Skeletal Adaptation to Training Responses to Injury

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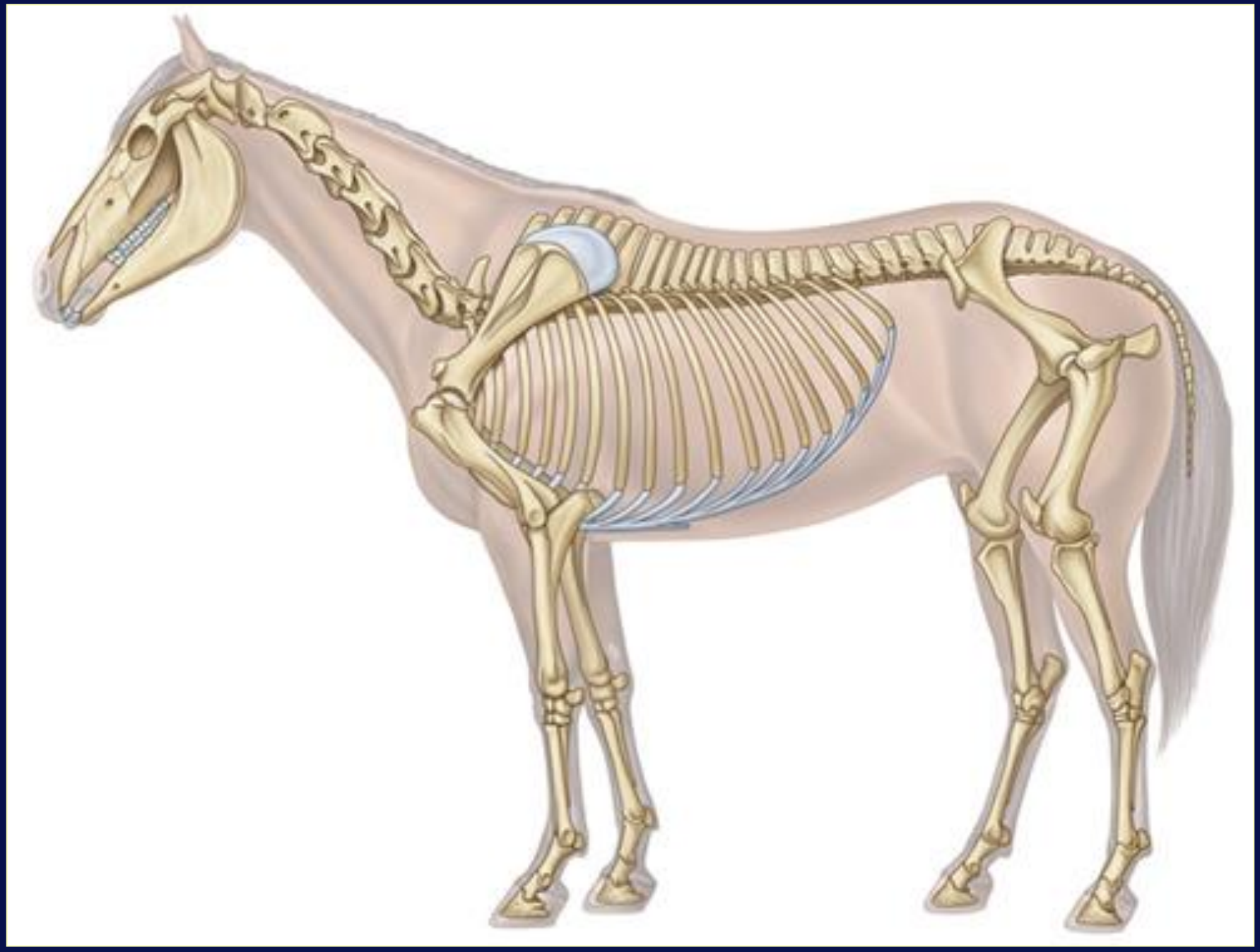
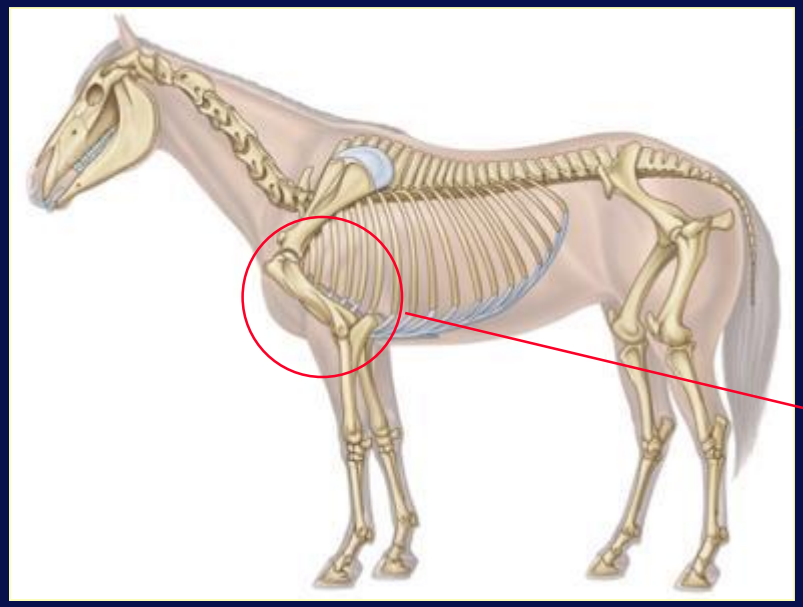
NHBPA Winter Convention 2014

Musculoskeletal System

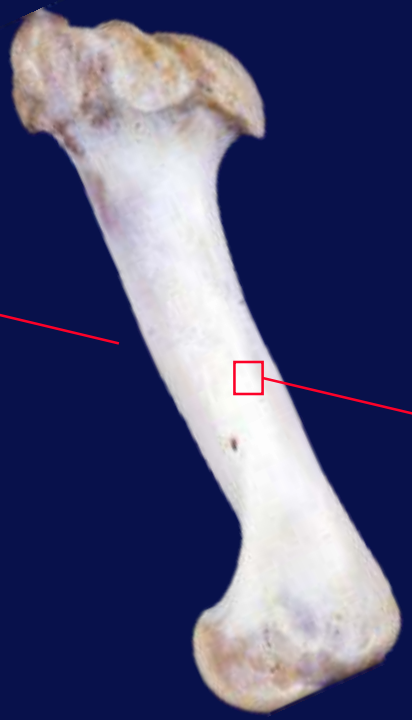
Courtesy of Mitch Taylor



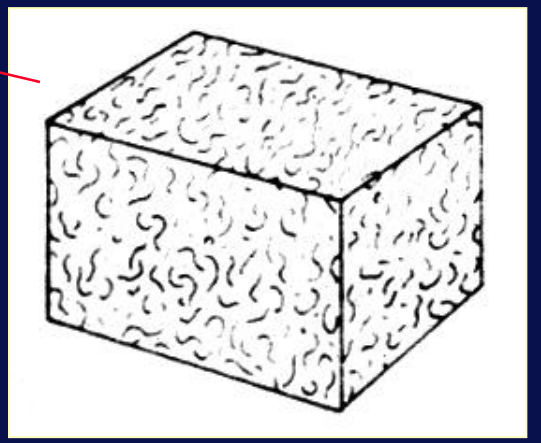
Skeletal Organization



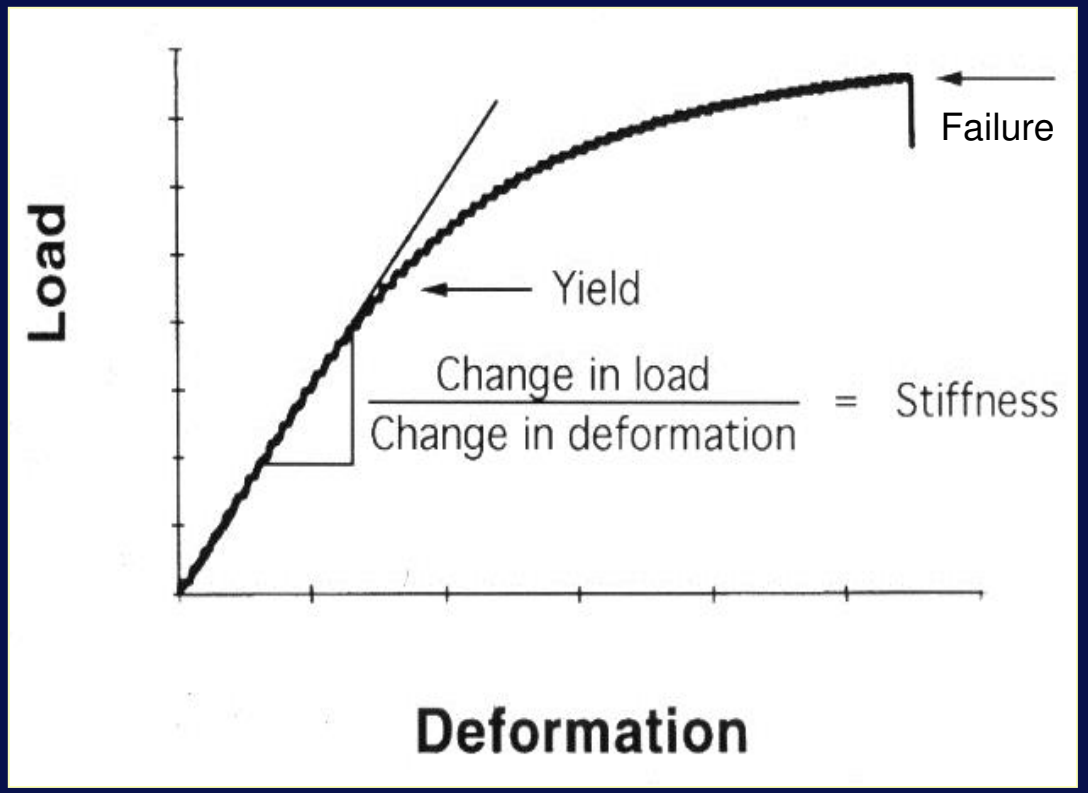
System



Organ



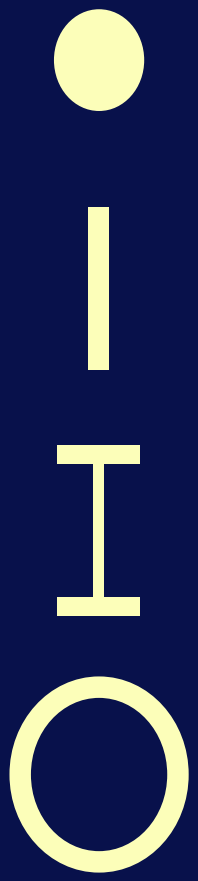
Tissue


Load
Failure
Yield
Change in load
Change in deformation
= Stiffness
Deformation

Bone Architecture

- *Related to mechanical function*
  - Supports the weight of animal
  - Energetically expensive because mineral is heavy

