1.2Origin of the ECG Signal and Waveform

1. Introduction to Bioelectric Signals

- **Cellular Origin:** Bioelectric potentials are generated at the cellular level by the movement of ions (sodium, potassium, and chloride) through semi-permeable membranes that act as selective filters.
- **Resting Potential:** In its resting state, a cell is **polarized**, maintaining a negative charge on the inner surface and a positive charge on the outer portion. This internal resting potential is approximately **–90 mV**.
- **Depolarization:** When stimulated, the outer membrane momentarily becomes negative relative to the interior. The potential changes to approximately **+20 mV**. This excitation wave propagates through the muscle, causing it to contract.
- **Repolarization:** Shortly after excitation, the cell discharges and recharges to re-establish its resting potential. This process is necessary for the muscle to return to a relaxed state.
- **Action Potential:** The electrical activity associated with a single muscle contraction generates a voltage waveform known as an action potential.

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2. The Heart as an Electrical Generator

- **The Signal:** The Electrocardiogram (ECG) is a recording of the electrical activity associated with heart function.
- **The Dipole:** The heart acts as a **simple electric dipole** (a pair of positive and negative charges). This dipole generates an electrical field vector that changes periodically in time and space as the heart functions.
- **Measurement:** These electrical effects are measured on the body's surface using electrodes. Standardized waveforms reflect the normal amplitude and phase relationships of the heart's cycles.

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3. The Heart’s Conduction System

Electrical activity follows a specific physiological path to ensure coordinated pumping:

- **SA Node (Sino-atrial Node):** Known as the "natural pacemaker," located in the right atrium, where the impulse originates.
- **AV Node (Atrio-ventricular Node):** The impulse travels through the atria to the AV node, which provides a critical delay (approx. 0.12s) to allow the atria to finish contracting before the ventricles begin.
- **Bundle of His & Purkinje Fibres:** After the delay, the impulse travels rapidly through the interventricular system and into the free walls of the ventricles via the Purkinje network.

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4. The Standard ECG Waveform

The standard ECG wave pattern is categorized into specific waves, intervals, and segments:

Component	Description	Physiological Event
P Wave	Initial small upward deflection	**Atrial Depolarization** (contraction).
QRS Complex	Large spike (typical amplitude **1 mV**)	**Ventricular Depolarization**.
T Wave	Final upward deflection	**Ventricular Repolarization**.
U Wave	Small wave following the T wave	Occurs during the intermediate interval.

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5. Key Clinical Intervals

- **PR (or PQ) Interval:** Measured from the start of the P wave to the start of the QRS complex. It represents the time taken for the impulse to travel from the SA node to the ventricles. **Normal range: 0.12 to 0.2 s**.
- **QRS Interval:** The time taken for the impulse to travel through the ventricles. **Normal range: 0.05 to 0.10 s**.
- **QT Interval:** Represents the total period for one complete ventricular contraction (**systole**).
- **ST Segment:** The time between ventricular depolarization and repolarization.
- **TP Interval:** The period from the end of the T wave to the start of the next P wave, corresponding to ventricular diastole.

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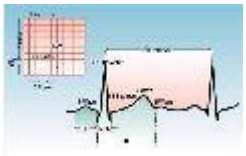
6. Visual Representations (Descriptions of Diagrams)

- **Cell Potential (Fig 2.1):** Shows a baseline at 0 mV, a resting state at –90 mV, a sudden spike (depolarization) to +20 mV upon stimulus, and a return curve (repolarization) back to –90 mV.
- **Conduction Path (Fig 2.3):** Illustrates the heart structure with arrows showing the impulse starting at the SA Node, traveling through the Right/Left Atria, pausing at the AV Node, and then racing through the Bundle of His and Purkinje network.
- **Standard ECG Pattern (Fig 2.4):** Displays the characteristic "P-QRS-T" sequence on a grid, labeling the distinct waves and the critical time intervals (PR, QRS, QT, and ST).

The Standard 12 Lead ECG

The standard 12-lead electrocardiogram is a representation of the heart's electrical activity recorded from electrodes on the body surface. This section describes the basic components of the ECG and the lead system used to record the ECG tracings.

ECG Waves and Intervals:



What do they mean?

- P wave: the sequential activation (depolarization) of the right and left atria
- QRS complex: right and left ventricular depolarization (normally the ventricles are activated simultaneously)
- ST-T wave: ventricular repolarization
- U wave: origin for this wave is not clear - but probably represents "afterdepolarizations" in the ventricles
- PR interval: time interval from onset of atrial depolarization (P wave) to onset of ventricular depolarization (QRS complex)
- QRS duration: duration of ventricular muscle depolarization
- QT interval: duration of ventricular depolarization and repolarization
- RR interval: duration of ventricular cardiac cycle (an indicator of ventricular rate)
- PP interval: duration of atrial cycle (an indicator of atrial rate)

Orientation of the 12 Lead ECG

It is important to remember that the 12-lead ECG provides spatial information about the heart's electrical activity in 3 approximately orthogonal directions:

- Right ⇔ Left
- Superior ⇔ Inferior
- Anterior ⇔ Posterior

Each of the 12 leads represents a particular orientation in space, as indicated below (RA = right arm; LA = left arm, LL = left foot):

Bipolar limb leads (frontal plane):

- Lead I: RA (-) to LA (+) (Right Left, or lateral)
- Lead II: RA (-) to LL (+) (Superior Inferior)
- Lead III: LA (-) to LL (+) (Superior Inferior)

Augmented unipolar limb leads (frontal plane):

- Lead aVR: RA (+) to [LA & LL] (-) (Rightward)
- Lead aVL: LA (+) to [RA & LL] (-) (Leftward)
- Lead aVF: LL (+) to [RA & LA] (-) (Inferior)

Unipolar (+) chest leads (horizontal plane):

- Leads V1, V2, V3: (Posterior Anterior)
- Leads V4, V5, V6:(Right Left, or lateral)

Lead Placement Diagrams: