Chapter 1. Introduction to Physiology and Biochemistry

Part 1 | Basics of Physiology

1 Learning Objectives

By the end of this section you will be able to …

1. **Define "physiology"** and outline its interdisciplinary relationship with physiotherapy.
2. **Explain the concept of homeostasis** and identify the key components of physiological control systems.
3. **Describe negative- and positive-feedback regulation**, including at least three clinical examples relevant to rehabilitation.
4. **Recognise how ageing, disease and exercise modify homeostatic set-points**, shaping assessment and treatment decisions in physiotherapy practice.

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2 Definition & Scope of Physiology in Physiotherapy

Aspect	Explanation	Physiotherapy Touch-point
Physiology (classic definition)	Scientific study of normal **function** in living organisms—from molecular to whole-body level	Guides safe exercise dosing, vital-sign monitoring, modality parameters
Scope for PTs	• Cellular energetics (ATP, pH) • Neuro-muscular transmission • Cardiorespiratory dynamics • Endocrine & metabolic adaptation • Integumentary repair	Exercise prescription, electrotherapy, pulmonary rehab, wound care
Why PTs must master physiology	1. Predict systemic response to intervention 2. Detect adverse events early 3. Translate pathology into functional goals	Example: Knowing β-blocker effect on HR use RPE instead of HR training zones

> **Key Point:** *Anatomy tells us **where** and **what**; physiology tells us **how** and **how much**—crucial for evidence-based rehabilitation.*

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3 Homeostasis – The Core Concept

Component	Definition	Example in PT Context
Variable	Physiological parameter kept within limits	Blood glucose during therapeutic exercise
Sensor / Receptor	Detects change; sends afferent signal	Pancreatic β-cell senses ↑ glucose
Control (Integrating) Centre	Compares with set-point; plans response	Hypothalamus for temperature; spinal cord for stretch reflex
Effector	Executes corrective action	Sweat glands for cooling; quadriceps reflex to prevent knee buckling
Negative Feedback	Output negates the original stimulus → stability	↑ BP → baroreflex ↓ HR/BP (orthostatic training)
Positive Feedback	Output amplifies stimulus → rapid change, self-limiting	Clot formation after injury; contraction cascade in labour

Dynamic Nature of Set-points

Situation	Variable Shift	Clinical Implication
Fever	Body temp set-point ↑ 1-2 °C	Active limb movement CI until temp normal
Endurance training	Resting HR set-point ↓ (bradycardia)	Lower HR response—use HR reserve not absolute HR for intensity
Ageing	Baroreflex sensitivity ↓	Gradual positional changes to avoid dizziness in older adults

4 Physiological Regulation Pathways

1. **Neural (fast, point-to-point)**
   Reflex latency ~ 50 ms → stretch reflex governs postural adjustments during balance training.
2. **Hormonal (slow-to-medium, broadcast)**
   Adrenaline surge raises HR & BP during high-intensity interval—factor in rest intervals.
3. **Autocrine / Paracrine (local)**
   Nitric-oxide release by endothelial cells causes local vasodilation → warm-up improves muscle perfusion.
4. **Intrinsic Rhythms (circadian)**
   Cortisol peaks 06 – 09 h; schedule demanding therapy when alertness high for stroke patients.

5 Clinical Examples Linking Homeostasis to Physiotherapy

PT Scenario	Monitored Variable	Feedback Loop at Work	Intervention Adjusted?
Early ambulation post-MI	BP & HR	Baroreflex; sympathetic drive	Keep RPE ≤ 11; sit if SBP drops 20 mm Hg
Hydrotherapy for CP child	Core temperature	Thermoregulatory vasodilation & sweating	Limit session to 30 min at 34 °C water
Inspiratory muscle training in COPD	$PaCO_2$ / pH	Chemoreceptor-driven ↑ ventilation	Titrate load to 30 % PImax to avoid fatigue
Isometric quad set with Valsalva	Intrathoracic pressure / BP	Positive feedback— ↑ BP may overshoot	Coach exhale on effort to break loop