Effect of Architecture on Strength

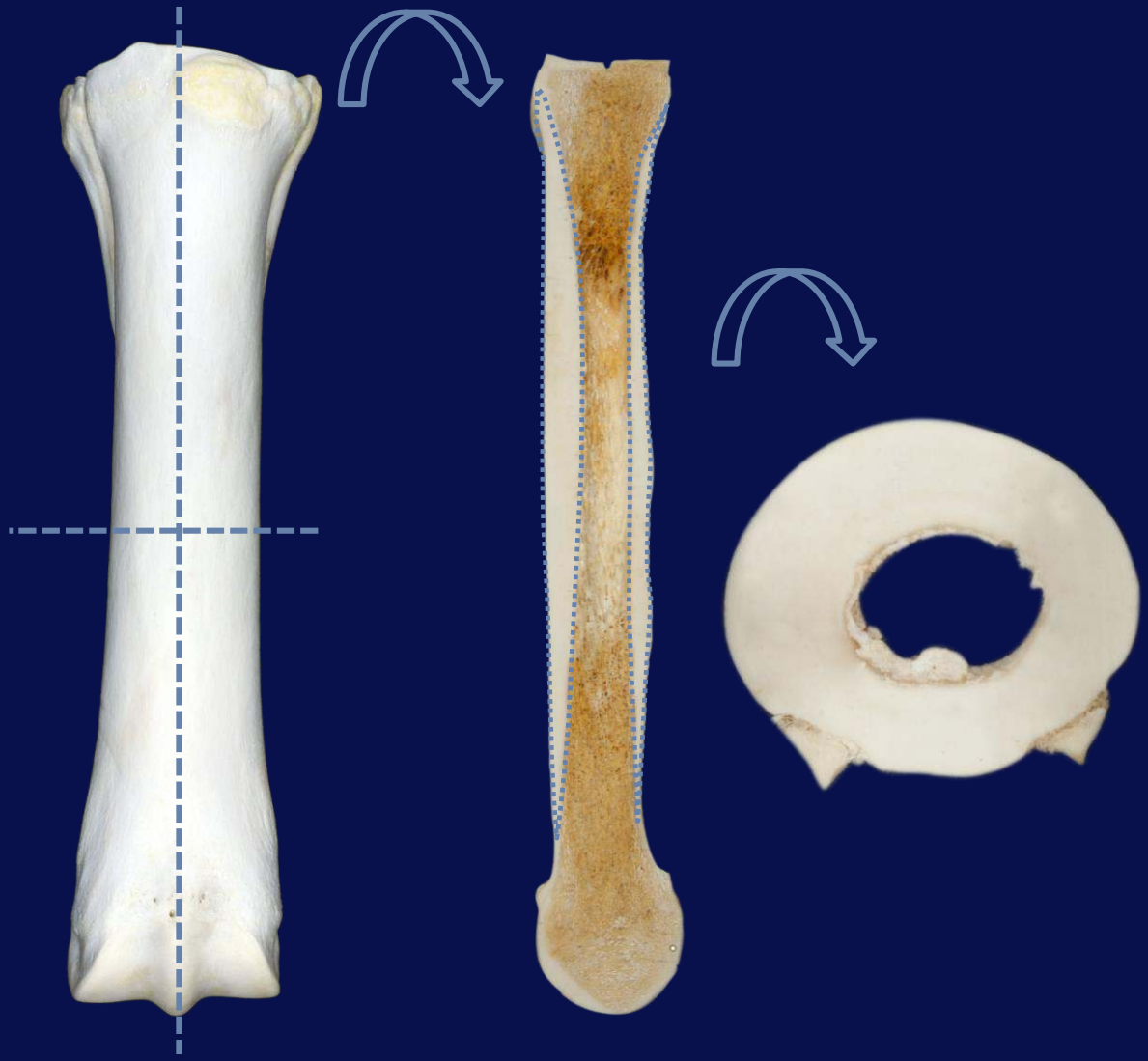


= 100%

= 350%

= 588%

= 533%



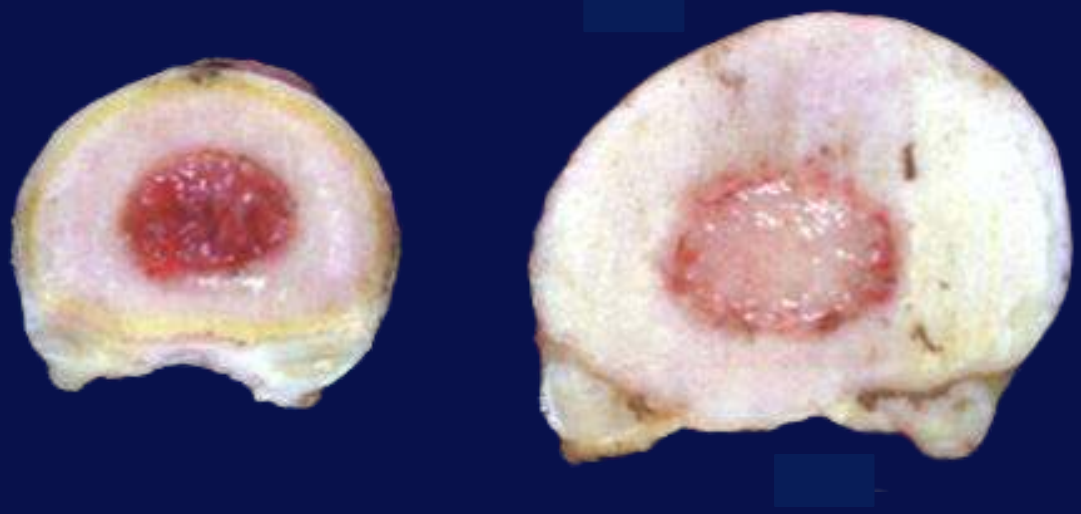
Bone structures adapt to …

minimize mass (weight)

