FICS EXERCISE PHYSIOLOGY - 1

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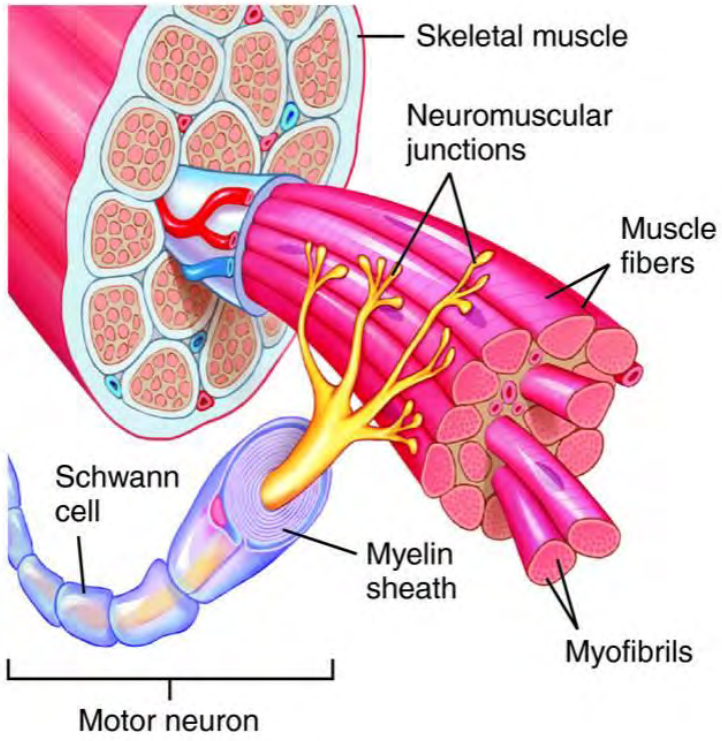
MUSCLE PHYSIOLOGY

- Muscle Structure
  - Muscle fiber
  - Motor unit – the anterior motor neuron and the muscle fibers it innervates
  - Sarcomere – the smallest contractile unit of the skeletal muscle
    - Actin-myosin
    - Intermediate fibers
    - Z disc streaming

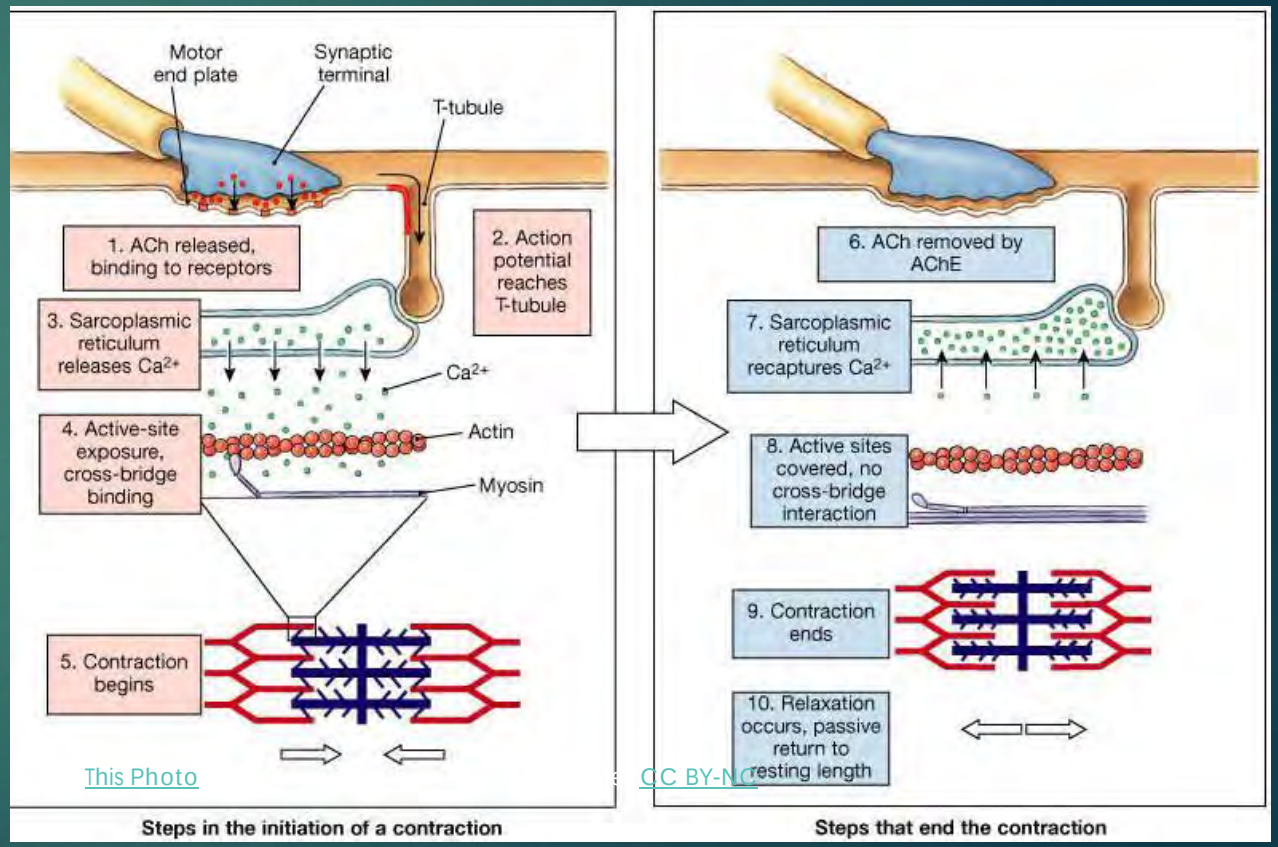
MUSCLE PHYSIOLOGY

Motor Unit – A single motor neuron as well as all the muscle fibers that neuron activates.



MUSCLE PHYSIOLOGY

- Sliding Filament Theory
  - Cross bridges – actin/myosin/ATP connections
  - Depolarization causes calcium release
  - Calcium ions bind with troponin
  - This bond shifts tropomyosin
  - There is a resting phase in which very little calcium is present in the myofibril



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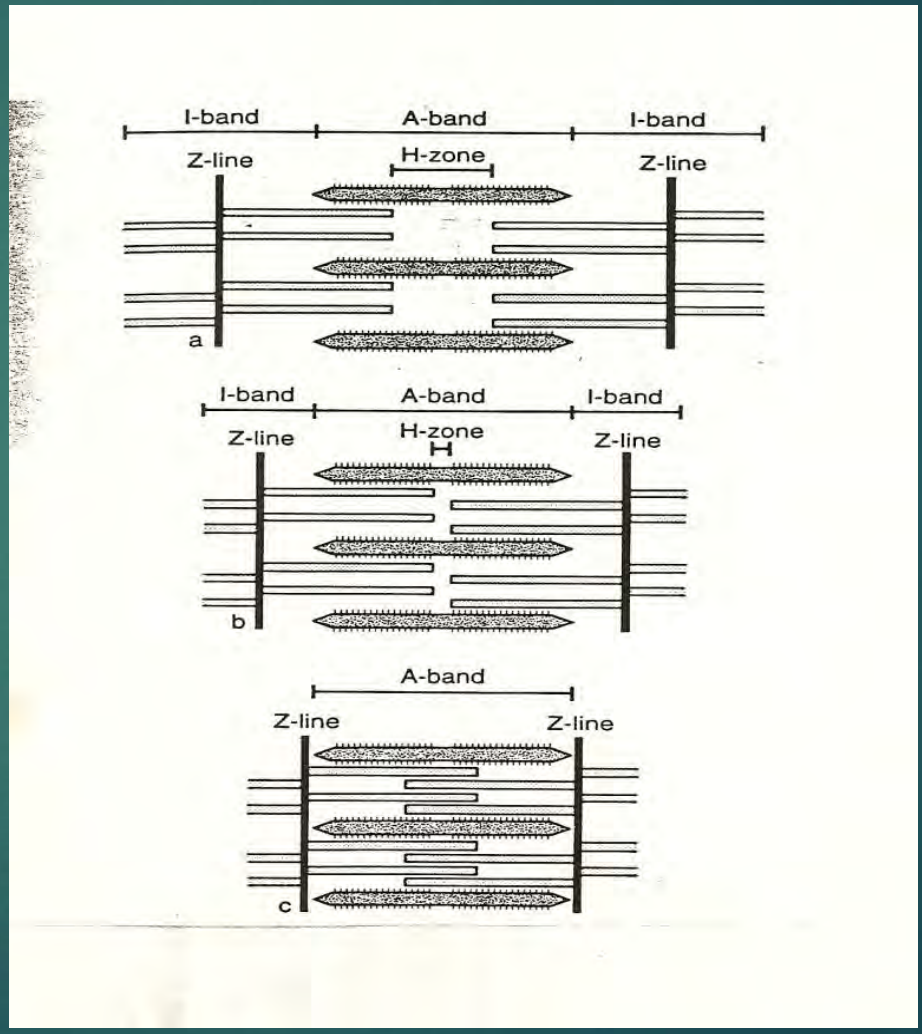
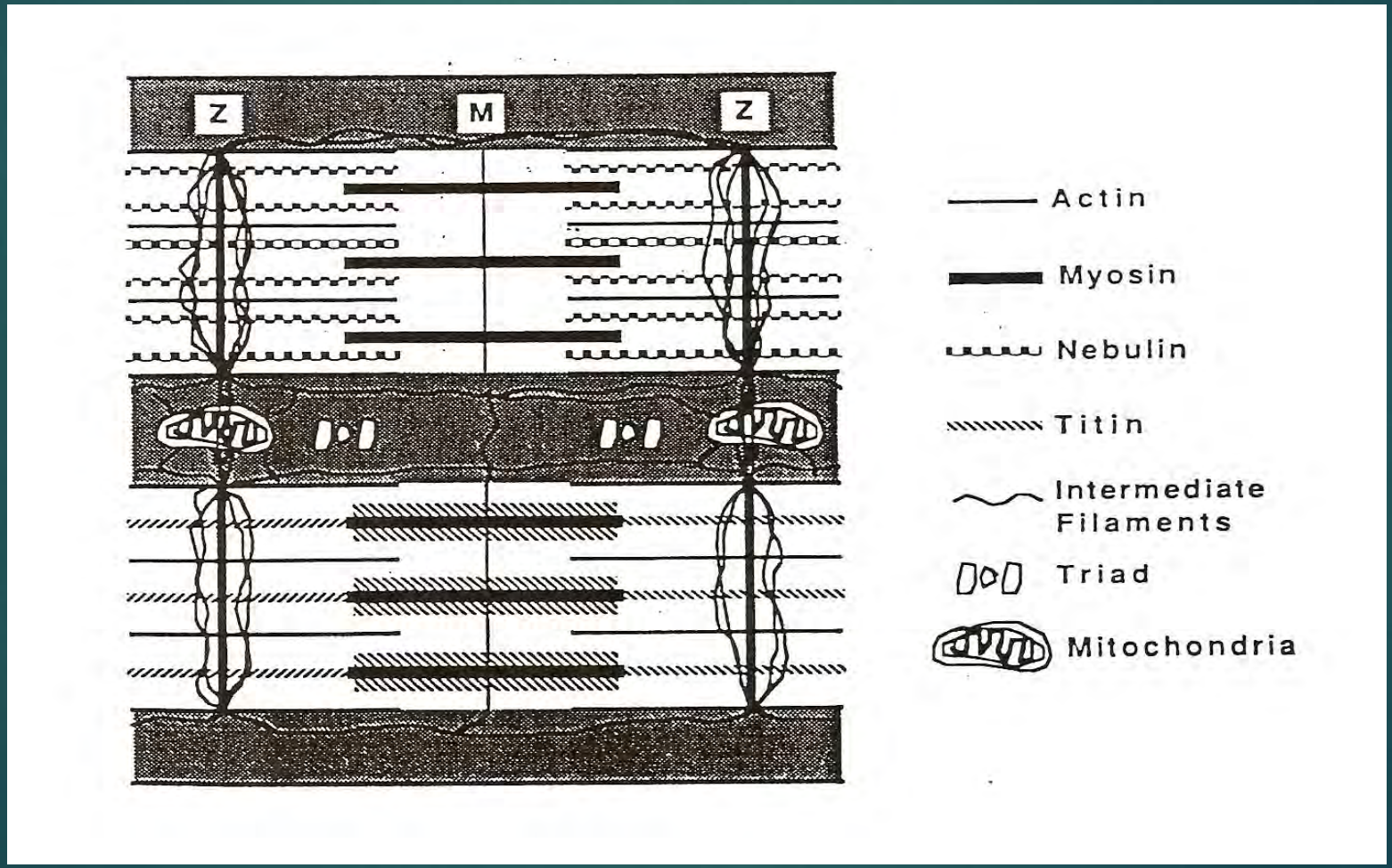
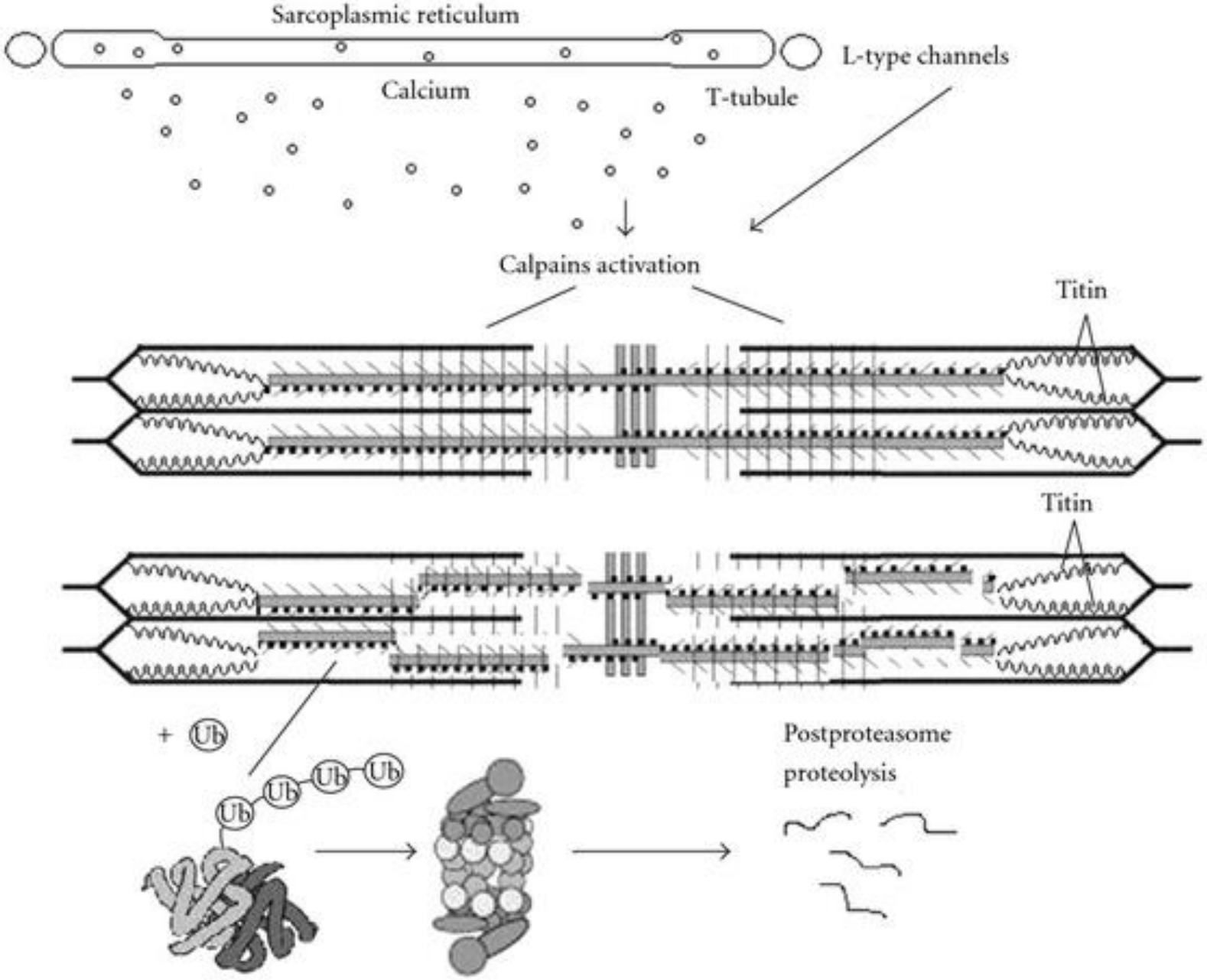
MUSCLE PHYSIOLOGY