6 Self-Check Quiz (answers below)

1. **Define homeostasis in one sentence.**
2. **Which feedback type is involved in lactation?**
3. **Name the primary sensor for arterial O_2 tension and its location.**
4. **During prolonged standing a patient faints. Which homeostatic circuit failed to compensate?**
5. **Why can beta-blockers mask early signs of hypoglycaemia in diabetic patients?**

Answers

1. Maintenance of a **stable internal environment** by coordinated physiological responses despite external change.
2. **Positive feedback** via oxytocin release from posterior pituitary.
3. **Peripheral chemoreceptors** in the **carotid bodies** at the bifurcation of the common carotid artery.
4. **Baroreceptor reflex** (negative feedback regulating BP).
5. They blunt **sympathetic adrenergic symptoms** (tachycardia, tremor) that normally alert the patient to low glucose.

7 • Suggested Learning Activities

Activity	Purpose
Set-point Shift Simulation (computer lab)	Model HR, BP, temp changes during exercise & recovery
Homeostasis Role-Play	Students act as sensor, integrator, effector to visualise feedback loops
Vitals Monitoring Practicum	Record HR/BP before & after postural change; identify compensatory patterns

8 Key Take-Home Points

- **Physiology underpins every clinical decision** a physiotherapist makes—from safe mobilisation post-surgery to writing aerobic programmes.
- **Homeostasis is dynamic**, not static; understanding shifting set-points is crucial for individualised care.
- **Feedback mechanisms** can be therapeutically harnessed (training) or inadvertently disrupted (over-stretch, heat, Valsalva)—stay vigilant.

Part 2 | Introduction to Biochemistry

1 Learning Objectives

On completing this section you will be able to …

1. **Explain why biochemistry matters to physiotherapists** and give three concrete clinical examples.
2. **Recall the core chemical principles**—atomic structure, bonding, water chemistry, pH, buffers, energy coupling—that underpin human physiology.
3. **Describe the four major classes of biomolecules** and relate each to tissue structure or metabolism important in rehabilitation.
4. **Interpret common biochemical data** (e.g., blood glucose, creatine-kinase, lactate) and adjust treatment plans accordingly.

2 Why Biochemistry for Physiotherapists?

Physiological Process	Biochemical Basis	PT Relevance
Muscle contraction	ATP hydrolysis by myosin ATPase; Ca^{2+} binding to troponin	Guides rest intervals in strength programmes; explains fatigue ↓ ATP
Bone remodelling	Collagen cross-linking, hydroxy-apatite mineralisation (Ca^{2+}, PO_4^{3-}, vitamin D)	Weight-bearing exercise ↑ osteoblast activity; nutrition advice on Ca^{2+}, Vit D
Energy supply during exercise	Glycolysis, Krebs cycle, oxidative phosphorylation	HIIT taps anaerobic glycolysis → ↑ lactate; aerobic endurance uses β-oxidation
Inflammation & healing	Cytokines, prostaglandins, collagen synthesis (vit C co-factor)	Plan loading around inflammatory vs proliferative phases; advise vit C for tendon repair
Nerve conduction	Na^+/K^+ ATPase gradients; neurotransmitter synthesis (ACh, GABA)	Electrotherapy parameters & fatigue risk in neuropathies

Bottom line: **Biochemistry translates cellular events into functional outcomes**—the core of evidence-based rehabilitation.

3 Essential Chemical Principles

Concept	Key Points	Clinical Link
Atoms & Ions	H, C, N, O = 96 % body mass; Ca^{2+}, Na^{+}, K^{+}, Cl^{-} crucial ions	Na^{+}–K^{+} imbalance alters nerve excitability—watch electrolyte labs before NMES
Chemical Bonds	Covalent (strong) in proteins; Ionic in bone salts; H-bonds in DNA & water	Wound collagen cross-link density affects tensile strength; glycosaminoglycan H-bonding retains water in cartilage
Water	High heat capacity & solvent of life; 60 % body weight	Hydration status influences thermoregulation during hydrotherapy
pH & Buffers	Blood pH 7.35-7.45; bicarbonate buffer + respiratory compensation	High-intensity exercise ↓ pH; cue active recovery and breathing control
Concentration / Osmosis	Osmotic pressure drives capillary exchange; albumin maintains oncotic pressure	Edema management—muscle pump & compression garments aid venous/lymph return
Energy Transfer	ATP ⇄ ADP + Pi + 7.3 kcal; NAD^{+}/FAD redox pairs	Creatine supplementation ↑ phospho-creatine buffer → may aid high-load rehab

