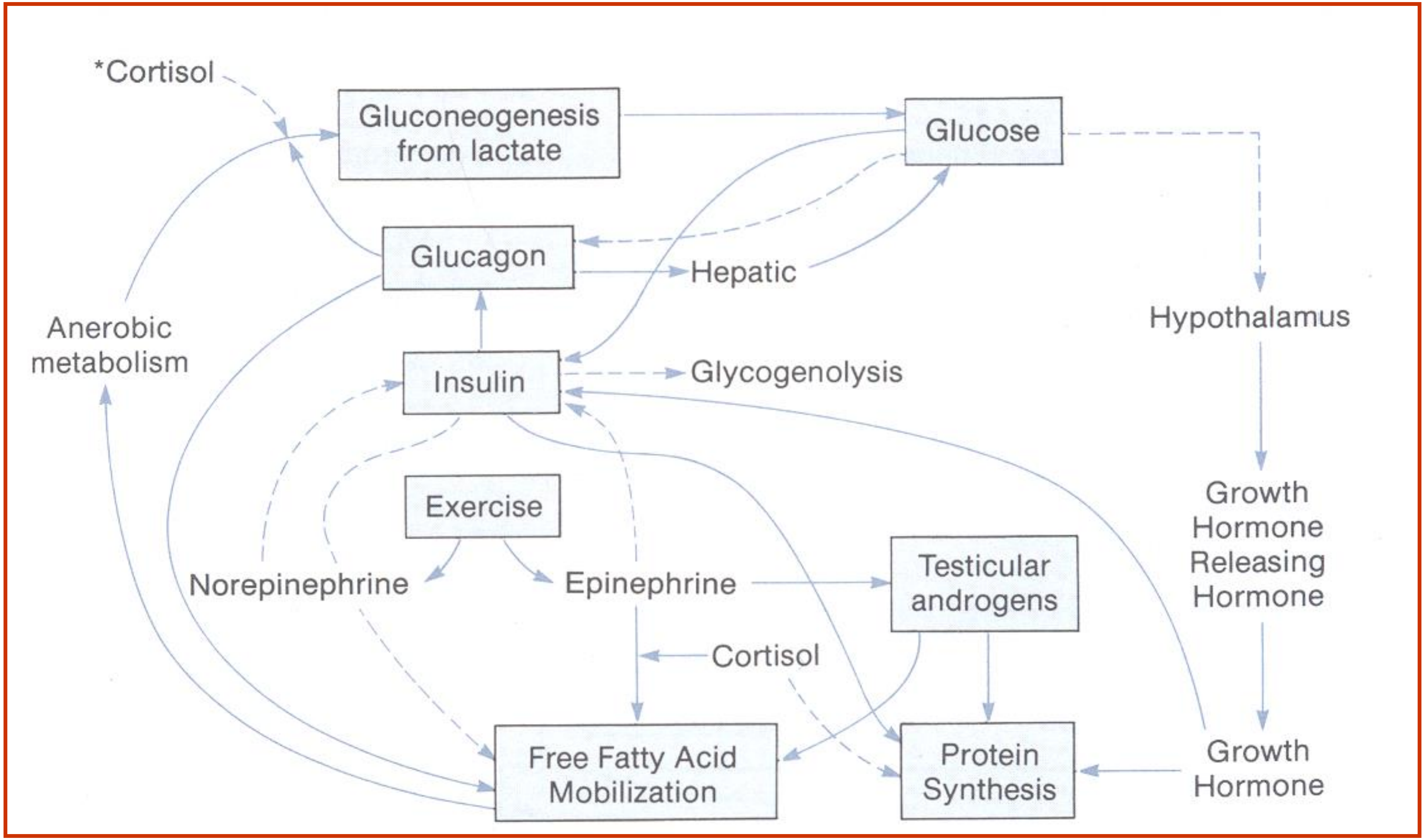
*Cortisol
Gluconeogenesis from lactate
Glucose
Glucagon
Hepatic
Hypothalamus
Anerobic metabolism
Insulin
Glycogenolysis
Exercise
Growth Hormone Releasing Hormone
Norepinephrine
Epinephrine
Testicular androgens
Cortisol
Free Fatty Acid Mobilization
Protein Synthesis
Growth Hormone

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# FITNESS

- Spiroergometry
- Types of ergometers
- Index $W_{170}$
- Training
- Fatigue (aerobic, anaerobic threshold)
- Adaptation to exercise