- Sarcomere and muscle length
  - Length-tension relationship



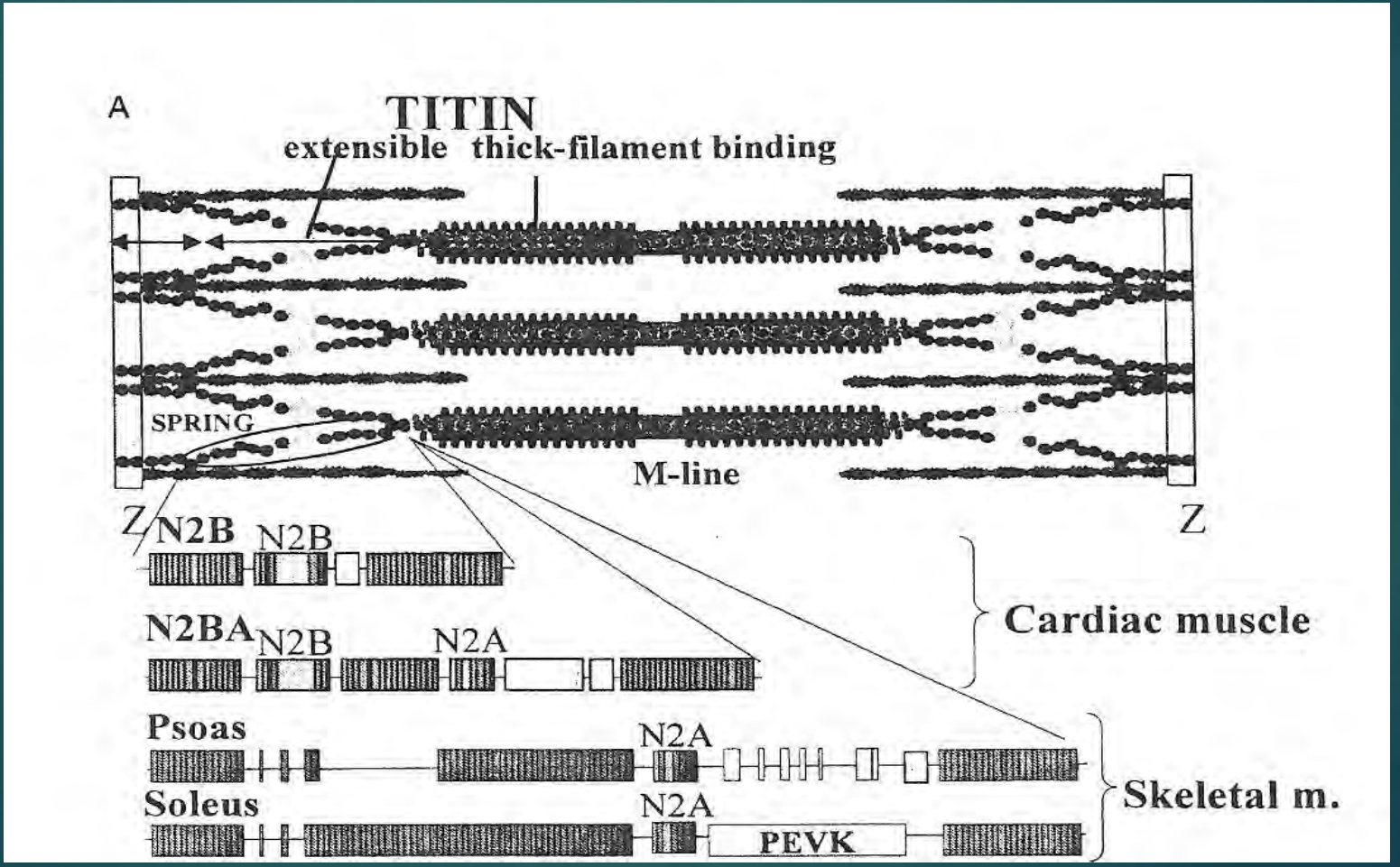
MUSCLE PHYSIOLOGY
Z DISC STREAMING





- Calpain function

MUSCLE PHYSIOLOGY
TITIN



MUSCLE PHYSIOLOGY
TITIN

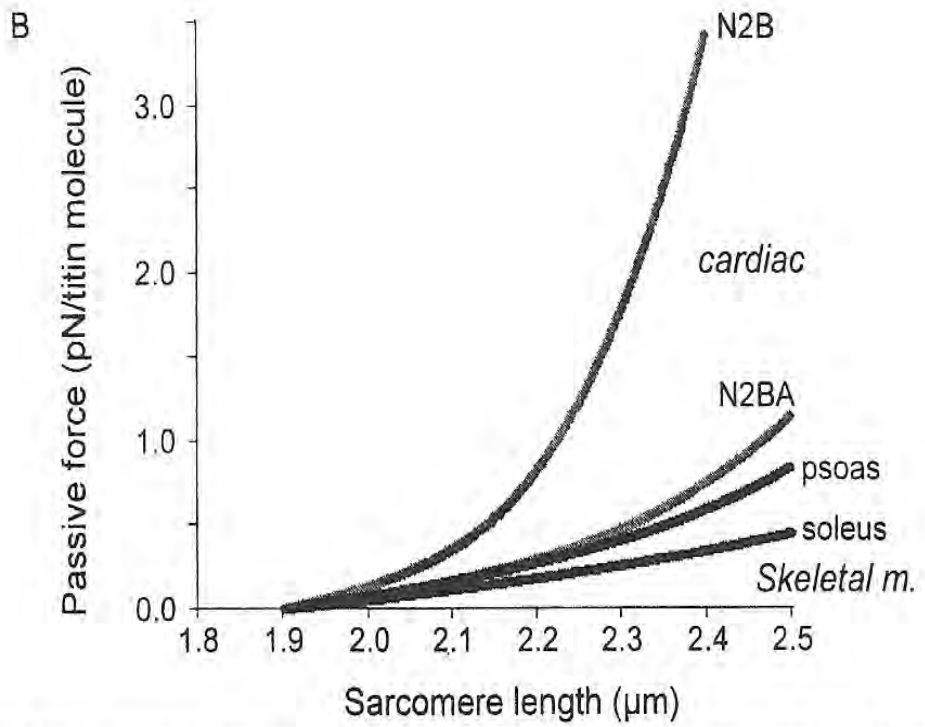


Figure 1. (A) Layout of titin in sarcomere. Titin spans from the z-disk to the M-line region of the sarcomere. Titin in and near the z-disk is inextensible as is titin in the A-band region of the sarcomere (here titin binds to the thick filament). The remaining I-band region is elastic and functions as a molecular spring. The molecular spring region varies in sequence due to differential splicing. The sequences of four different isoforms are shown at the bottom (red: Ig domains, yellow: PEVK domain, and blue: unique sequences). (B) Passive force-sarcomere length relations of different titin isoforms.

MUSCLE PHYSIOLOGY

- Muscle Fiber Types

  Slow twitch – type I
  - Slow oxidative

  Fast twitch – type II
  - type IIA fast, oxidative/glycolytic
  - type IIX fast, glycolytic
  - type IIC an undifferentiated fiber type

	Type I	Type II
Myosin ATPase	Low	High
Energy utilization	Low	High
Mitochondria	Many	Few
Color	Red	White
Myoglobin	Yes	No
Contraction rate	Slow	Fast
Duration	Prolonged	Short

MUSCLE PHYSIOLOGY

- Type IIA fibers have 6x greater power and 26% greater CSA than Type I fibers.
- Type IIX fibers have 10x greater power and 39% greater CSA than Type I fibers.

The effects of endurance, strength, and power training on muscle fiber type shifting.

Wilson JM, et al. J Strength Cond Res 2012;26(6):1724-1729

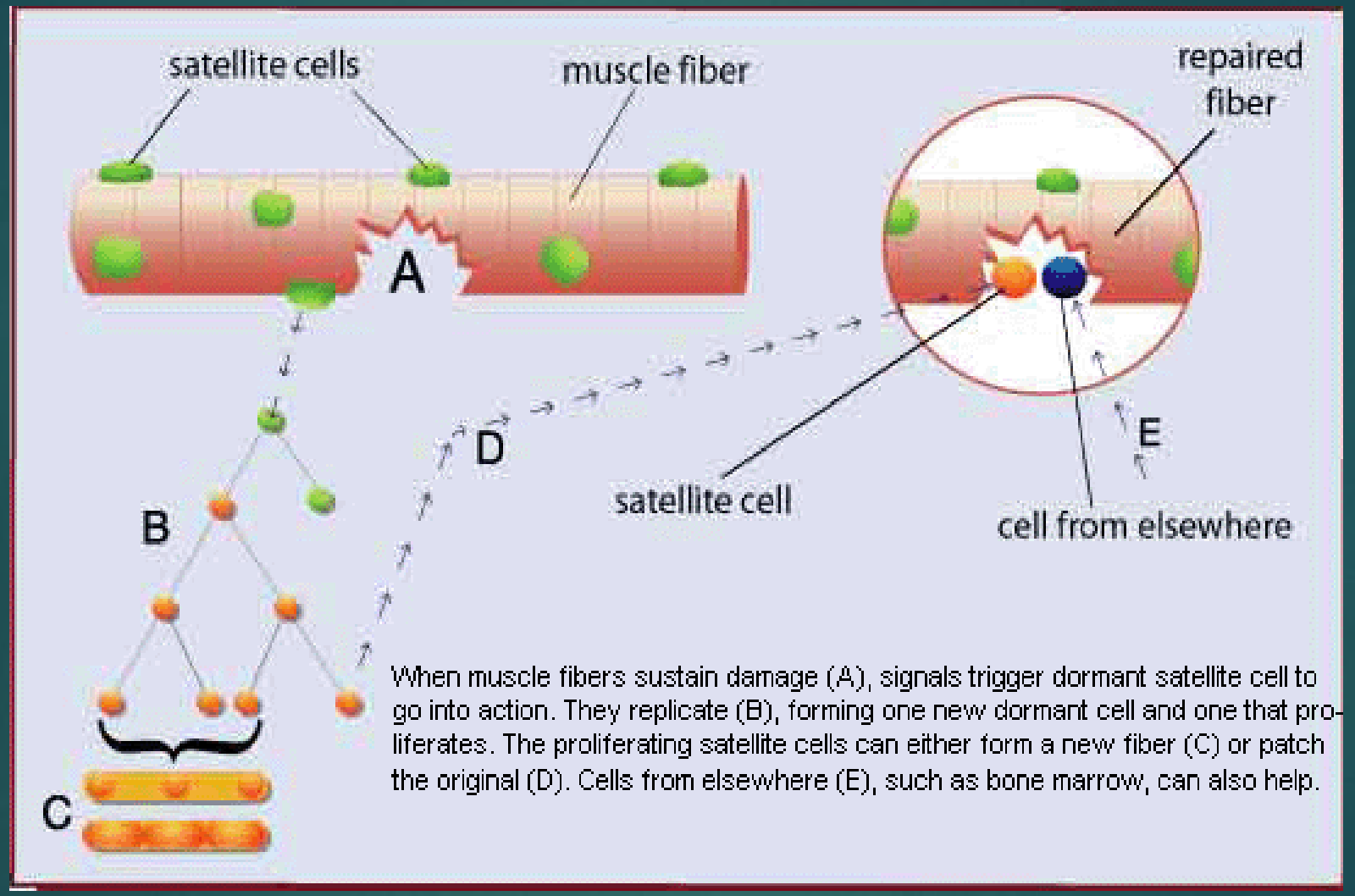
MUSCLE PHYSIOLOGY

MHC IIX ⟷ IIA at about 5 weeks.

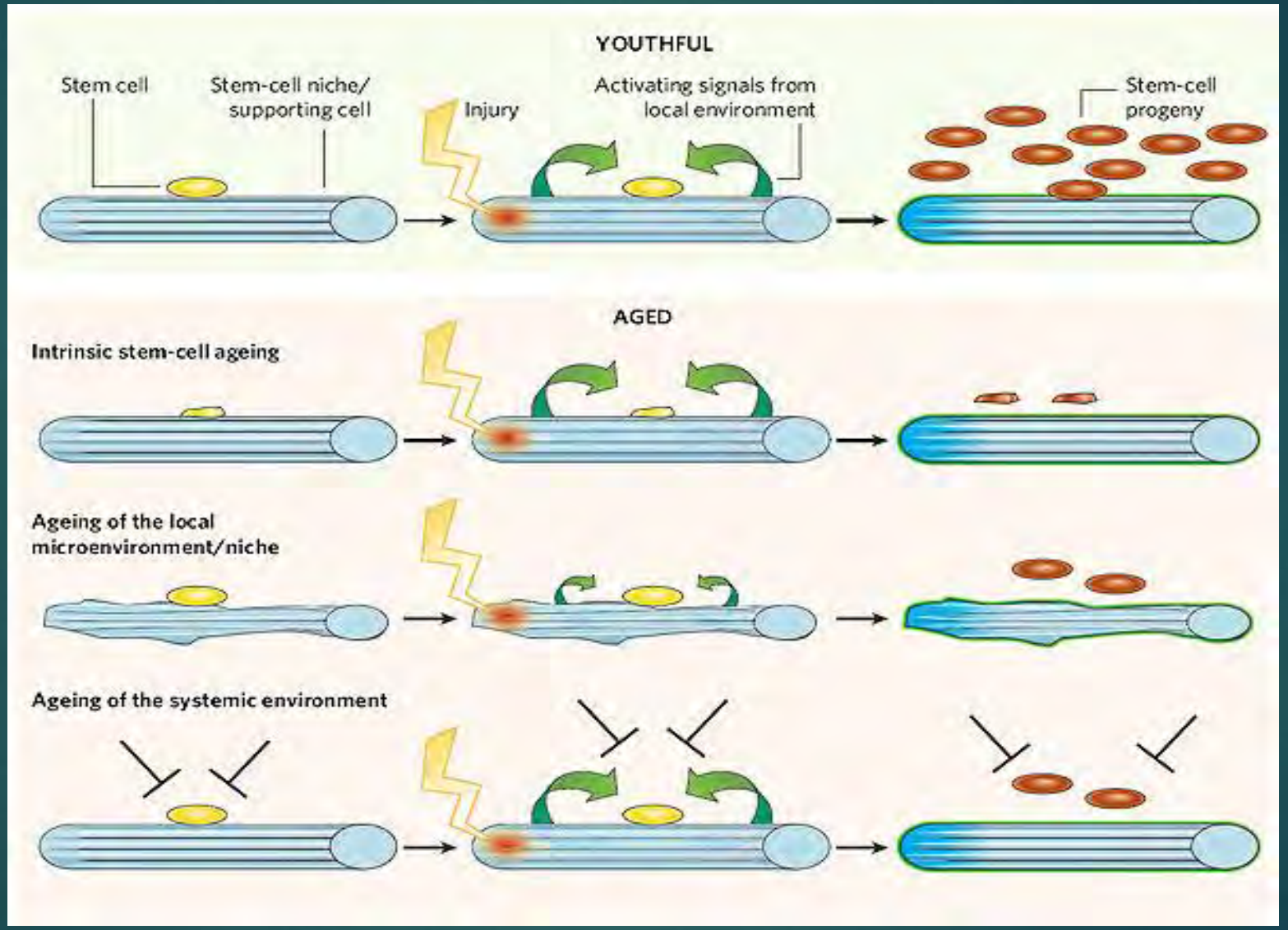
A limited body of evidence suggests that you may be able to shift between fast and slow fibers.

MUSCLE PHYSIOLOGY

- Satellite cell activation is necessary for hypertrophy.



When muscle fibers sustain damage (A), signals trigger dormant satellite cell to go into action. They replicate (B), forming one new dormant cell and one that proliferates. The proliferating satellite cells can either form a new fiber (C) or patch the original (D). Cells from elsewhere (E), such as bone marrow, can also help.


YOUTHFUL
Stem cell
Stem-cell niche/
supporting cell
Injury
Activating signals from
local environment
Stem-cell
progeny
AGED
Intrinsic stem-cell ageing
Ageing of the local
microenvironment/niche
Ageing of the systemic environment

Satellite cell

- A single bout of high force eccentric exercise increases muscle fiber SC content and activation status in Type II but not Type I muscle fibers.
- This occurred within 24 hours post-exercise recovery.
  - *Eccentric exercise increases satellite cell content in type II muscle fibers. Cermak et al., MSSE 2013;45(2):20-237.*

- High-intensity resistance training at a normal speed resulted in significant fiber type–specific adaptations (increased MND and SC content) compared with low-intensity training at both normal speed and slow speed.
- A high-intensity resistance training protocol (~85% 1RM) will yield the greatest overall adaptive response within the skeletal muscle fiber.
  - *Early-Phase Satellite Cell and Myonuclear Domain Adaptations to Slow-Speed vs. Traditional Resistance Training Programs. Herman-Montemayor, et al. JSCR 2015;29(11):3105-3114.*

Satellite cell

- Eccentric overload during leg extension exercise (single bout) induced significant SC activation, SC content increases and SC numbers related to type II myofibers. This occurred within 24 hours post-exercise recovery.
- There were no signs of increased SC differentiation or formation of new myofibers.
  - *Eccentric Overload during Resistance Exercise: A Stimulus for Enhanced Satellite Cell Activation. Wehrstein M, et al., MSSE 2021:Oct 22.*

- SC number, activation, and myogenic potential are modulated in different physiological and pathophysiological contexts.

Muscle PGC-1A modulates satellite cell number and proliferation by remodeling the stem cell niche. Dinulovic I, et al. Skeletal Muscle. 2016;6:39.

- **Local transient fibronectin (FN) secretion by SC's** is an important step in the cascade of SC activation and an increase in FN in the muscle is necessary for successful regeneration.
- Excess FN in the BL in an uninjured state is correlated with a reduced ability of SCs to respond to injury.

Delayed onset muscle soreness (DOMS)

- Exercise-related muscle pain that develops after excessive and unaccustomed exercise. More commonly occurs with eccentric exercise.
- Eccentric exercise may damage desmin predominantly and cause an increase in intracellular fibronectin

- It is suggested that type IIX fibers are more vulnerable to glycogen depletion and endurance training may help limit exercise-induced muscle damage.

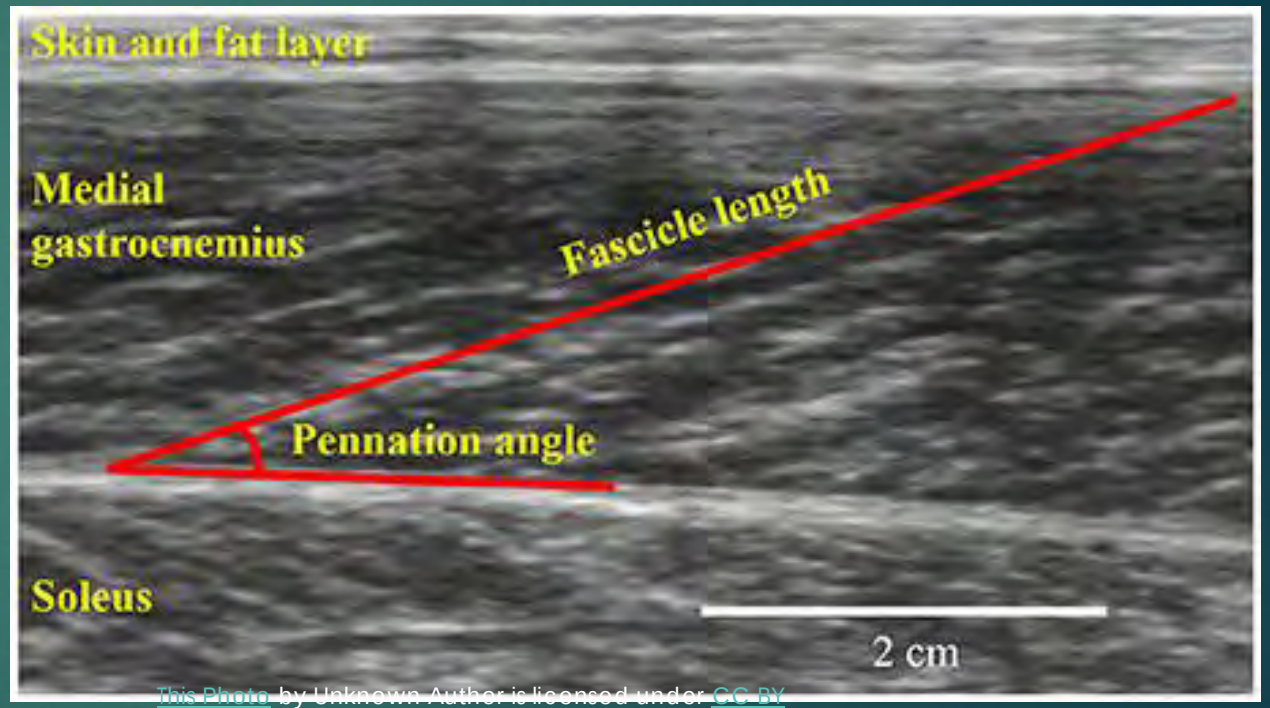
MUSCLE PHYSIOLOGY

- Types of muscle action
  - Concentric
  - Isometric
  - Eccentric

- Types of muscle action
  - Concentric
  - Isometric
  - Eccentric

MUSCLE PHYSIOLOGY

- Force production
  - Fascicle length
  - Muscle pennation
- Physiological factors – neural, preloading
- Cross-sectional area (CSA)



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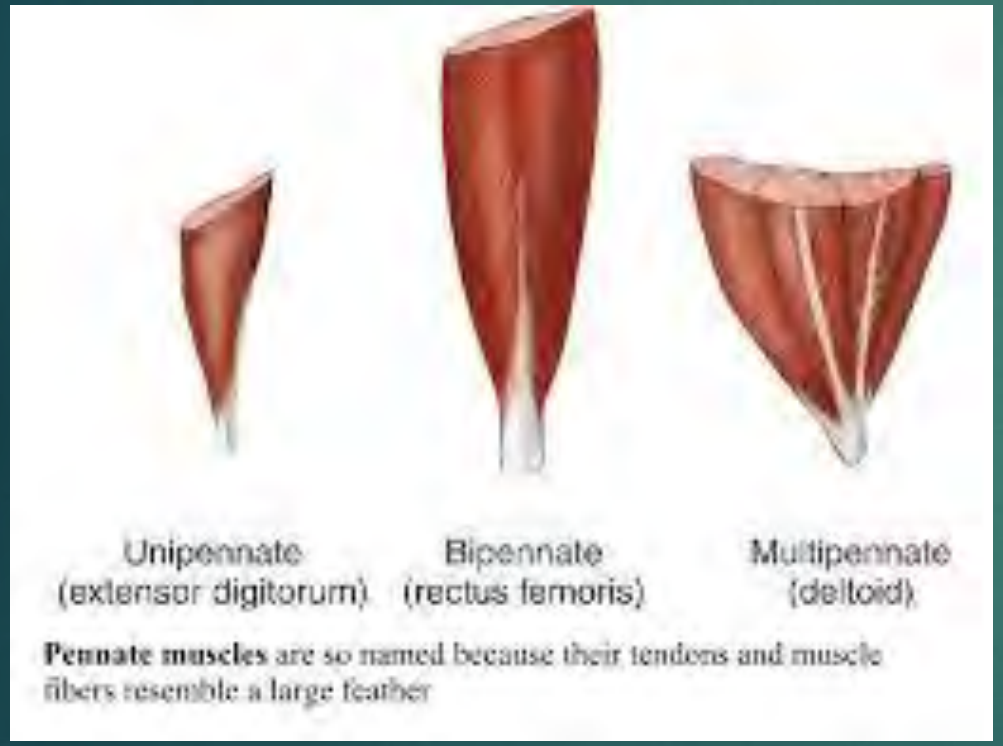
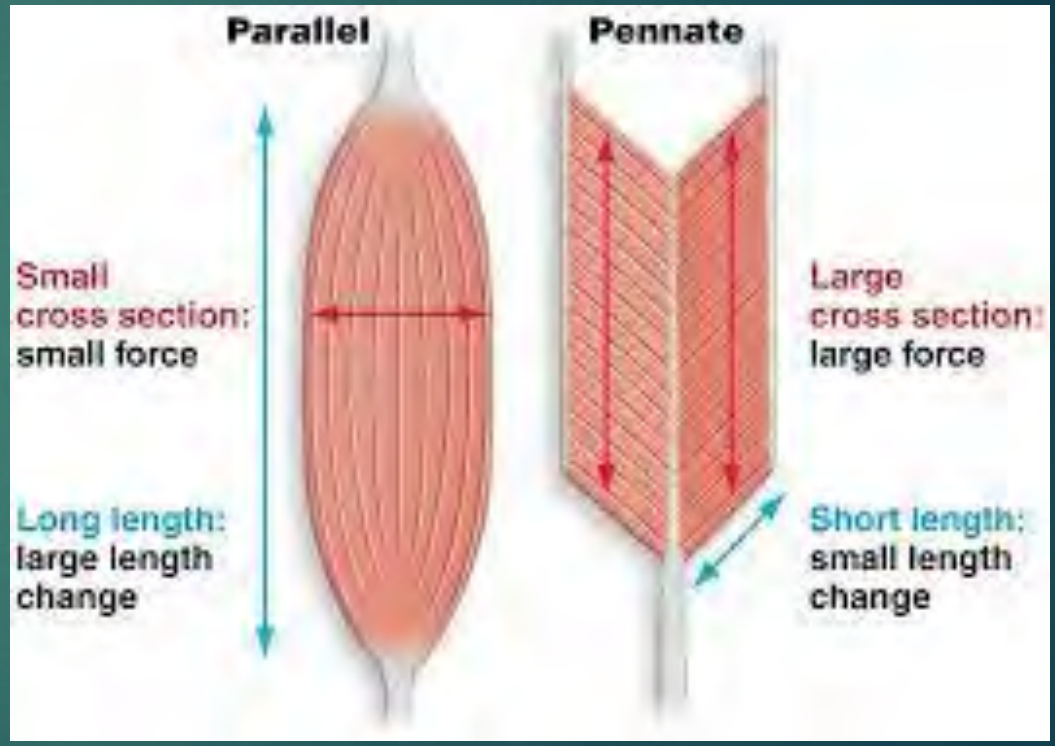


Pennate muscles are so named because their tendons and muscle fibers resemble a large feather

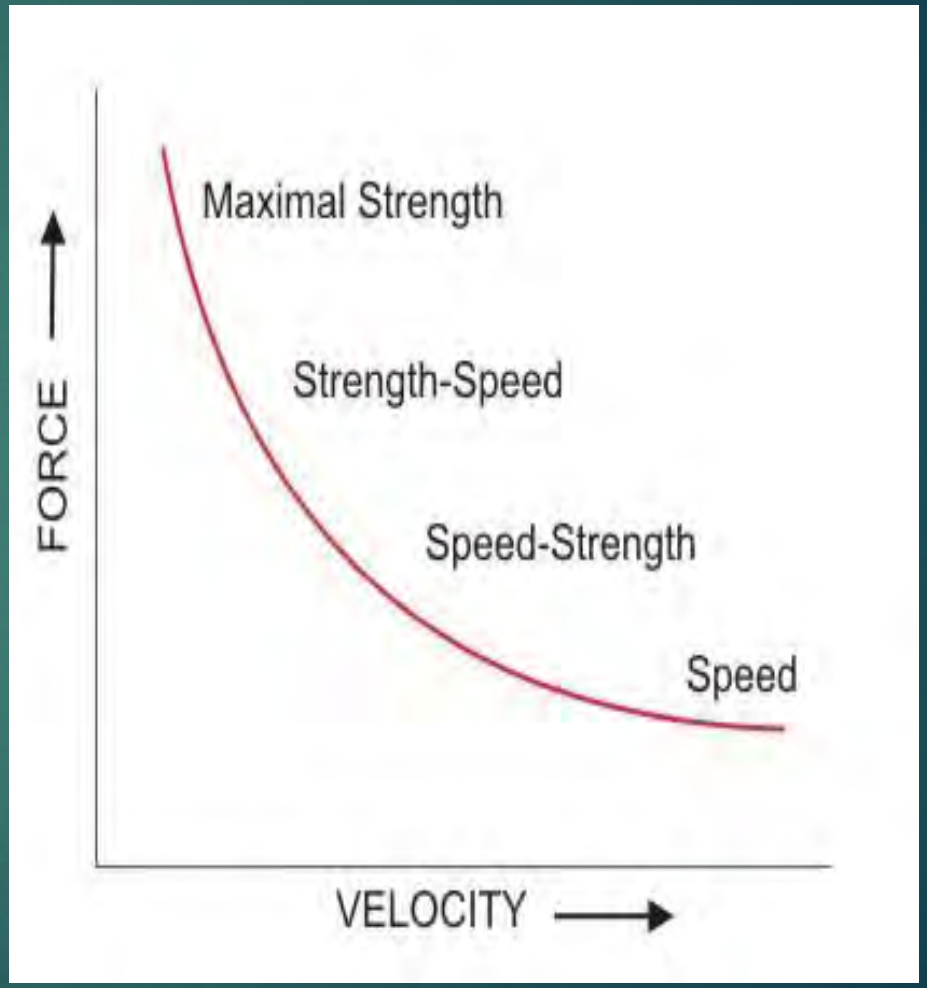


MUSCLE PHYSIOLOGY

- High force, low velocity training – increases CSA, FL, and angle of PEN
- Low force, high velocity training - no change in CSA, increase in FL, decrease in angle of pennation

MUSCLE PHYSIOLOGY

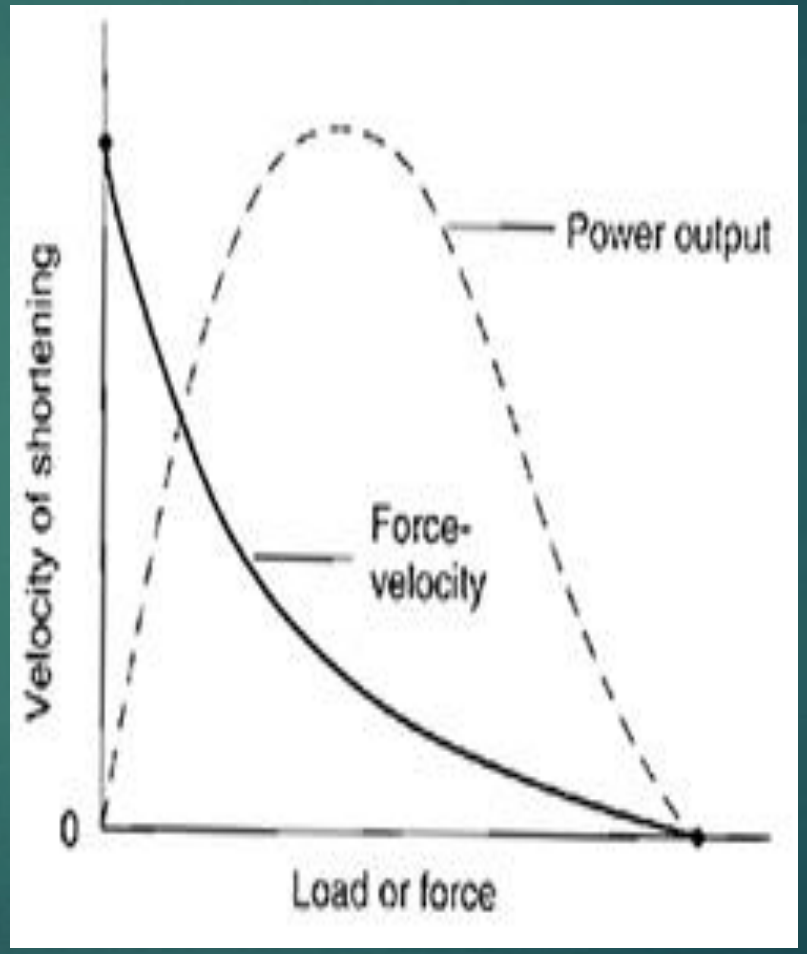
Force – Velocity Curve



MUSCLE PHYSIOLOGY

Power – force curve

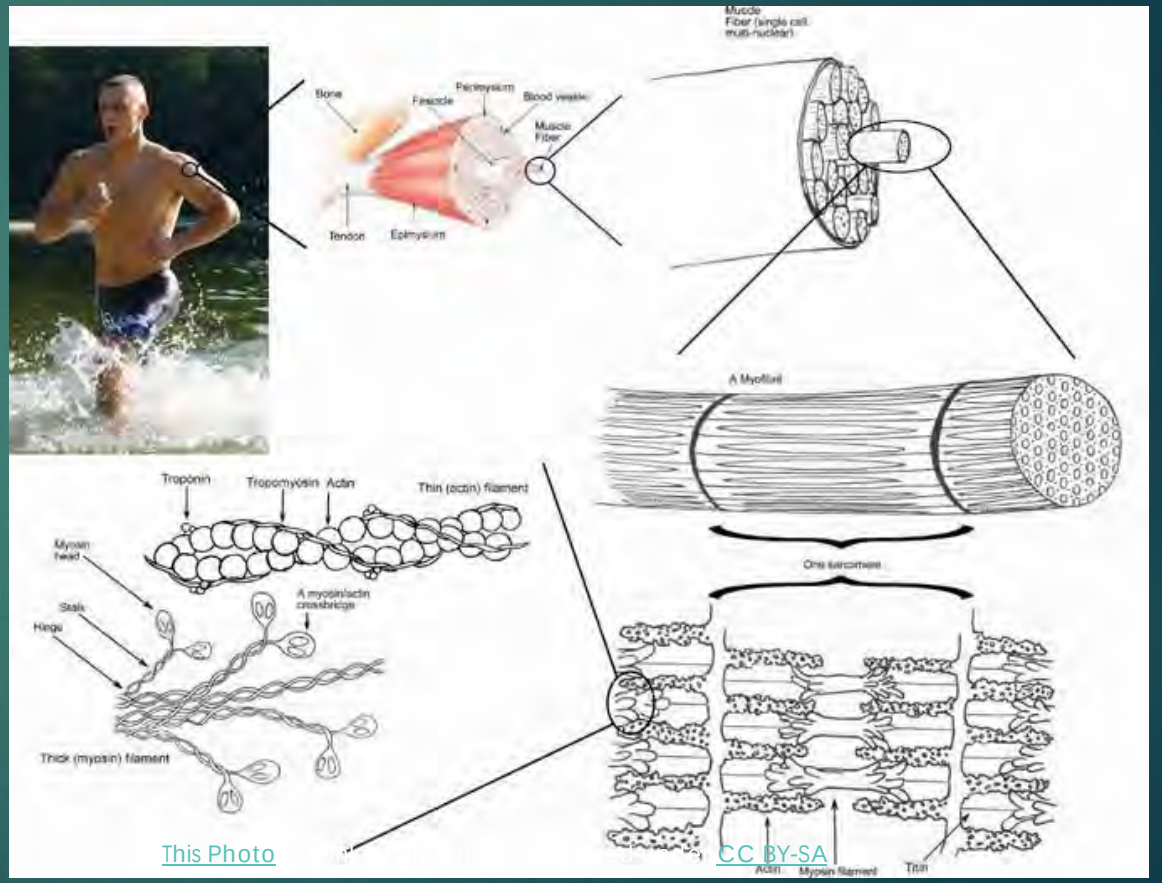
What is power lifting?



MUSCLE PHYSIOLOGY

- Cross Sectional Area (CSA)- The number of force generating sarcomeres arranged in parallel which predicts maximum force generating capability.

