Physiol-11A12 Compare and contrast a single twitch and a tetanic contraction in a skeletal muscle fibre. Include in your answer the physiological basis for the development of a tetanic contraction

**Background**

Skeletal muscle consists of muscle fibres that contract in response to electrical stimulation

Depending on nature of electrical stimuli → different mechanical responses

**Single Twitch Contraction**

*Single twitch* = brief contraction of a motor unit – e.g. in response to brief threshold stimulus – followed by complete relaxation

**Mechanism (excitation-contraction coupling)**

1. Motor neuron action potential → arrives at neuromuscular junction (NMJ)
2. Depolarisation of presynaptic membrane → release of ACh
3. ACh diffuses across NMJ → binds to postsynaptic nAChR on motor endplate
4. EPSP partial depolarise motor endplate → once temporal ΣEPSP reaches threshold (-50 mV) → muscle action potential
5. Action potential propagates down whole muscle via T-tubule system → opens voltage gated L-type (dihydropyridine) Ca²⁺ channels → stimulate SR ryanodine receptors → SR releases Ca²⁺
6. ↑intracellular [Ca²⁺] → Ca²⁺ binds and unlocks troponin-tropomyosin system → activates myosin-actin cross-bridges → *muscle contraction*
7. when intracellular [Ca²⁺] falls (via ATP dependent pumps + exchangers) → *muscle relaxation*

Single twitch duration usu. 10 – 100 ms depending on fibre type

Repeated single twitches → *same force and duration*

**Tetanic Contraction**

*Tetanic contraction* = sustained maximum possible contraction of a motor unit – e.g. in response to repeated high frequency threshold stimuli

Action potential and refractory period of skeletal muscle are *very short* ∴ AP and RP are over before onset of relaxation

Thus, repetitive stimulation → summation of strength of mechanical contraction → state of tetanic contraction

With each stimuli → build up of intracellular [Ca²⁺] → ↑cross-bridges → ↑tension ∴ tetanic contraction up to 4x tension of single twitch contraction ∴ tetanic contraction consumes more energy (ATP) than single twitch
**Critical Frequency Required for Tetany**

Depends on the contraction-relaxation time of muscle fibre

Slow twitch fibres – contraction time ~ 100 ms
∴ require repeated stimuli > 10 Hz for tetanus

Fast twitch fibres – contraction time ~ 10 ms
∴ require repeated stimuli > 100 Hz for tetanus

**Offset of Tetanus**

Tetanus offset when:
- cessation of electrical stimuli → muscle action potential stops
- ATP depletion → muscle fatigue
- inhibitory effect from local lactic acidosis

**Diagram – Single Twitch → Summation → Tetany**

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**Examiner’s comments** – This question was passed by 25% of candidates.

Better answers included a brief description of a skeletal muscle fibre and its contractile mechanism, definitions of a single muscle fibre twitch and tetanic contraction, an explanation of the difference between the membrane electrical refractory period and fibre relaxation time and the implications of each, the reasons re-stimulation within fibre relaxation time results in additional contraction, the role of calcium, the impact of relaxation times for different fibre types on the frequency required to create a tetanic contraction (with example values for each), and the differences between single twitch and tetanic contractions with respect to the reasons that relaxation occurs, force achieved, and energy requirements.

**Common mistakes** included providing excessive detail about synaptic events or excitation-contraction coupling and missing the important points above, describing summation and tetany as electrical events rather than mechanical events, and writing about the use of a nerve stimulator.