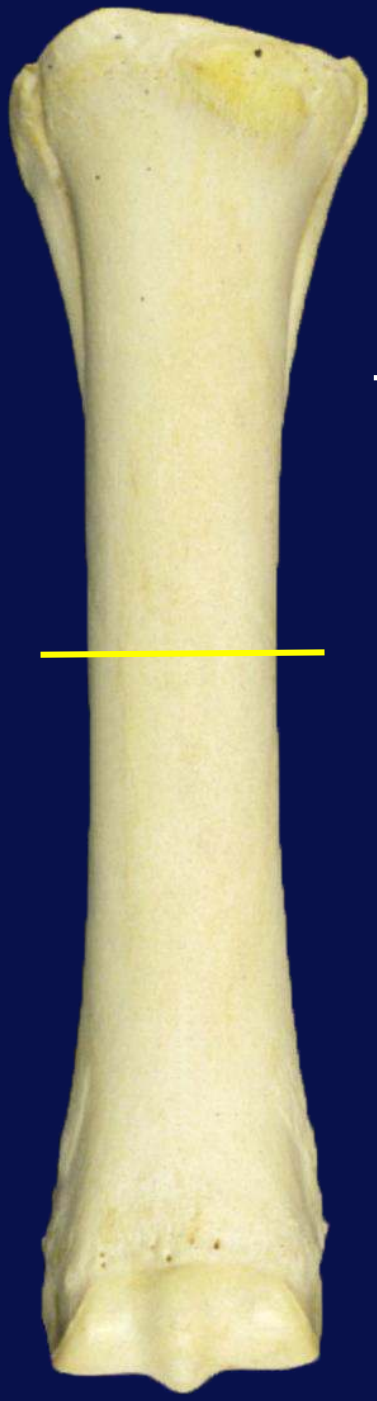
while …

maximizing stiffness and strength

for common loading conditions

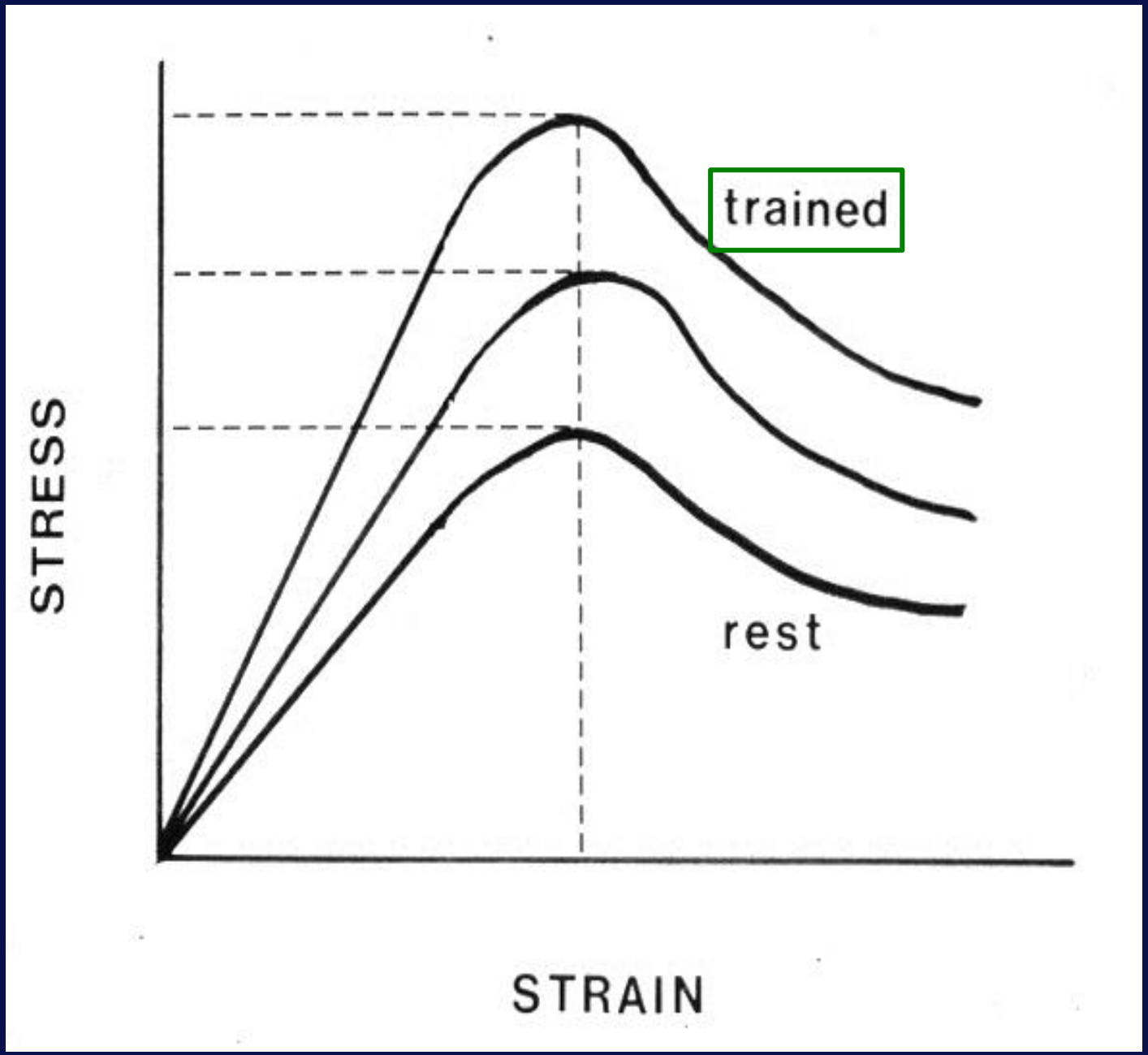


Exercise



Three different 2-yr-old Thoroughbred Horses

Untrained Training, unraced Raced

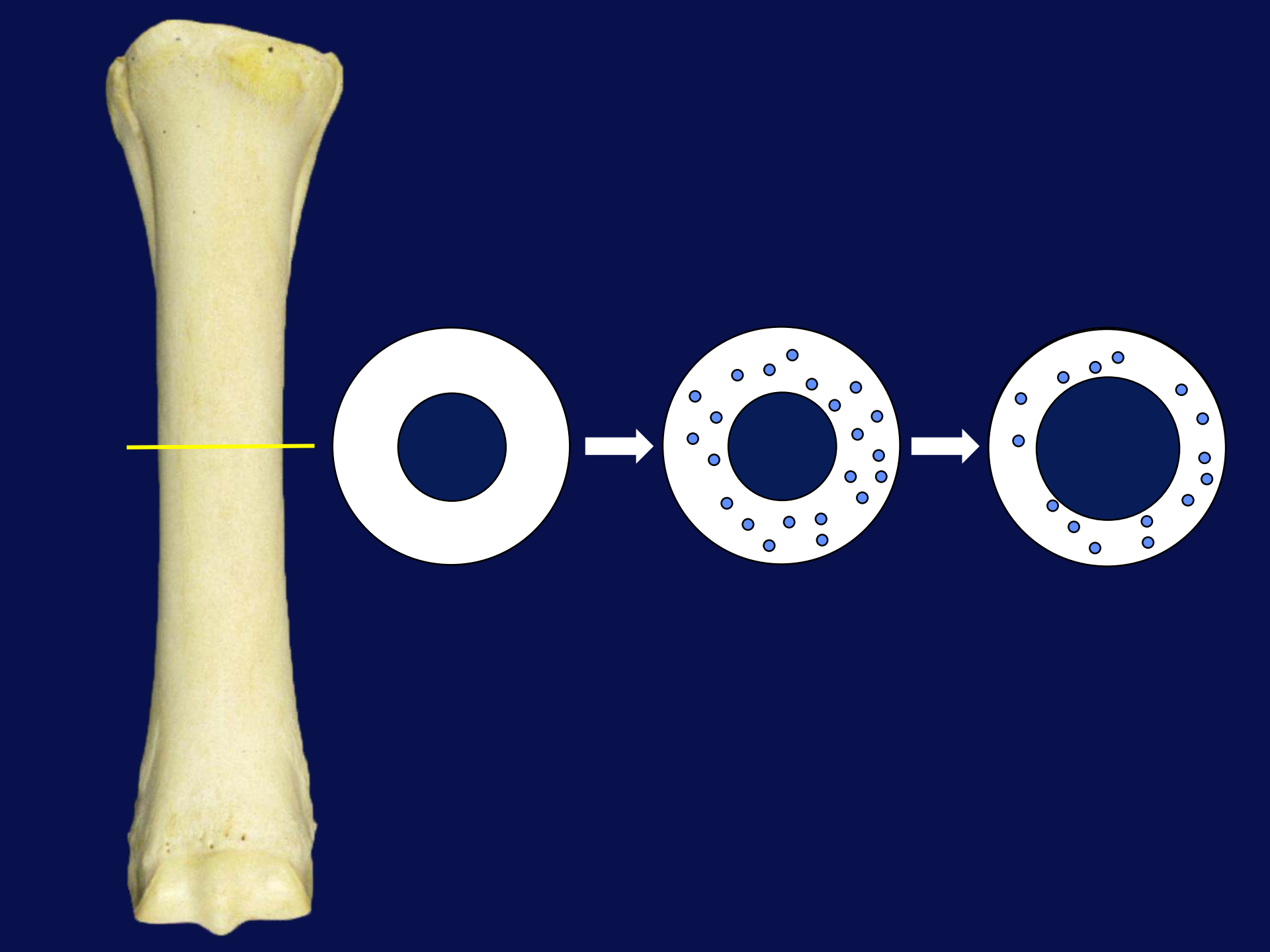

trained
rest
STRESS
STRAIN

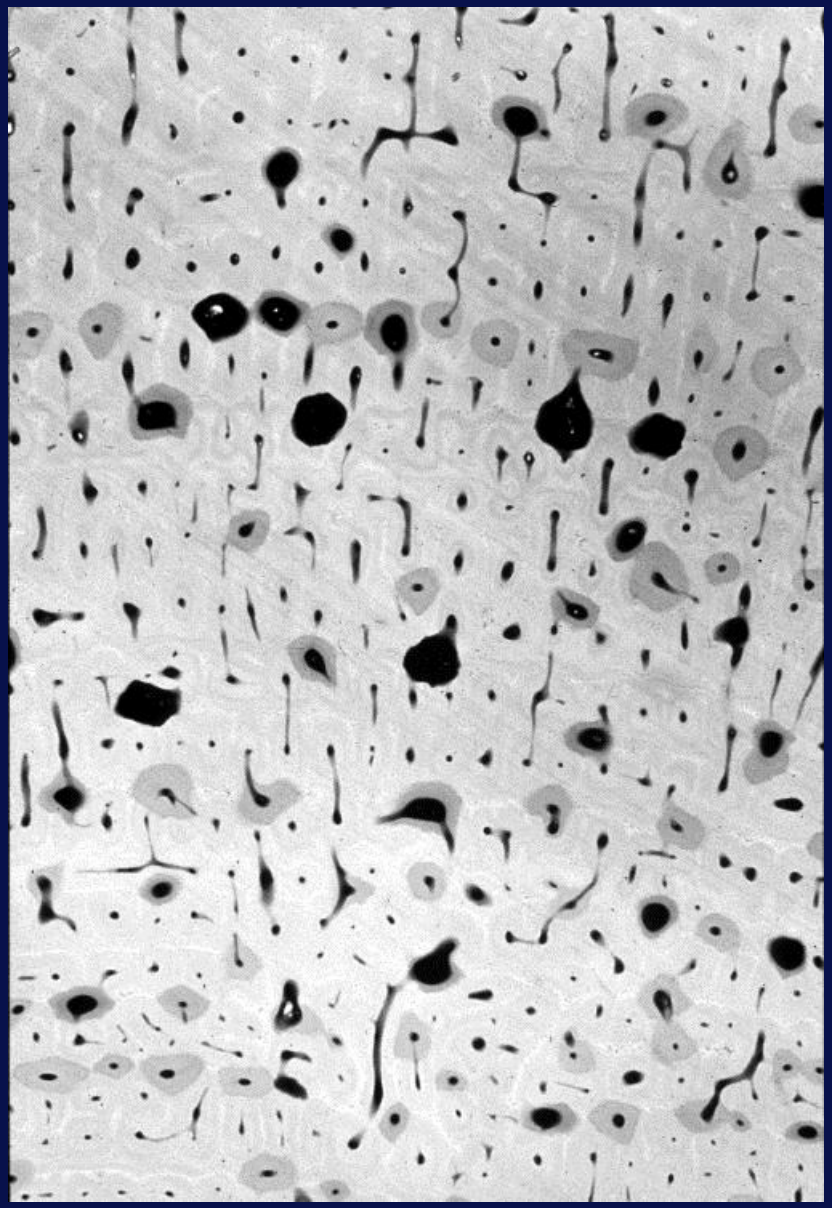
Exercise

- Needed to *maintain* bone mass
- However…
  - Less exercise is needed to maintain mass than is needed to gain mass
  - Fewer load cycles on a regular basis

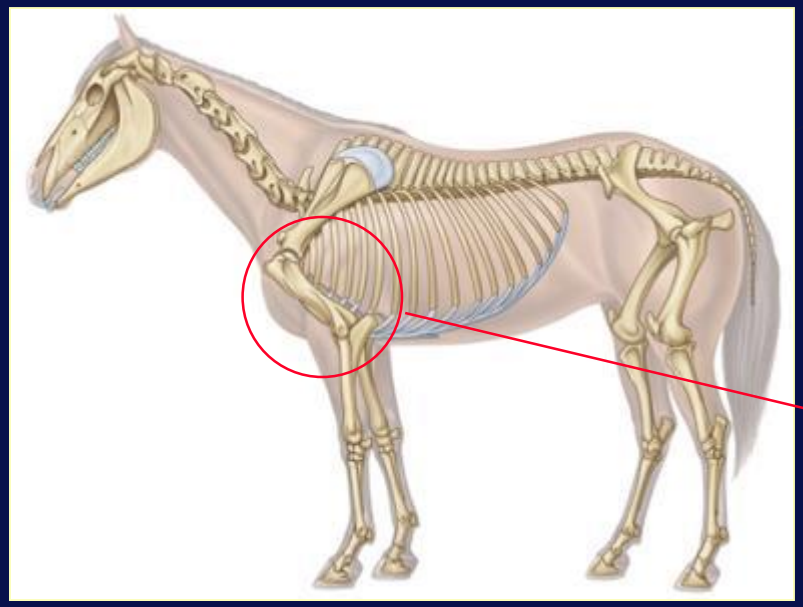
Inactivity

- If you don’t use it – you lose it





STRENGTH
is exponentially related to skeletal MASS



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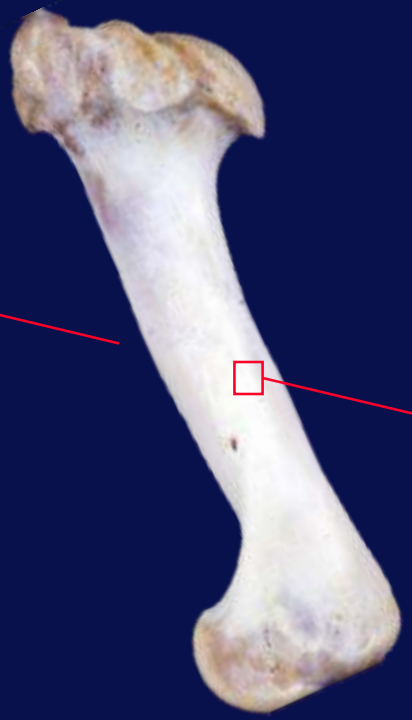