- *Physiological Cross Section Area (PCSA)*



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MUSCLE PHYSIOLOGY

- Fundamental principles of muscle contraction
  - Peak rate of contraction is dependent on myosin ATPase activity and the size of the motoneuron
  - Maximal force is dependent on the actin-myosin action
  - Continuation of the contraction is dependent on the ability to recycle ATP
  - Muscle fatigue is the decrease in the ability of a muscle to generate force.

MUSCLE PHYSIOLOGY

- Velocity of shortening
- Force-velocity curve for eccentric and concentric actions

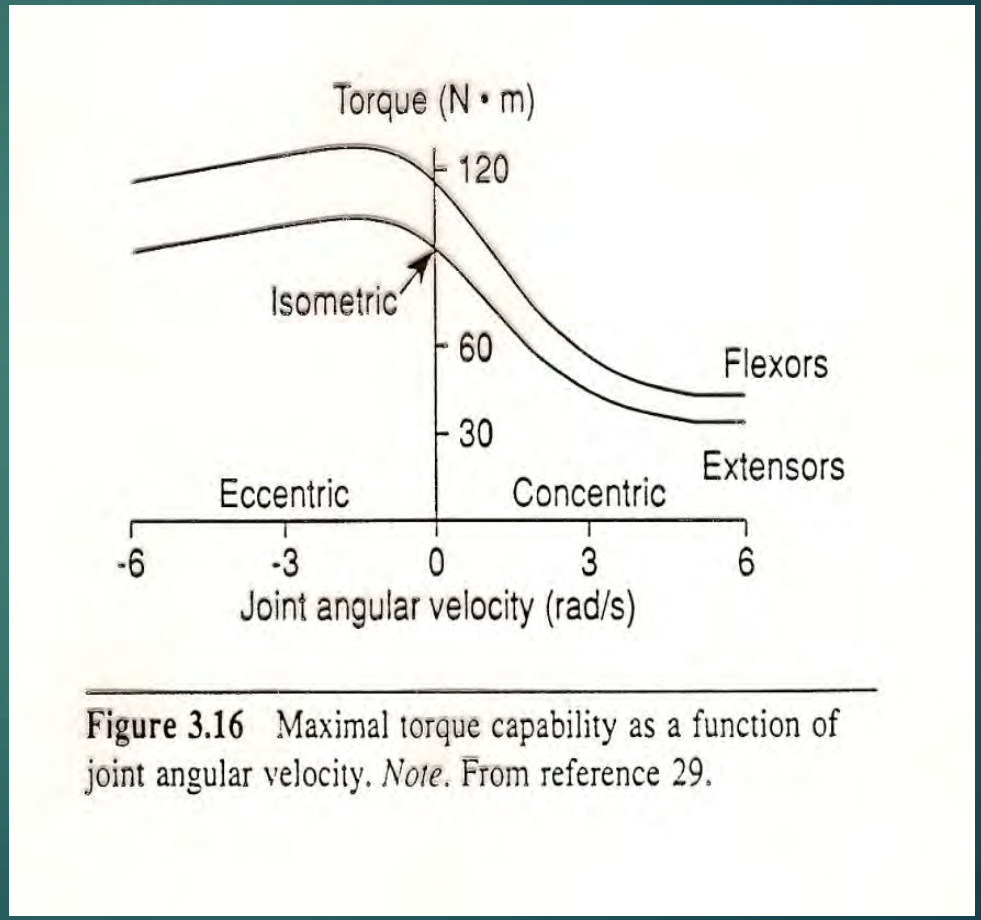


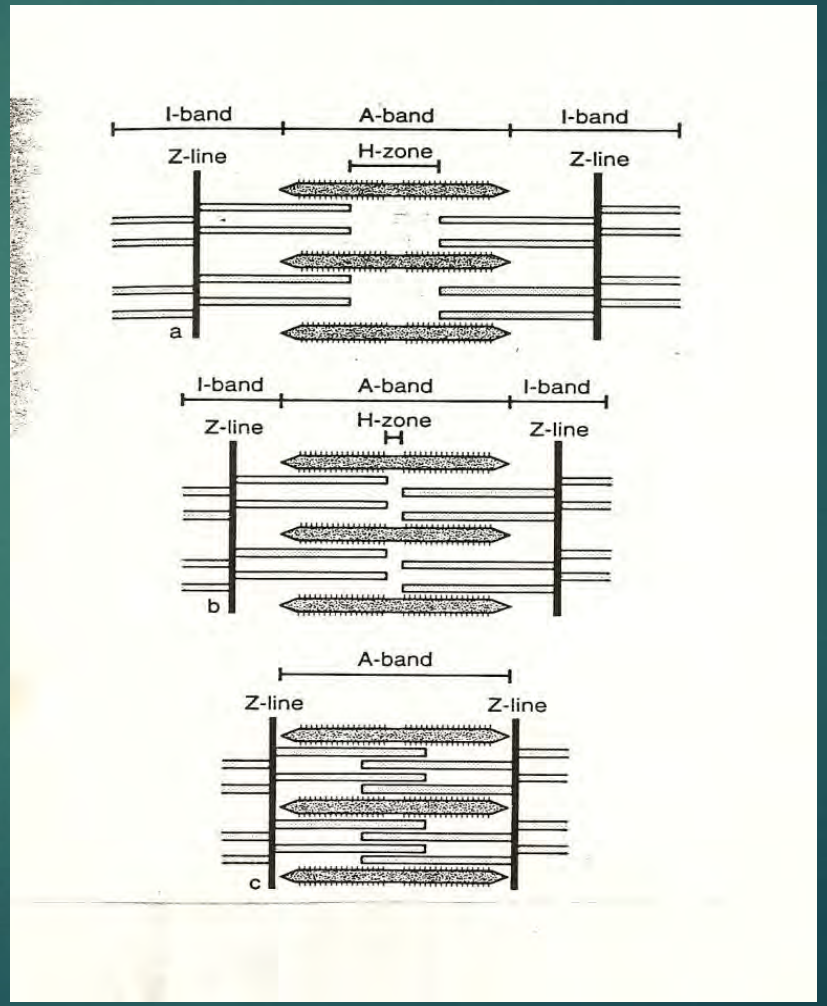
Figure 3.16 Maximal torque capability as a function of joint angular velocity. *Note*. From reference 29.

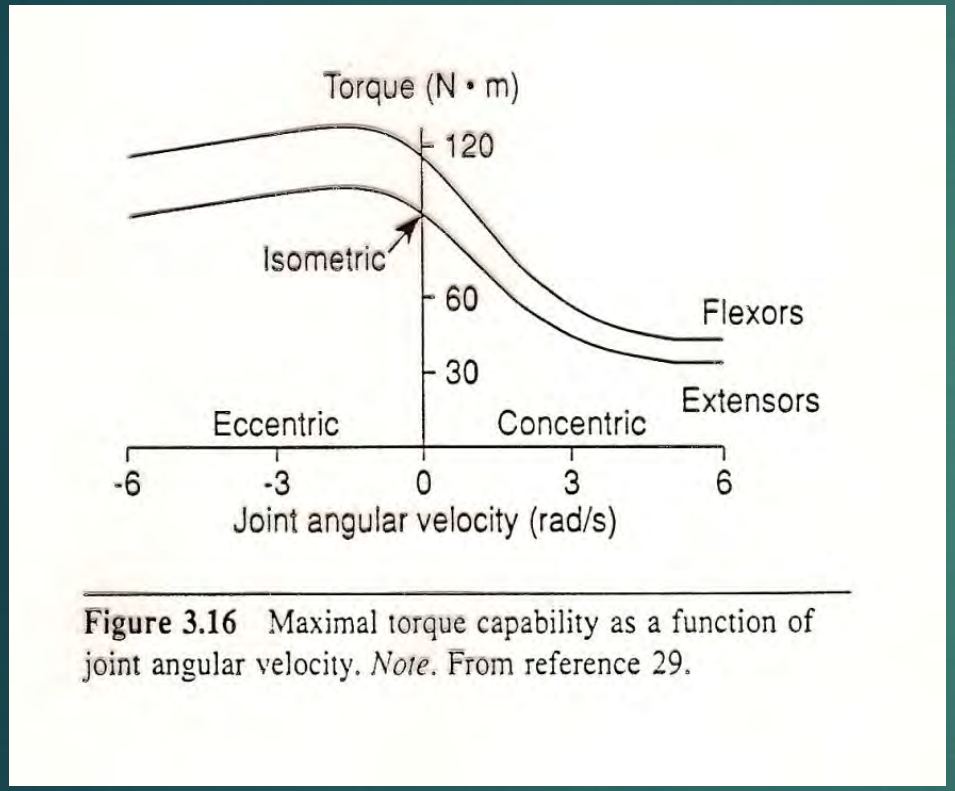
Using negatives in weight training.

Accentuating eccentric strength.

MUSCLE PHYSIOLOGY

- Sarcomere and muscle length
  - Length-tension relationship





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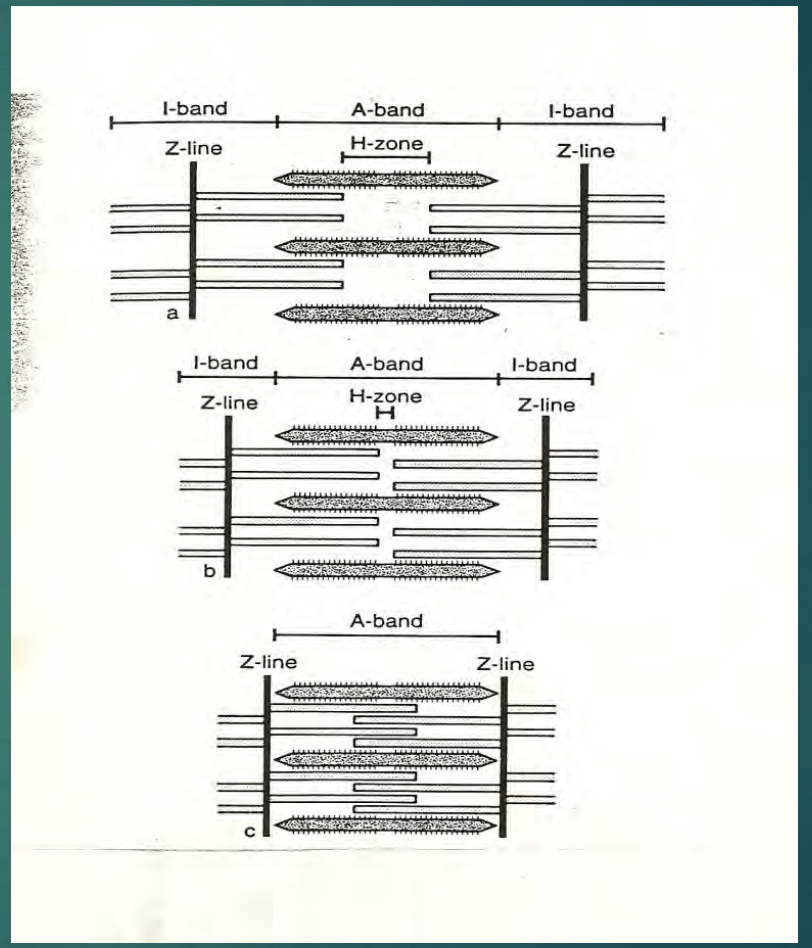


MUSCLE PHYSIOLOGY

- Muscle Proprioceptors
  - Stretch reflex is a muscle contraction in response to stretching within the muscle. When a muscle lengthens, the muscle spindle is stretched and its nerve activity increases.
  - Golgi Tendon Organs – Connects extrafusal fibers and detects tension, not length changes.
  - Pacinian Corpuscles – **Located close to GTO's and are** sensitive to quick movement and deep pressure.

