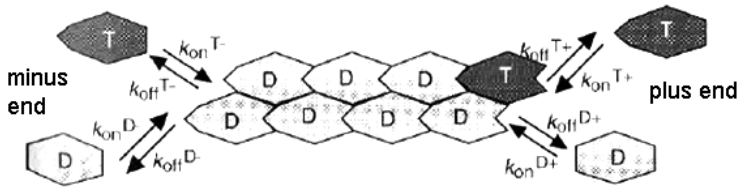
Quantitative Physiology I / Molecular and Cellular Systems; BMEN E4001x
HW5: Cell cytoskeleton and muscle physiology
Due Nov. 19, 2025.

1) Actin dynamics (10 points)

Consider the representation of actin thin filament assembly from ATP-bound and ADP-bound monomers:



	plus end			minus end		
	k_{on}, $(\mu M^{*}s)^{-1}$	k_{off}, s^{-1}	M_C, µM	k_{on}	k_{off}	M_C
ATP-actin	11.6±1.2	1.4±0.8	0.12±0.07	1.3±0.2	0.8±0.3	0.6±.17
ADP-actin	3.8	7.2	1.9	0.16	0.27	1.7

This question focuses on the phenomenon of actin treadmilling, in which the structure undergoes net disassembly at the minus end net growth at the plus end. Consider the activity of ATP-bound actin only; assume that ADP-bound actin is not present.

1.1) Over what range of ATP-actin monomer concentration is treadmilling observed? Base this on the average values stated for the various rate constants. (5 pts)

1.2) At what ATP-actin monomer concentration is constant-length treadmilling observed? (5 pts)

2) Muscle physiology (10 points)

2.1) What is the molecular-level force associated with a single cross-bridge interaction? (5 pts)

2.2) What are two things that distinguish cardiac from skeletal muscle? (5 pts)

Note: The Boron & Boulpaep text is useful for these questions.

3) Continuous cell lines (10 points)

Continuous cell lines are a valuable tool in research, and have led to major discoveries in cellular physiology. In using these models, it is important to recognize and respect their specific history. For a continuous cell line of your choice, describe:

- Why did you choose this type of cell?
- The type of cell (*e.g.*, neuron, osteoblast, or macrophage) that the model represents.
- The source of the cell line, including species and method of preparation.
- Ethical impacts associated with the generation of the cell line.
- Shortcomings of the cell line, such as species or relevance to disease.
- A discovery or insight that was made using these cells. Cite your source, such as primary research, webpage, or book chapter.

A paragraph of up to 15 sentences is appropriate for this question. The American Type Culture Collection (www.atcc.org) is a good source for identification of cell lines. As appropriate, summarize a range of perspectives on the issues surrounding the chosen cell line.

Solution

1) Actin treadmilling

1.1) 0.12 to 0.6 µM, the range defined by the M_c's for the plus and minus end for ATP-actin. It is in this range (inclusive of the Mc's) that the ends are showing different behaviors associated with treadmilling.

1.2)

$dn/dt = k_{on,ATp,plus}*[actin]-k_{off,ATP,plus}+k_{on,ATP,minus}*[actin]-k_{off,ATP,minus}$;

$dn/dt=(11.6+1.3)*[actin]-(1.4+0.8)$; in µM

$dn/dt=12.9*[actin]-2.2$; equals zero when actin = 0.1705 µM;

2) Muscle physiology

2.1) 5 pN, B&B laser trapping experiment associated with Fig 9-10.

2.2) B&B Chapter 9. See Table 9-3

TABLE 9-3 Comparison of Properties among Muscle Types

	SKELETAL	CARDIAC	SMOOTH
Mechanism of excitation	Neuromuscular transmission (release of ACh, activating nicotinic ACh receptor)	Pacemaker depolarization, spread electrotonically via gap junctions	Synaptic transmission Agonist-activated receptors Electrical coupling Pacemaker potentials
Electrical activity of muscle cell	Action potential spikes	Action potential plateaus	Action potential spikes, plateaus Graded membrane potential changes Slow waves
Ca^{2+} sensor	Troponin C	Troponin C	CaM
EC coupling	L-type Ca^{2+} channel (Cav1.1, DHP receptor) in T-tubule membrane mechanically activates Ca^{2+}-release channel (RYR1) in SR membrane	Ca^{2+} entry via L-type Ca^{2+} channel (Cav1.2, DHP receptor) triggers Ca^{2+}-induced Ca^{2+} release (sparks) via RYR2 in SR membrane	Ca^{2+} entry via voltage-gated Ca^{2+} channel, Cav1.2 Ca^{2+}- or IP_3-mediated Ca^{2+} release (sparks) via RYR3 or IP_3R1, IP_3R2, IP_3R3 in SR membrane Ca^{2+} entry through SOCs via Orai and TRP channels
Terminator of contraction	Breakdown of ACh by acetylcholinesterase SR Ca^{2+} uptake	Action potential repolarization SR Ca^{2+} uptake	MLCP SR Ca^{2+} uptake
Twitch duration	20–200 ms	200–400 ms	200 ms—sustained
Regulation of force	Frequency and multifiber summation	Regulation of calcium entry	Balance between MLCK phosphorylation and dephosphorylation Latch state
Metabolism	Oxidative, glycolytic	Oxidative	Oxidative