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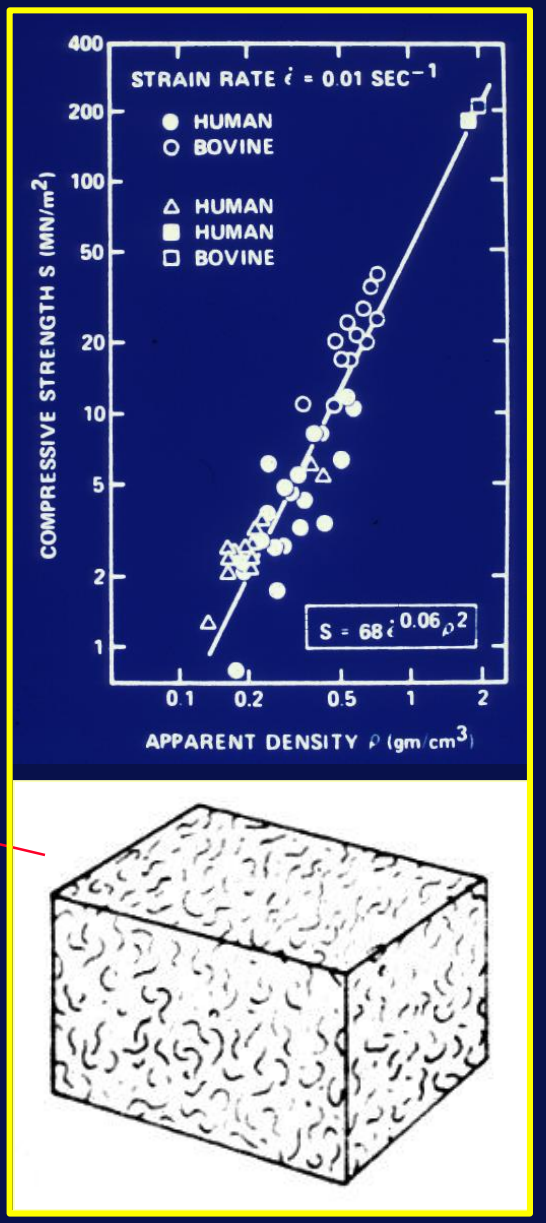

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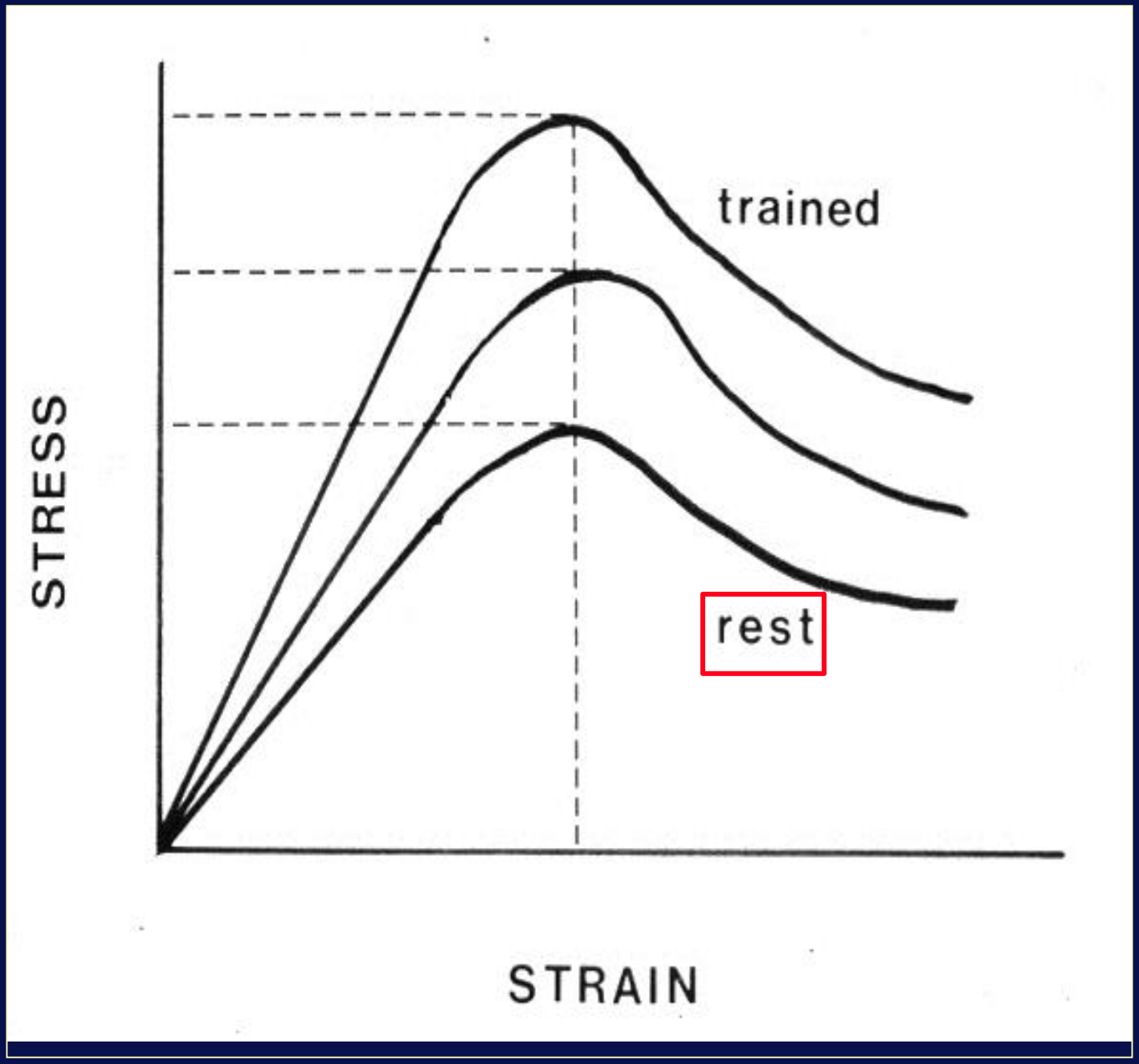

trained
rest
STRESS
STRAIN

Maintaining Fitness

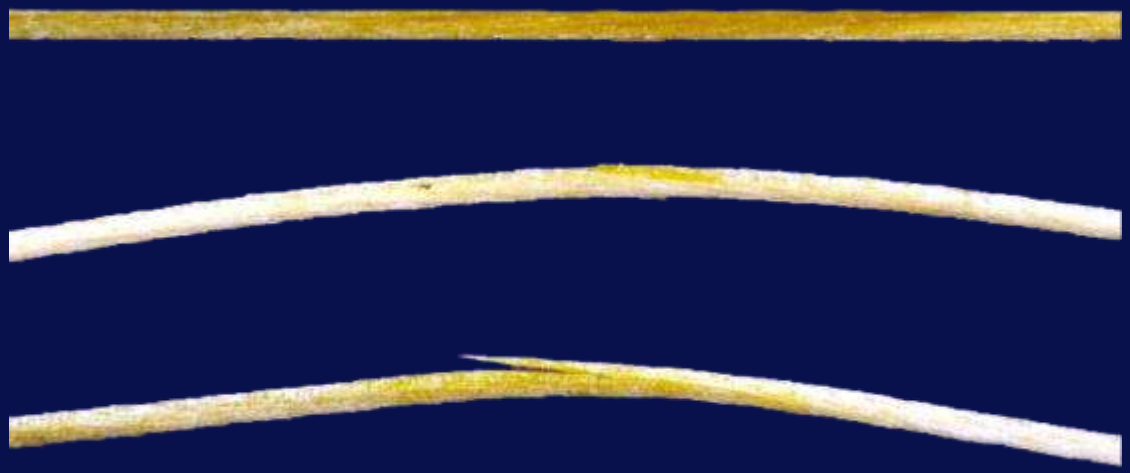
- Relatively little exercise is required to maintain bone mass

- The work must be relevant to the work the horse is expected to do

Bone Fatigue

- Degradation in stiffness
- Degradation in residual strength
- Failure with cyclic loading