4 Macromolecules – Quick Reference

Class	Monomer	Physiological Role	Rehab Touch-Point
Carbohydrates	Glucose, glycogen	Rapid ATP; cell-surface recognition	Carb timing for glycogen re-synthesis post-exercise
Lipids	Fatty acids, triglycerides, phospholipids	Energy store, membrane fluidity	Essential fatty acids modulate inflammation (ω-3 intake)
Proteins	20 amino acids	Enzymes, contractile filaments, carriers	Adequate protein (1.2–1.6 $g \cdot kg^{-1}$) for muscle hypertrophy
Nucleic Acids	Nucleotides	Genetic code, ATP	Satellite-cell activation in muscle repair depends on DNA transcription

5 Energy Systems Overview

System	Location	Duration	Fuel	Key Enzymes	PT Application
ATP-PCr (alactic)	Cytosol	0-10 s	Phospho-creatine	Creatine kinase	1-RM lifts, plyometrics
Anaerobic Glycolysis	Cytosol	10-120 s	Muscle glycogen	Phosphofructokinase	HIIT; monitor lactate
Aerobic Oxidative	Mitochondria	>2 min	Glucose, fatty acids	Citrate synthase, ETC complexes	Endurance walking programmes
β-oxidation	Mitochondrial matrix	20 min → hours	FFA from adipose	Acyl-CoA dehydrogenase	Long, low-intensity cardio for obese clients

6 Clinical Chemistry Markers Every PT Should Know

Marker	Normal Range	What It Indicates	PT Action Point
Fasting glucose	70-100 $mg \cdot dL^{-1}$	Energy supply; diabetes risk	If < 70 or > 250 $mg \cdot dL^{-1}$ postpone vigorous exercise
Creatine-Kinase (CK)	♂ 40-200 U/L ♀ 20-180 U/L	Muscle damage (rhabdomyolysis)	After eccentric session CK may rise; monitor hydration, load progression
Lactate (rest)	0.5-2.0 $mmol \cdot L^{-1}$	Anaerobic metabolism	Use lactate threshold to set endurance intensity
pH (arterial)	7.35-7.45	Acid–base balance	COPD exacerbation may show pH < 7.30; hold chest PT if unstable

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7 Self-Check Quiz (answers below)

1. **Which property of water helps maintain stable core temperature during a 30-minute cycling session?**
2. **Identify the buffer pair that regulates blood pH and state its Henderson–Hasselbalch equation.**
3. **Why does a low-carbohydrate diet impair high-intensity exercise performance?**
4. **Name the enzyme that converts pyruvate to lactate and explain why lactate is not a "waste" product.**
5. **Give two biochemical reasons muscle protein synthesis is blunted in the elderly.**

Answers

1. Water's **high specific heat capacity** absorbs excess heat with minimal temperature rise.
2. **Bicarbonate–carbonic acid buffer**; pH = 6.1 + log ($[HCO_3^-]/0.03 \times PaCO_2$).
3. Glycolysis depends on stored muscle **glycogen**; low carbohydrate means limited substrate → early fatigue.
4. **Lactate dehydrogenase (LDH);** lactate shuttled to heart/slow muscle & liver (Cori cycle) for ATP or gluconeogenesis.
5. ↓ Anabolic hormone (IGF-1) signalling **and** ↑ chronic inflammation (inflamm-aging) activate proteolysis pathways.

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8 Key Take-Home Points

- **Biochemistry explains the "why" behind physiological responses**—energy supply, tissue repair, acid–base balance.
- **Water, ions, pH and ATP** are foundational themes; disturbances show up in vitals and lab values every PT should interpret.
- **Integrating biochemical insight with anatomy and physiology** enables precise, safe rehabilitation programming.