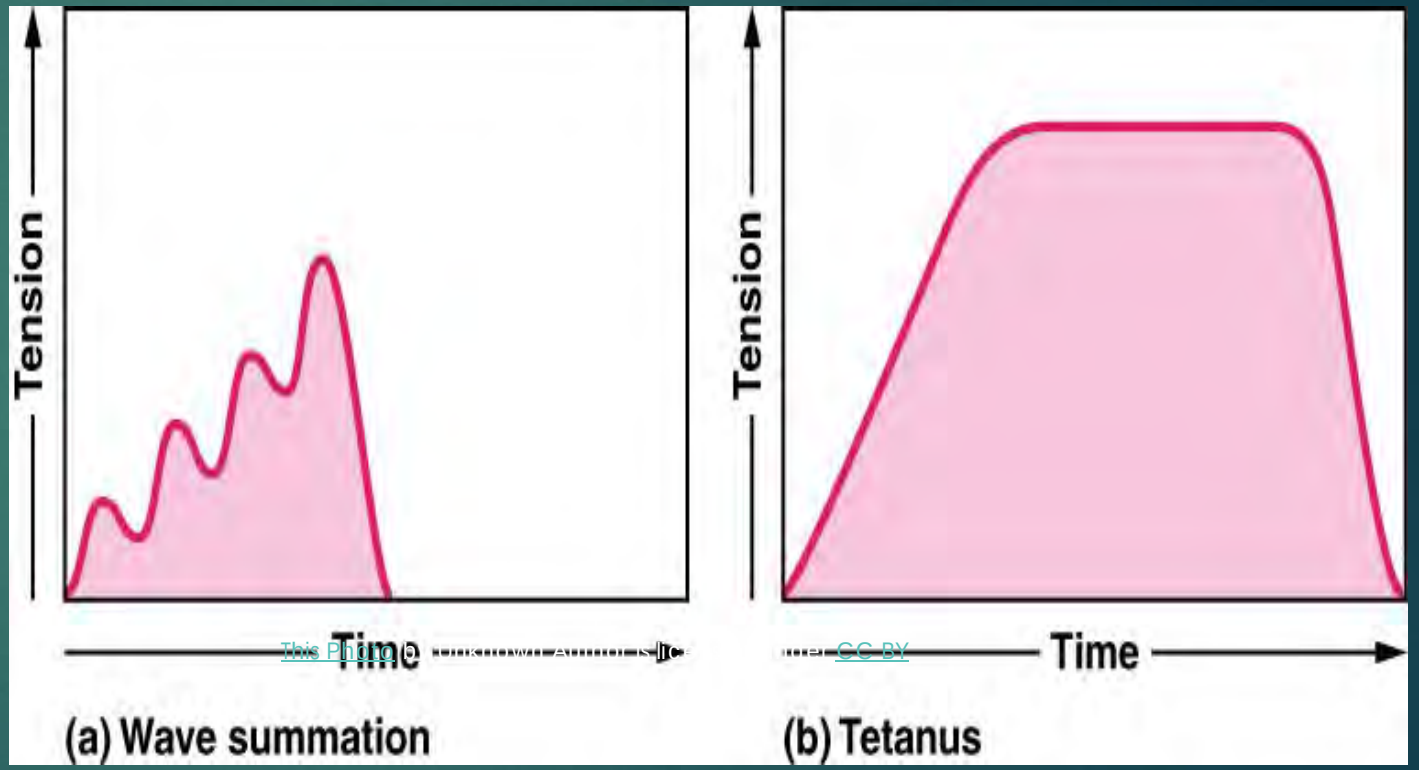
Elasticity of muscle and connective tissue

Stretch reflex

Using the eccentric preload – the countermovement jump

NEUROMUSCULAR ADAPTATIONS

- Anatomy and Physiology
  - All-or-none law
  - Twitch vs. Tetanus



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MUSCLE PHYSIOLOGY

- Gradation of force
  - Rate Coding – frequency of activation of motor units
  - Recruitment – number of motor units activated

MUSCLE PHYSIOLOGY

- Gradation of Force
- Type I – Increased recruitment to 50% MVC, then rate coding (RC).
- Type II – Increased RC to 10% MVC, increased recruitment from 10-90% MVC, increased RC from 90-100%.

MUSCLE PHYSIOLOGY

- Firing pattern is based on the Size principle. As muscle force increases, motor neurons with progressively larger motor axons fire.
- Neuromuscular fatigue – There is a decrease in muscle tension with repeated stimulation of the muscle fiber.

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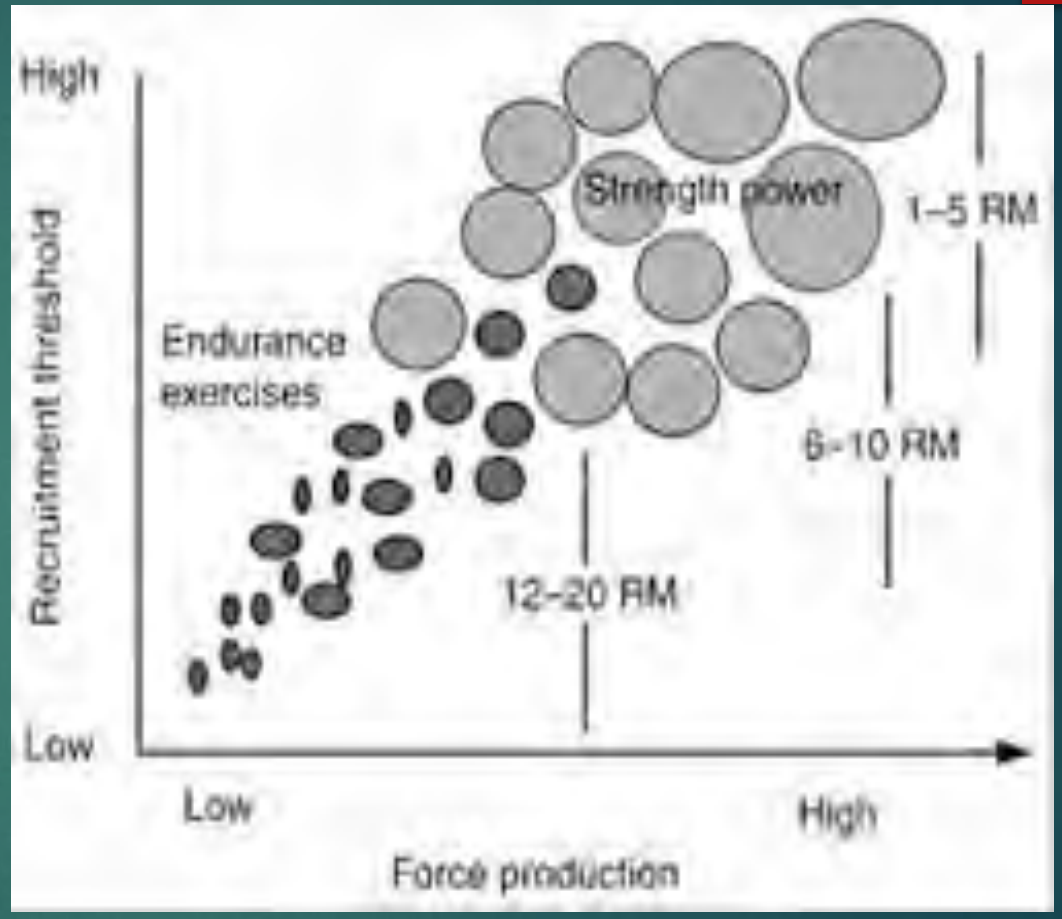


MUSCLE PHYSIOLOGY

- Neural plasticity can occur within the primary cortex in response to motor training. There is a greater number of synapses per pyramidal neuron in the motor cortex when complicated movements are practiced compared to simple tasks (Jones et al., 1999).

NEUROMUSCULAR ADAPTATIONS TO CONDITIONING

TRAINING ADAPTATIONS		
	RESISTANCE	ENDURANCE
Fiber size		
# of fibers		
Movement speed		
Endurance		
Strength		
Aerobic capacity		

Strength

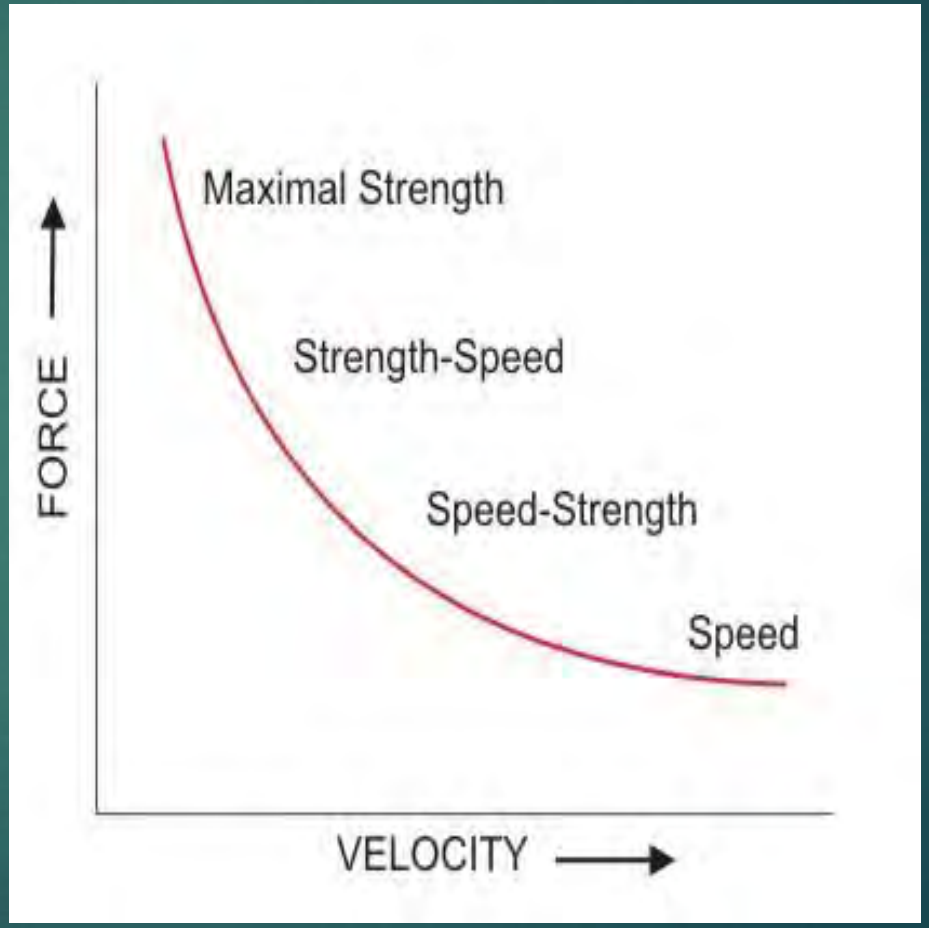
- The ability to transfer strength to sports performance.
- Principle of Dynamic Correspondence – The ability to use the means of special (sports specific) strength preparation that corresponds to the functioning of the neuromuscular system in a given sport (*Siff M, Verkhoshansky A*).

Strength

- Rate of force development (RFD) – “**explosive muscle strength**”
- Power – The amount of force exerted through a certain distance per unit of time. Peak power is defined as the highest power value achieved during the task being performed.

- Power = force x velocity
- There is an inverse relationship between force and velocity

- Force – velocity curve.




FORCE (N)
MAX STRENGTH (90 - 100% 1RM)
STRENGTH-SPEED (80-90% 1RM)
PEAK POWER (30-80% 1RM)
SPEED-STRENGTH (30%-60% 1RM)
MAX SPEED (<30% 1RM)
VELOCITY (M/S)

	Ben '88	Carl '88	Mo '99	Mo '01	Tim '02	Asafa '05	BOLT '08
RT	0.132	0.136	0.162	0.132	0.104	0.150	0.165
0-10m	1.83	1.89	1.86	1.83	1.89	1.89	1.85
10-20m	1.04	1.07	1.03	1.00	1.03	1.02	1.02
20-30m	0.93	0.94	0.92	0.92	0.91	0.92	0.91
30-40m	0.86	0.89	0.88	0.89	0.87	0.86	0.87
40-50m	0.84	0.86	0.88	0.86	0.84	0.85	0.85
50-60m	0.83	0.83	0.83	0.83	0.83	0.85	0.82
60-70m	0.84	0.85	0.83	0.83	0.84	0.84	0.82
70-80m	0.85	0.85	0.86	0.86	0.84	0.84	0.82
80-90m	0.87	0.86	0.85	0.89	0.85	0.85	0.83
90-100m	0.90	0.88	0.85	0.91	0.88	0.85	0.90
TIME	9.79	9.92	9.79	9.82	9.78	9.77	9.69
			Courtesy of SpeedEndurance.com				

- With untrained athletes, strength training will result in significant improvements in power.
- Athletes with established strength levels appear to be the ones who benefit from specific training (dynamic lifts, plyometrics) to optimize power development.