Repetitive Loading



- ↓ stiffness
- ↓ strength
- ultimately failure

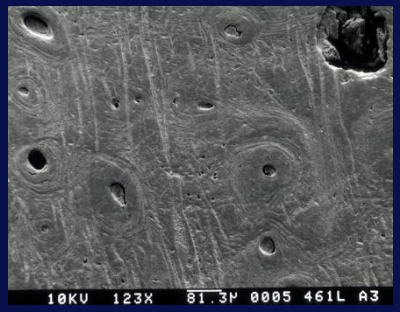
Musculoskeletal System

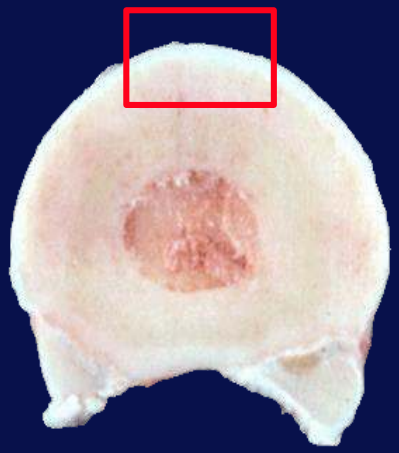
Courtesy of Mitch Taylor

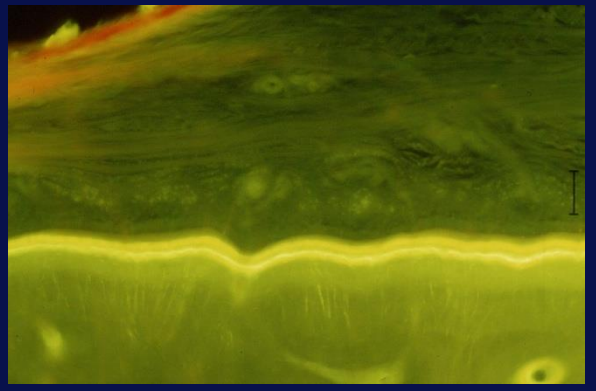

10KV 236X 42.4µ 0006 317A2A

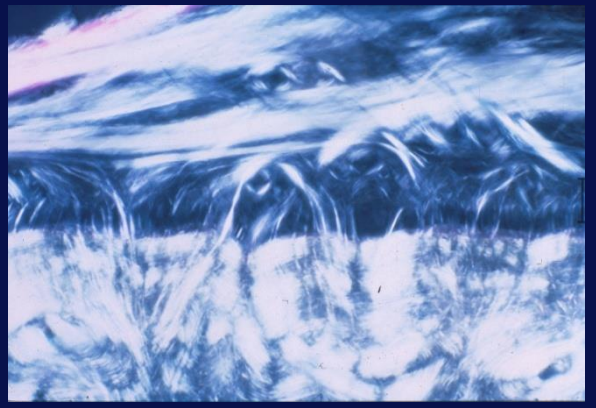
Injury

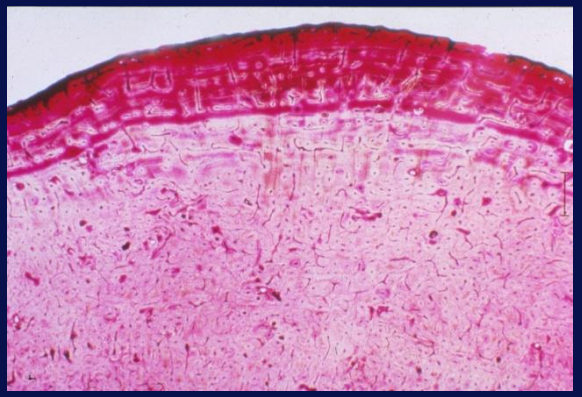
- Stimulates adaptation or repair depending on the severity of injury and opportunity for repair

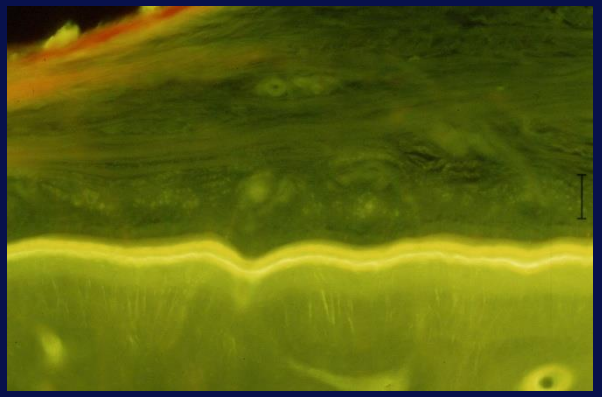

10KV 123X 81.3P 0005 461L A3

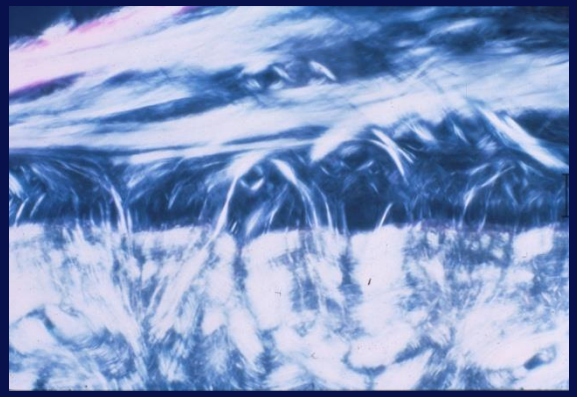








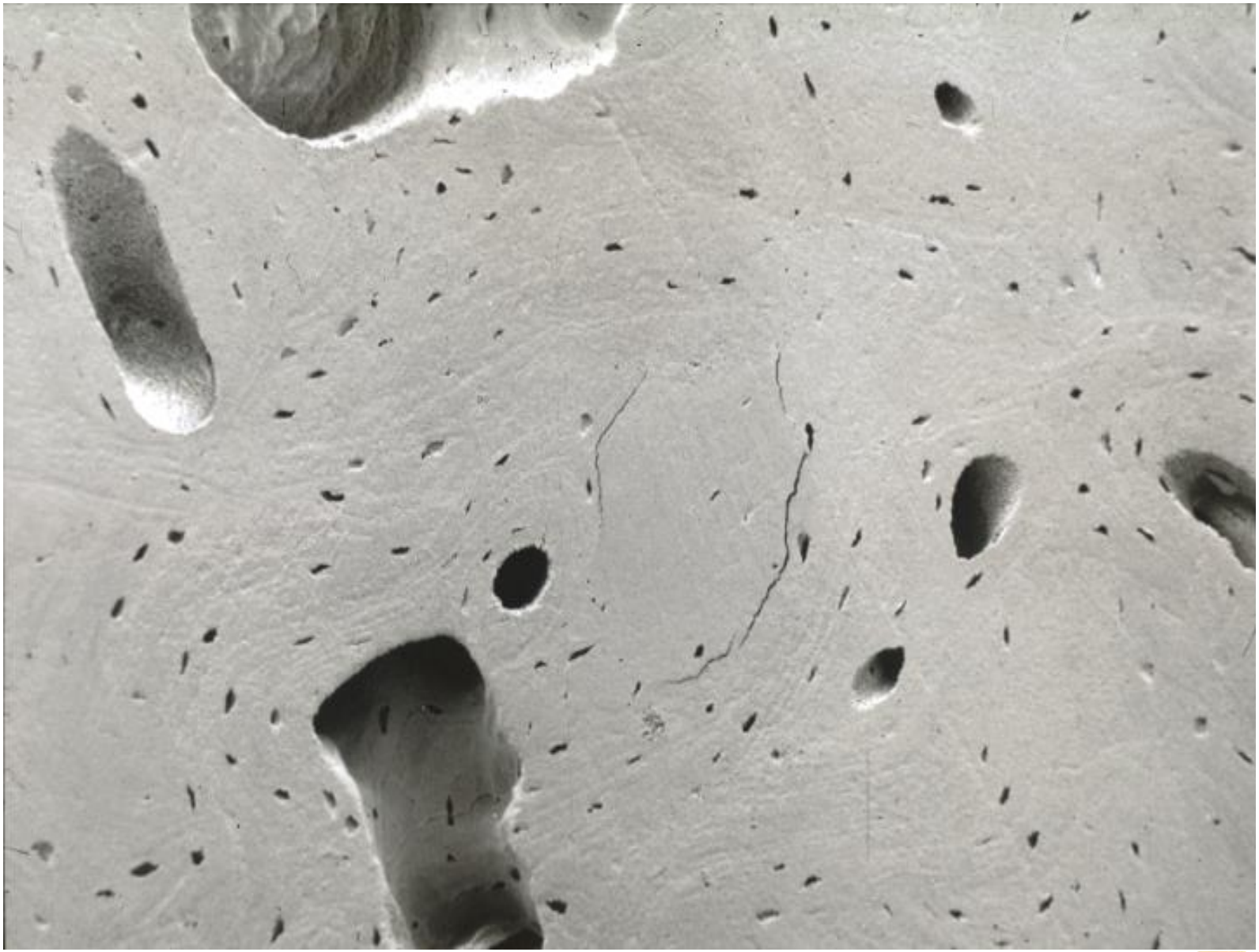




Adaptation

Increase the Daily Burden of Injury

- More severe damage
- Necessitates the removal of devitalized tissue



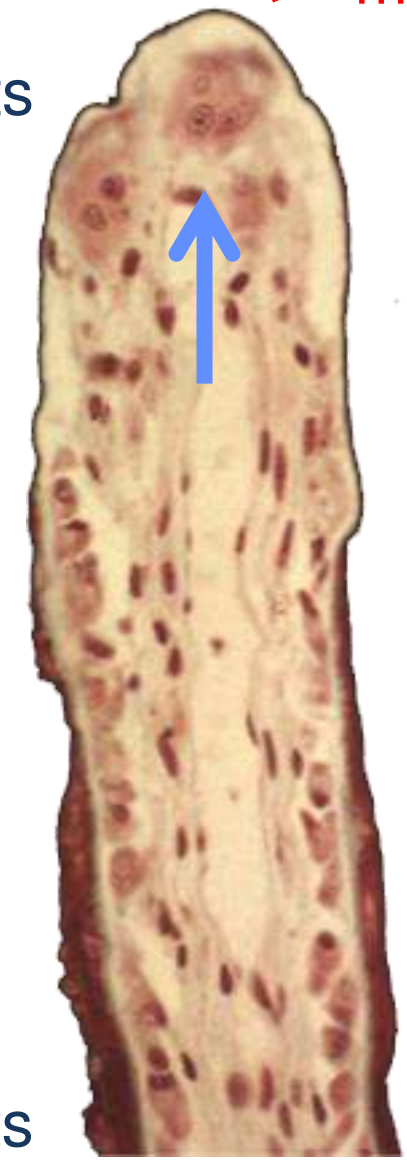
Bone Physiology

- Bone is actively being repaired throughout life

However, the time for repair is rate-limited

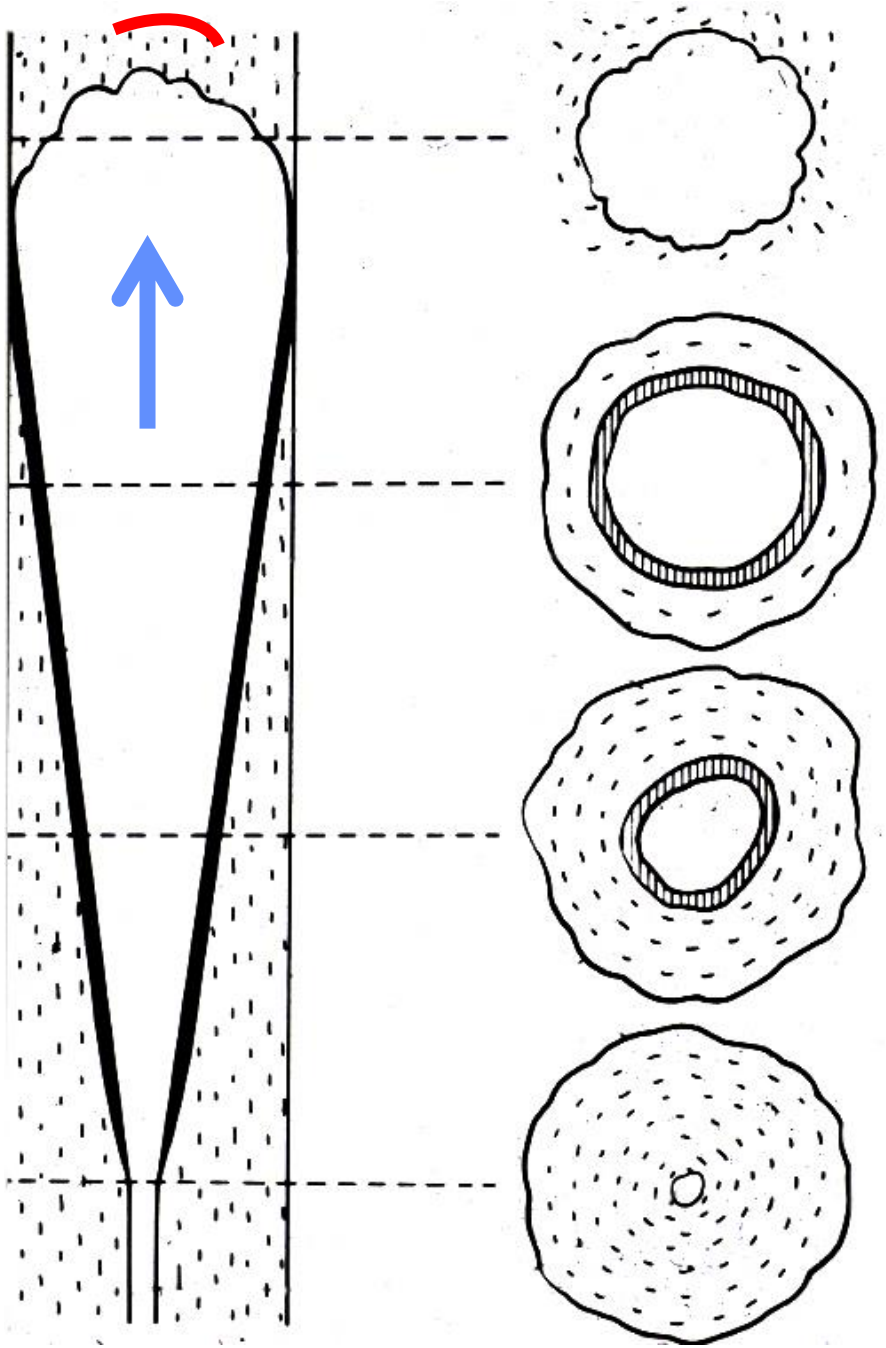
microcracks

osteoclasts



osteoblasts

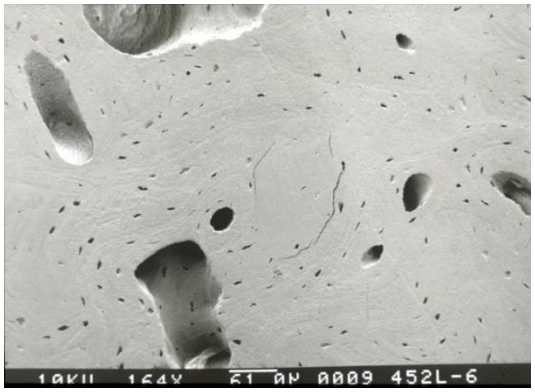
Bone Remodeling Unit (BMU)