Basic Concepts of Strength Training

- Overload
  - Stimulating loads
  - Retaining loads
  - Detraining loads
- Accommodation
- S.A.I.D. – Specific Adaptation to Imposed Demands
- Individualization

Assignments Based on Goal

Training goal	Repetitions	Sets	Rest period
Power	1-3	3-5	3-5 minutes
Strength	6 or less	3-5	3-5 minutes
Hypertrophy	6-12	3-6	30-90 seconds
Endurance	12 or greater	2-3	30 seconds or less

BIOMECHANICS OF RESISTANCE EXERCISE

- First class lever – the muscle force and the resistive force act on opposite sides of the fulcrum

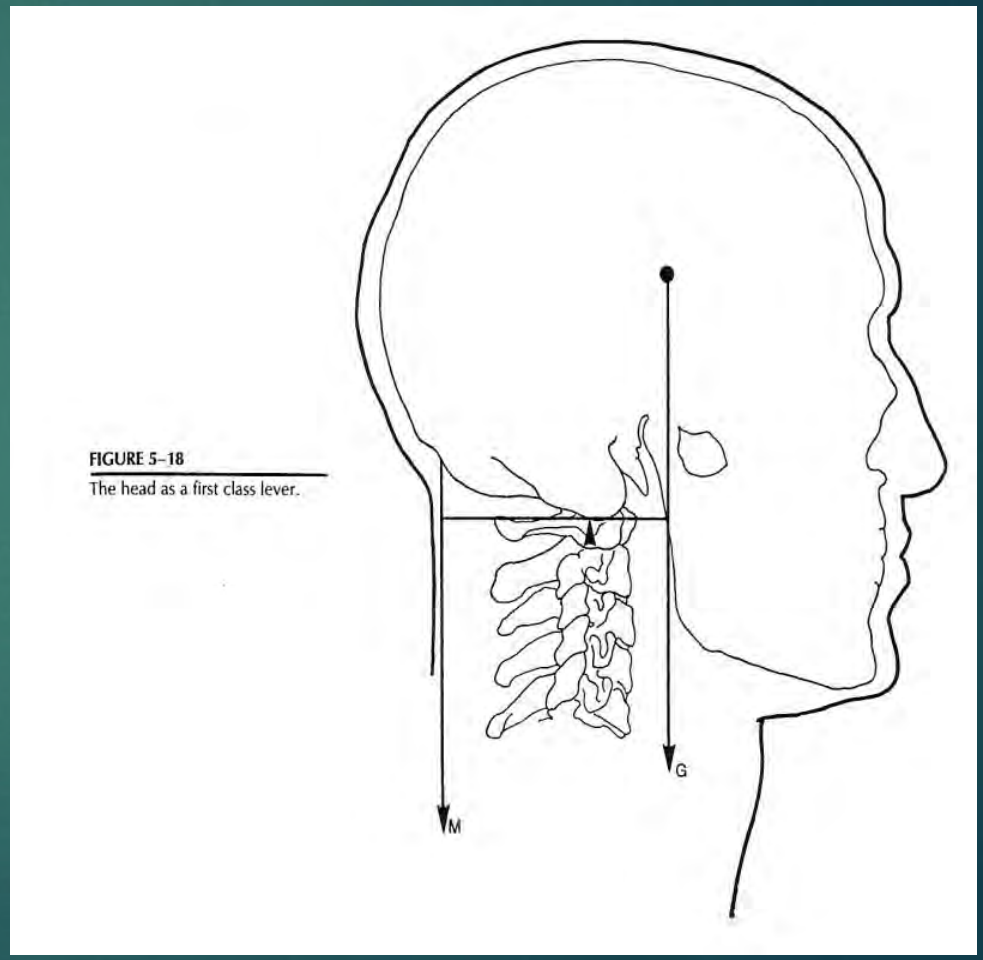


FIGURE 5–18
The head as a first class lever.

BIOMECHANICS OF RESISTANCE EXERCISE

- Second class lever – the muscle force and the resistive force act on the same side of the fulcrum, MM being greater than MR

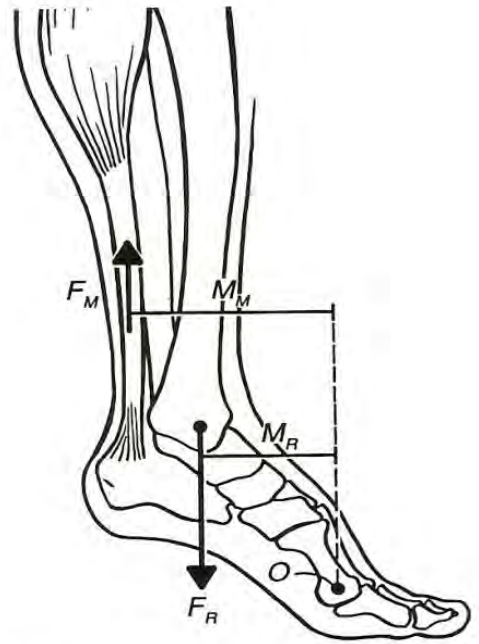


Figure 3.7 A second-class lever (the foot). When the body is raised, the ball of the foot, being the point about which the foot rotates, is the fulcrum (O). Because M_M is greater than M_R, F_M is less than F_R. (Abbreviations as in Figure 3.6.)

BIOMECHANICS OF RESISTANCE EXERCISE

- Third class lever – the muscle force and the resistive force act on the same side of the fulcrum, MR being greater than MM

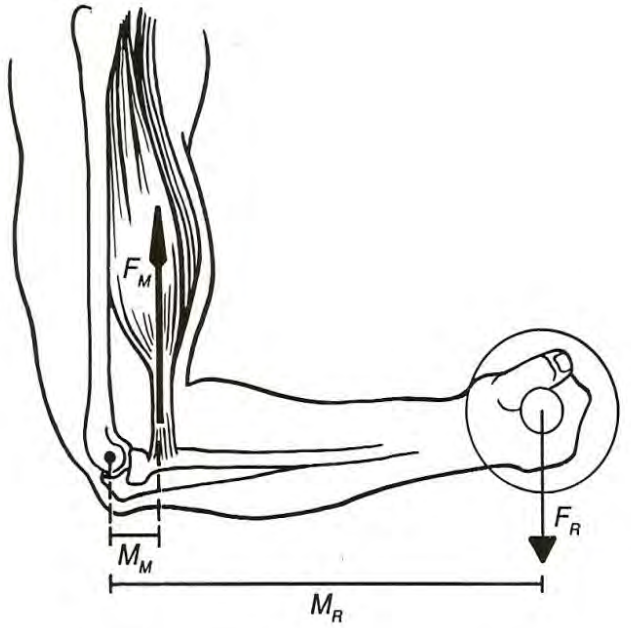


Figure 3.8 A third-class lever (the forearm). Because M_M is much smaller than M_R, F_M must be much greater then F_R.

BIOMECHANICS OF RESISTANCE EXERCISE

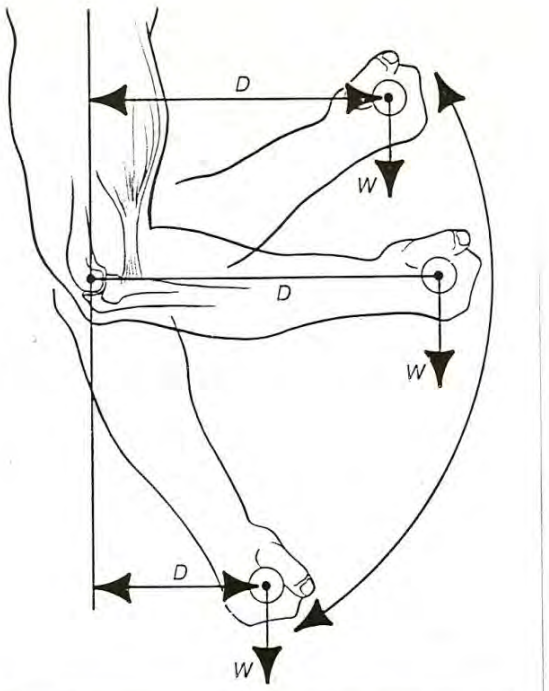


Figure 3.18 While the weight of the object (W) remains constant, the horizontal distance (D) from the weight to the elbow changes throughout a curl movement, directly affecting the resistive torque.

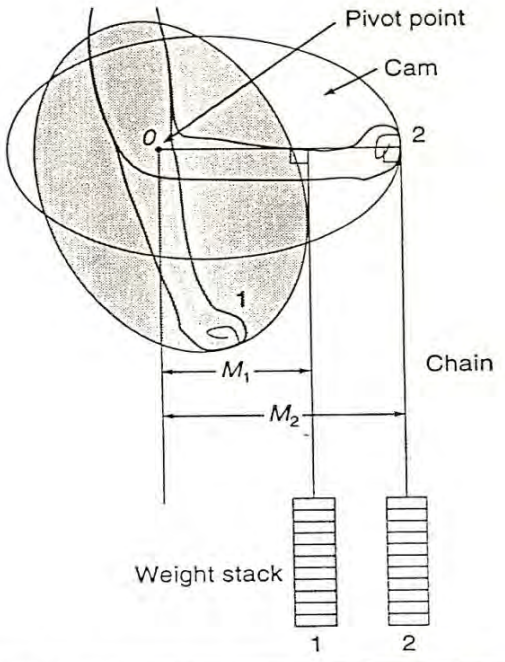


Figure 3.19 In cam-based weight stack machines the moment arm (M) of the weights (horizontal distance from the chain to the cam pivot point) varies during the exercise movement. When the cam is rotated in the direction shown from position 1 to position 2, the moment arm of the weights, and thus the resistive torque, increases.

The Sticking Point

"The weakest point in the range of motion of an exercise which probably occurs where the external resistance has the greatest mechanical **advantage"**. - *NSCA*

Good mornings

45-degree back extension

Horizontal back extension

Instantaneous hip extension torque, NM

Exercise	90 degrees	135 degrees	180 degrees
Good morning	478	338	0
45-degree back extension	338	478	338
Horizontal back extension	0	338	478

SPECIFIC EXERCISES

- Snatch
- Clean and jerk
- Power clean
- Hang clean
- Push press
- Push jerk

SPECIFIC EXERCISES

- Deadlift
- Squat
- Bench press

Snatch

Power Snatch

Clean and Jerk

The Clean

1) Clean high pull – power position
2) Power Clean – power position

The Clean

1) Power Clean – knee (hang)
2) Power Clean – floor
3) Power Clean + Front Squat

Push Press
Push Jerk

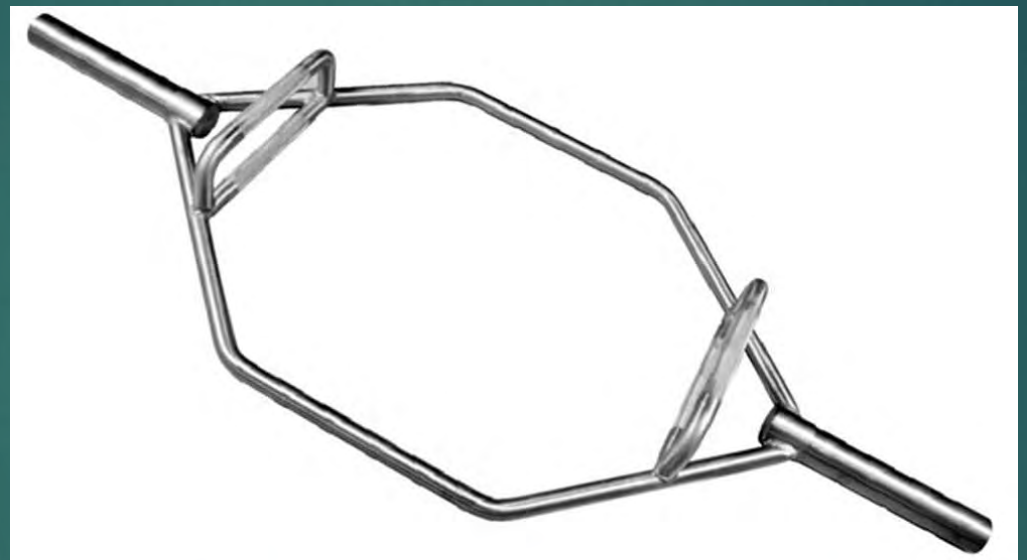
The Deadlift

- The Deadlift is a great exercise to engage many muscles in the body.

- In a Deadlift, you lift the weight from the ground to thigh-level using primarily your leg and hip muscles, but with the assistance of most of the large muscle groups of your body.

Deadlift

Hexagonal Bar Deadlift



The Squat

- Squatting is a fundamental human movement pattern that involves nearly every muscle in the body. Squatting improves fitness, performance, and mobility for daily-life tasks.

- Squatting is a fundamental human movement pattern that involves nearly every muscle in the body.

Squats

1) Assisted squats
2) BW squats

Squats

1) Assisted squats
2) BW squats

Squats

1) Assisted squats
2) BW squats
3) Landmine squats

Squats

1) Assisted squats
2) BW squats
3) Landmine squats
4) Goblet squats

Squats

1) Assisted squats
2) BW squats
3) Landmine squats
4) Goblet squats
5) Front squats
6) Back squats

Squats

***Compared to the deadlift, the squat is a more knee dominant pattern. The deadlift and hip-hinge based exercises place more emphasis on posterior chain development.

The Bench Press

- The bench press helps build muscles in the upper body. Primarily, chest, triceps, and shoulders.

Training Concepts

- Combination training – combining strength and power training.

  Traditionally, combination training often referred to adding aerobic training for anaerobic athletes – **“cross training”**.

Training Concepts

- Complex training – several sets of heavy strength training repetitions followed by lighter power movements.
- Contrast training – alternating strength exercise with power movements.

Complex Training

	% 1 RM	Reps per set	Rest
Back squat	55	5	90 sec
	70	3	90 sec
	85	3	180 sec
	85	3	180 sec
	85	3	180 sec
Tuck jumps	Body weight	5	30 sec
Tuck jumps	Body weight	5	30 sec

Contrast Training

	% of 1 RM	Reps per set	Rest
Back squat	55	5	90 sec
	70	3	90 sec
	85	3	60 sec
Split squat jump	Body weight	10	180 sec
Back squat	85	3	60 sec
Split squat jump	Body weight	10	180 sec

Training Concepts

- Increased excitability of CNS due to post activation potentiation (PAP)
- Increased variety of training

Athletes must work at high intensities

Exercises should be biomechanically similar

Volume should be low

Exercise Order Within a Session

- Power
  - Power clean, Push press
- Strength
  - Squat, Deadlift
- Supplemental
  - Hamstring curls

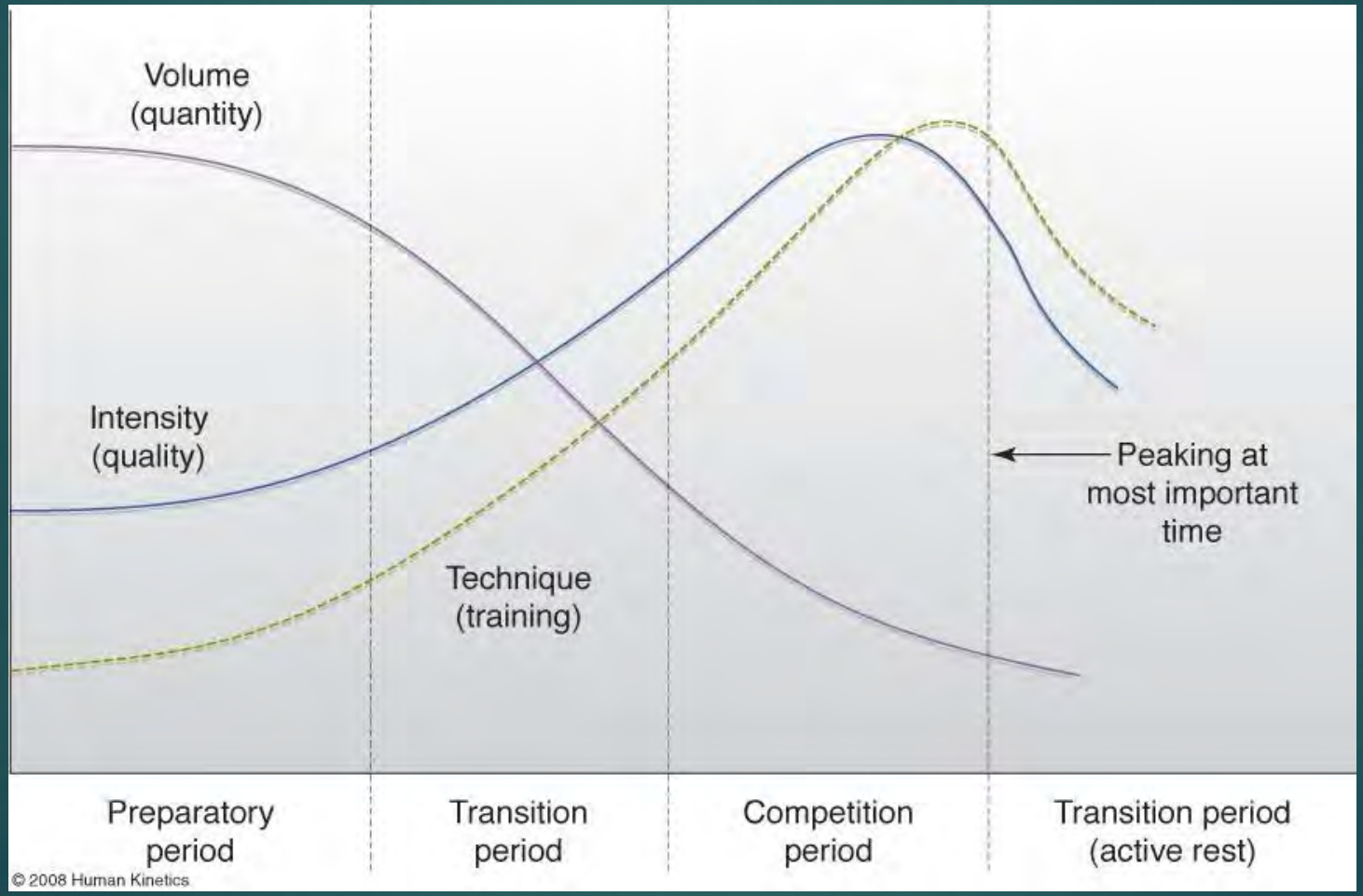
PERIODIZATION

- A strategy designed to prevent overtraining and optimize peak performance. Training is organized into cycles.
  - Macrocycle
  - Mesocycle
  - Microcycle

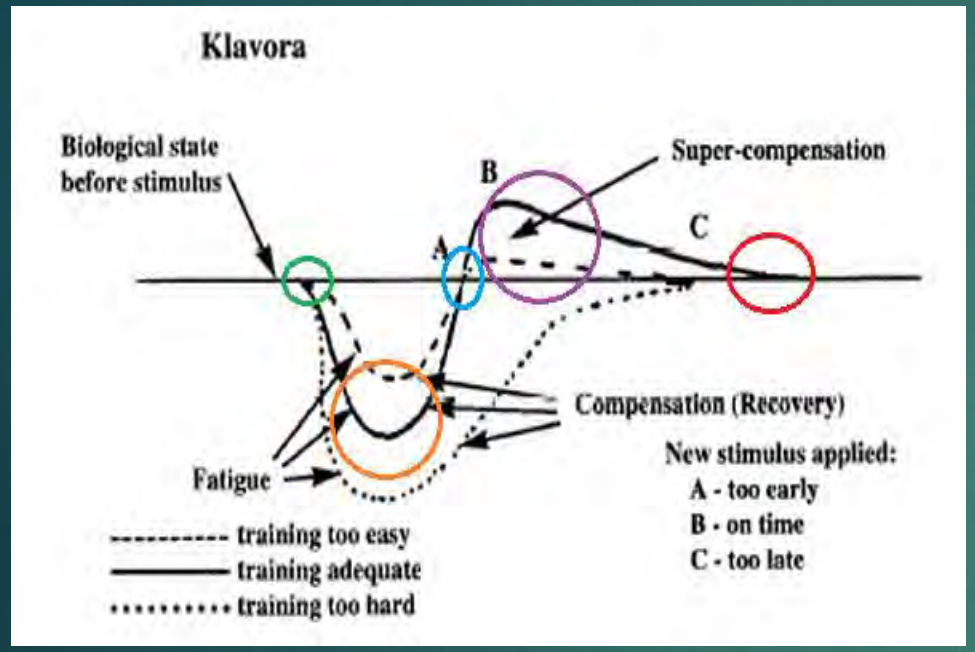
- Hans Selye General Adaptation Syndrome (GAS)
  - Alarm
  - Resistance
  - Exhaustion
- Stone et al. 1982 **"Theoretical Model** of Strength Training.
  - Alarm
  - Resistance
  - Overtraining

Selye introduced this concept after a series of rodent studies looking at stress responses to different drugs and stimuli such as temperature and forced exercise.

PERIODIZATION



PERIODIZATION



- Supercompensation occurs with glycogen but not with most of the other systems.
- Is recovery essential for the supercompensation?

PERIODIZATION

- Fitness-Fatigue Paradigm
  - Fitness and fatigue occur concurrently.
  - Fitness becomes apparent when fatigue dissipates.
  - The after effect of fitness and fatigue are exercise specific.

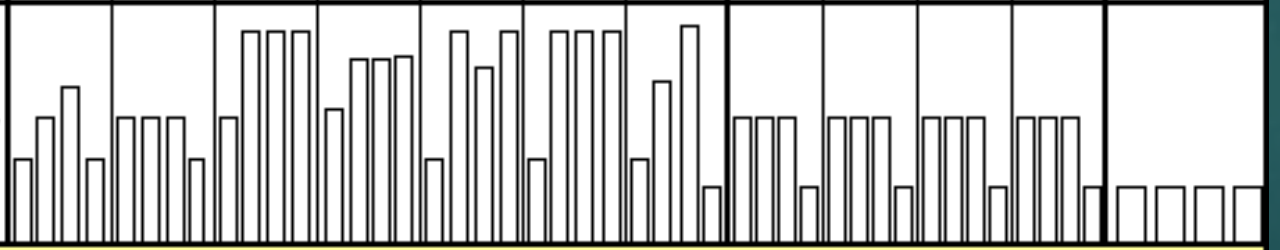
PERIODIZATION

- Taper – reduce training to enhance performance.
- Reduction in volume, intensity and/or frequency.
- Dissipate fatigue.

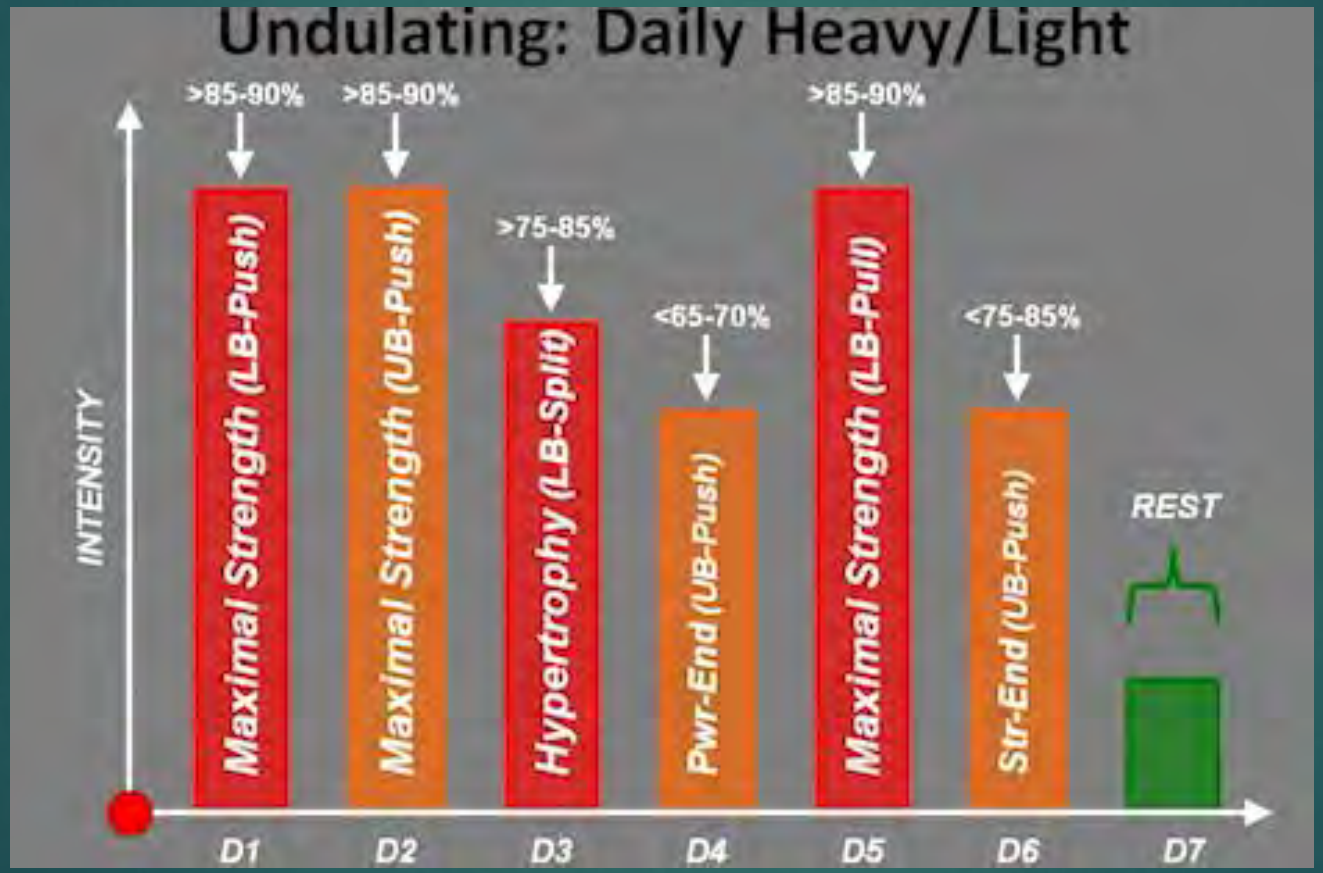
PERIODIZATION

- Linear periodization
  - Designed for peak performance at a specific time
- Undulating periodization
  - Designed to maintain higher performance for longer periods of time

Linear Periodization

12-Month Football Training Program												
Month	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**
Phase	**Off-season**							**In-season**				**Transition**
Strength Training	FST	HT	MST	PT	HT	MST	PT	Maintain power and maximal strength				Rest
Speed Agility Training	Low	Low	Med	High	Low	Med	High	Med	Med	Med	Med	Rest
Intensity												
Key:	FST = functional strength training MST = maximal strength training							HT = hypertrophy training PT = power training				

Undulating Periodization



The Basics of Training for Muscle Size and Strength: A Brief Review on the Theory.

BUCKNER, S.L., M.B.JESSEE,J. G. MOUSER, S. J.DANKEL, K. T. MATTOCKS, Z.W.BELL, T.ABE, andJ. P. LOENNEKE. Med.Sci. Sports Exerc., Vol. 52, No. 3, pp.645–653, 2020.

"Periodization (as presented in the available literature) does not appear necessary for achieving optimal increases in muscle size and strength within a training program. In the context of sports performance, no evidence exists outside of anecdotal reports that longer term periodization strategies (wherein adaptations are planned [i.e., yearly plan] and within that variation is used [i.e., periodized programming])support enhanced sports performance over merely repeated deliberate **practice of that specific task."**

- fics.sport
- acasc.org
- acsm.org
- nsca.com
- uksca.org.uk
- strengthandconditioning.org
- allthingsgym.com

THANK YOU!

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