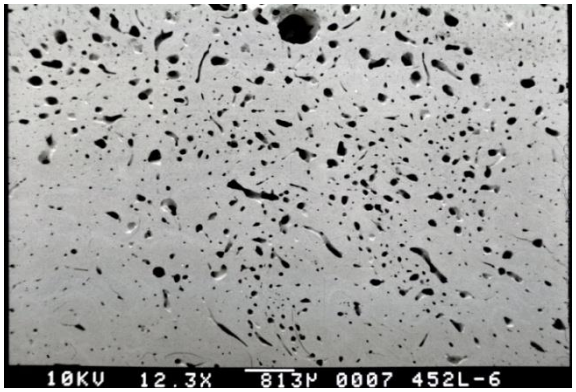


1-2 weeks

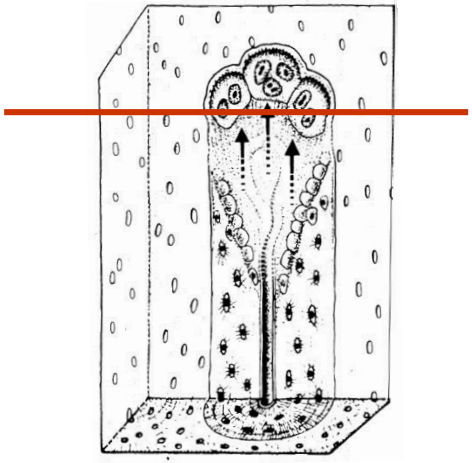
3 months

Injury stimulates repair & induces transient bone loss

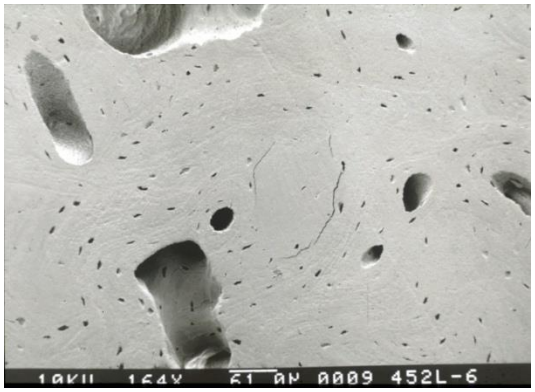


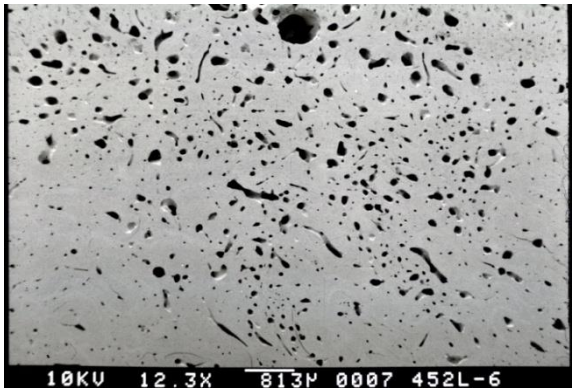


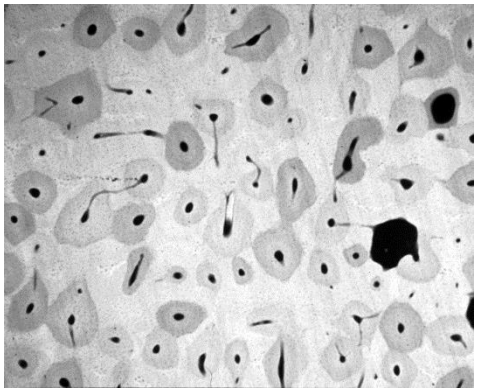
2-3 wks



Repair takes TIME

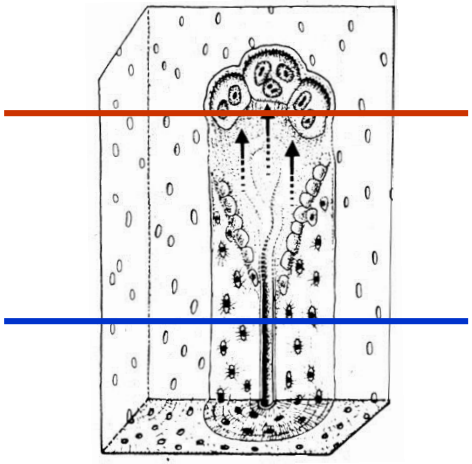






2-3 wks

3 mos

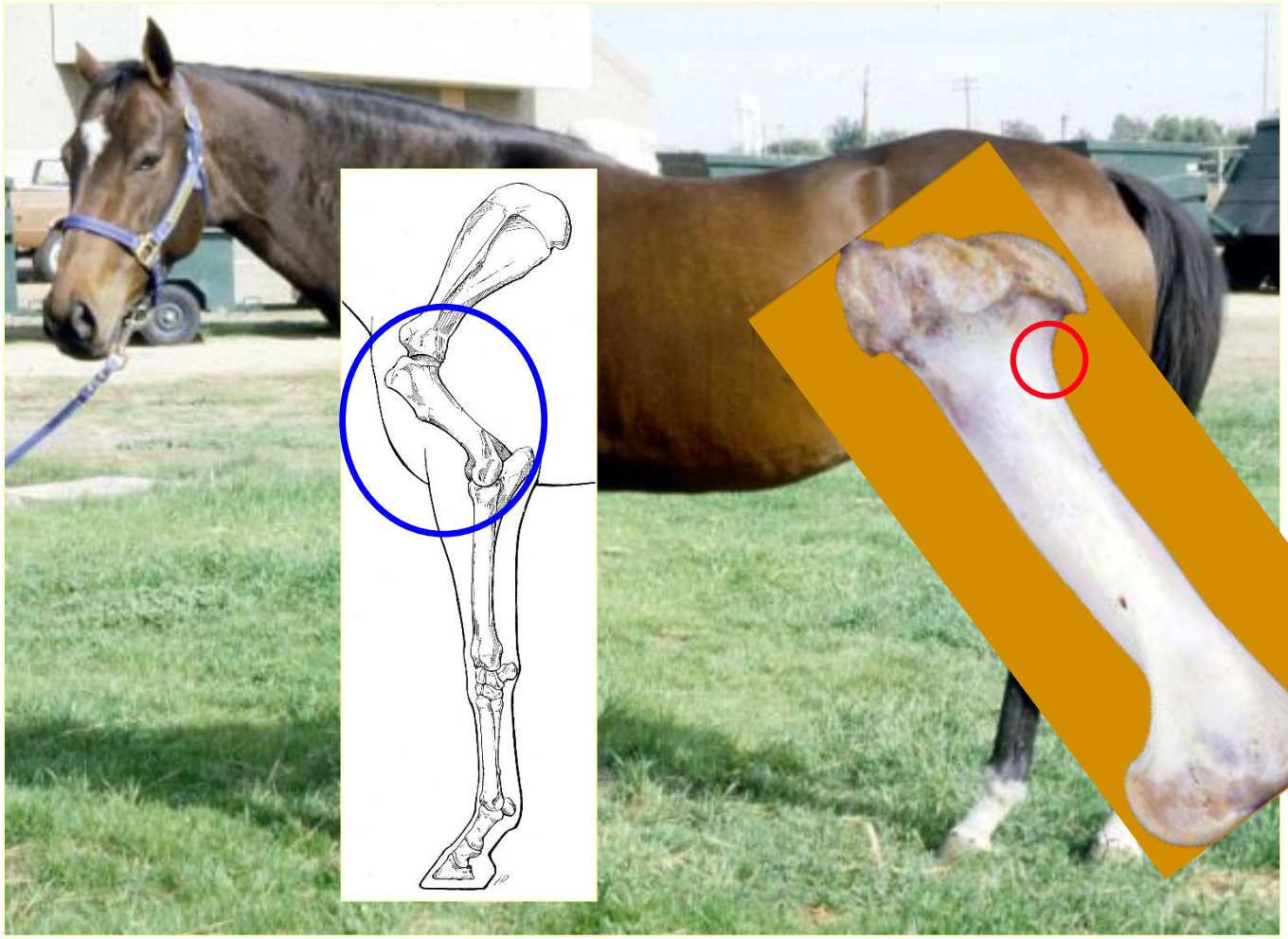


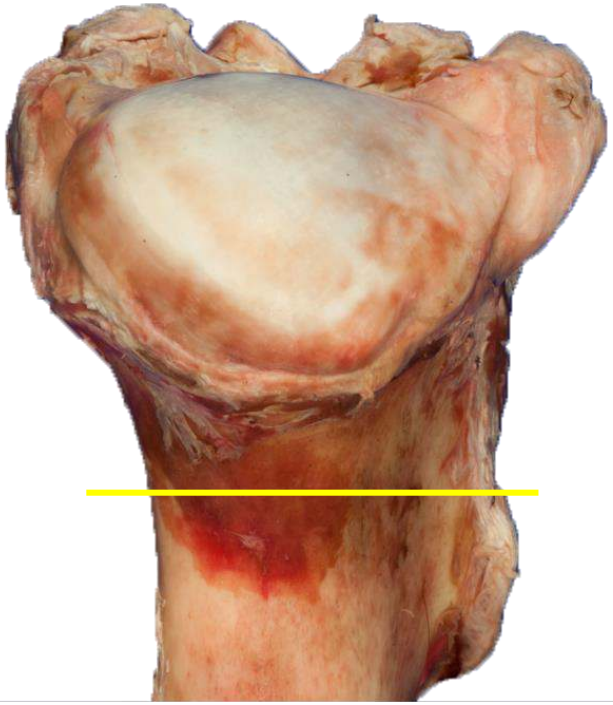
Bone Physiology

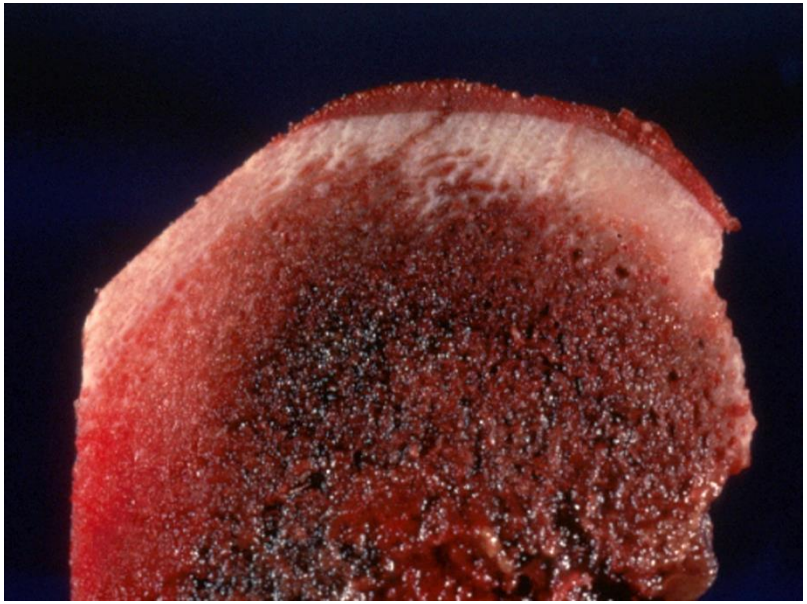
- Bone is actively being repaired throughout life

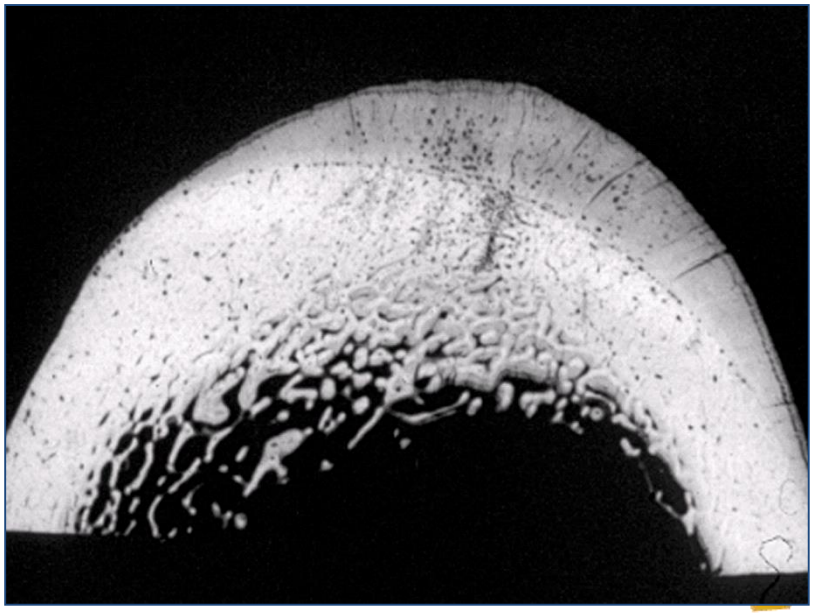
A transient period of enhanced weakness follows injury during repair

Humeral Stress Fracture

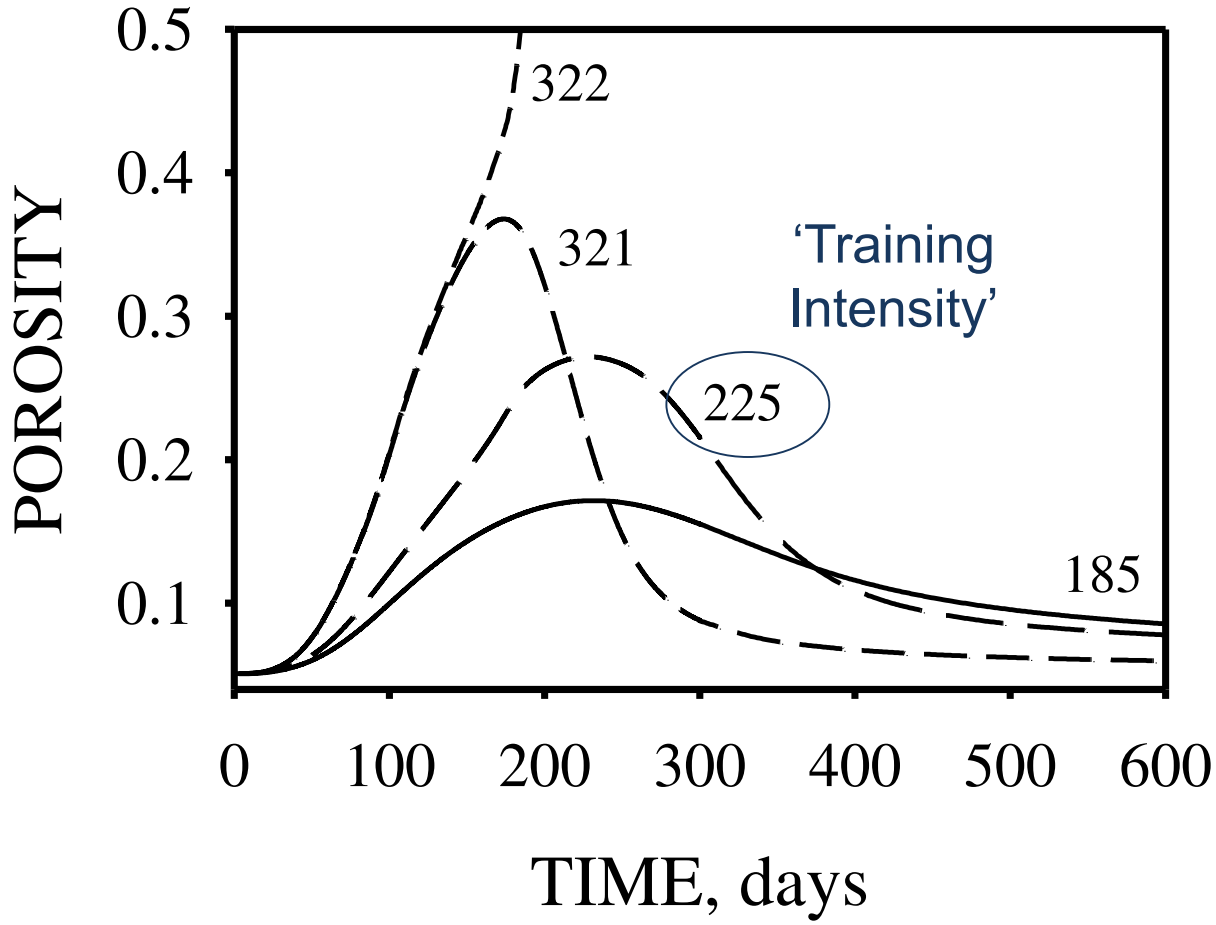






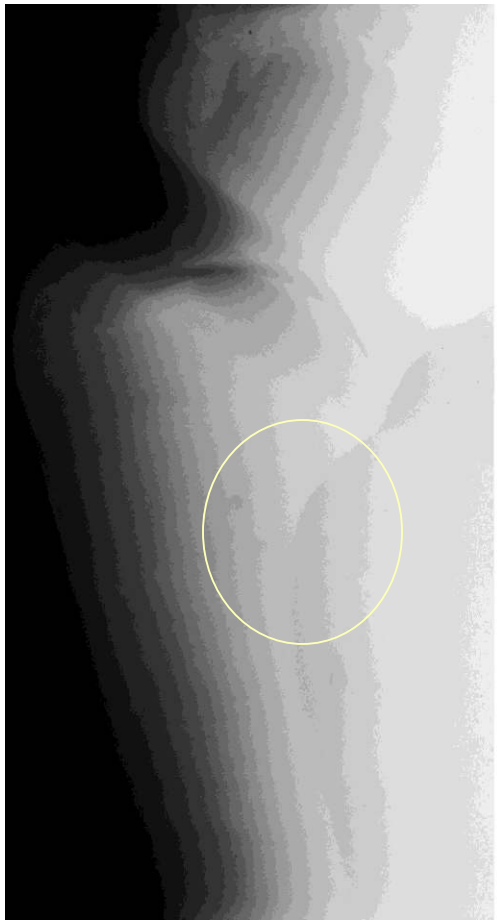


Training Intensity

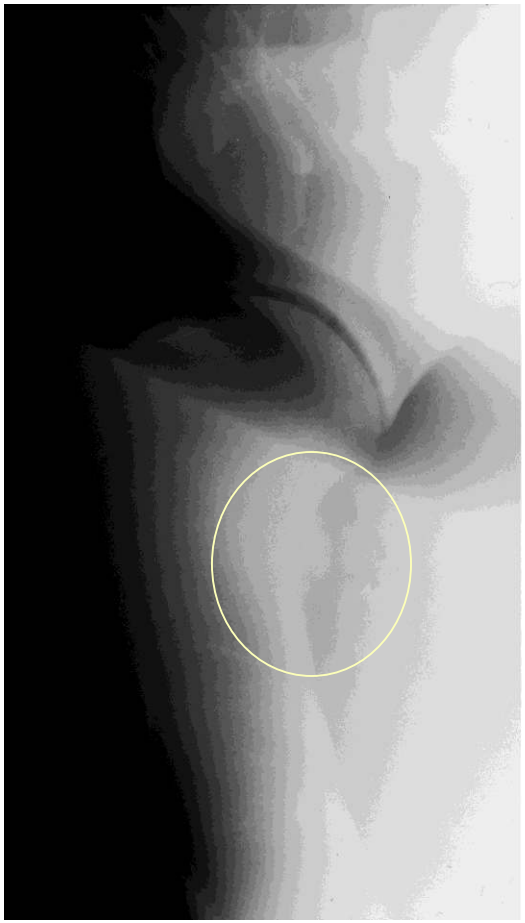


2001 Martin, R.B.: The Role of Bone Remodeling in Preventing or Promoting Stress Fractures. In Musculoskeletal Fatigue and Stress Fractures, D.B. Burr and C. Milgrom, eds., CRC Press, Boca Raton, FL

Given TIME - damaged bone can heal



Early clinical signs

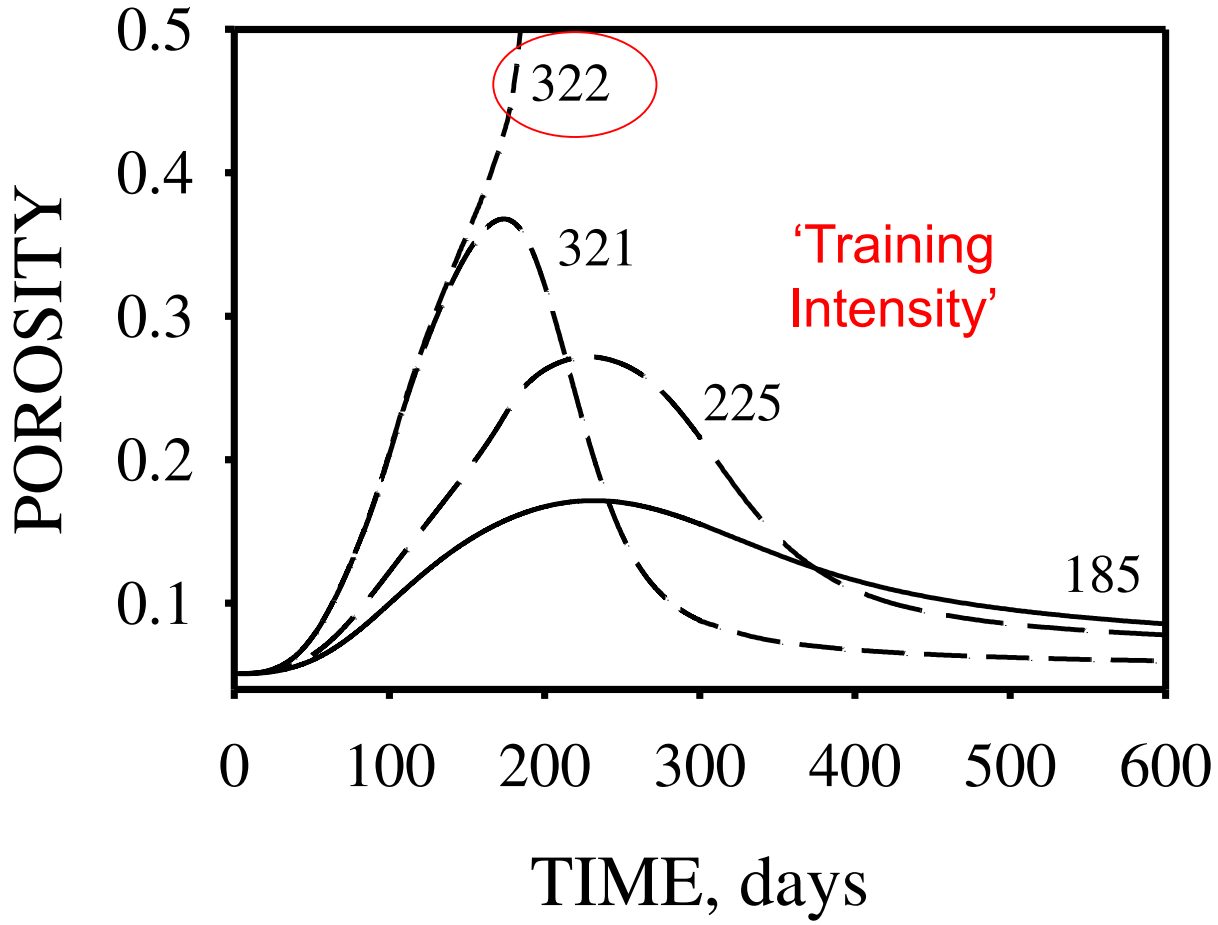


1 month later

3 months later

Courtesy of Dr. Rick Arthur

Damage exceeds Repair



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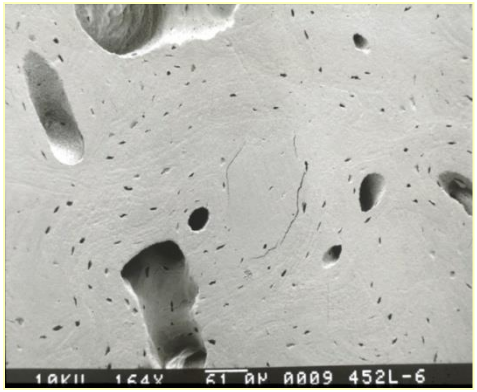
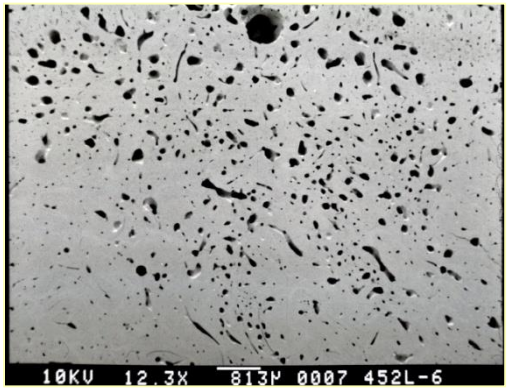
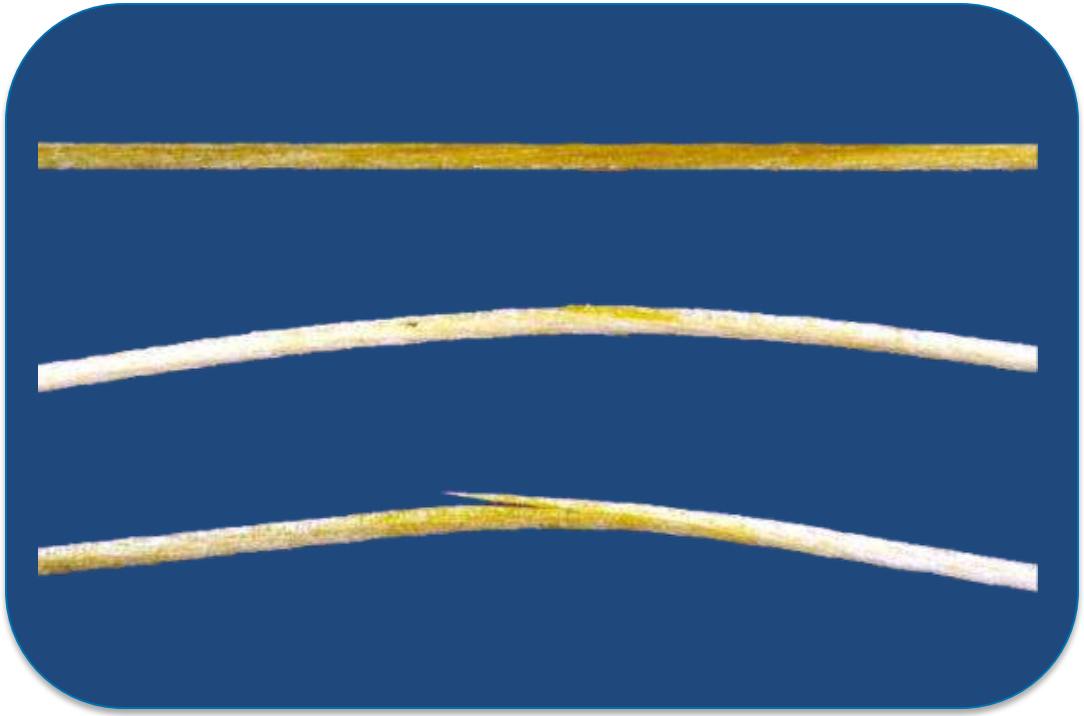
Continued loading of damaged, WEAKENED bone





Catastrophic Injury

Repetitive Loading

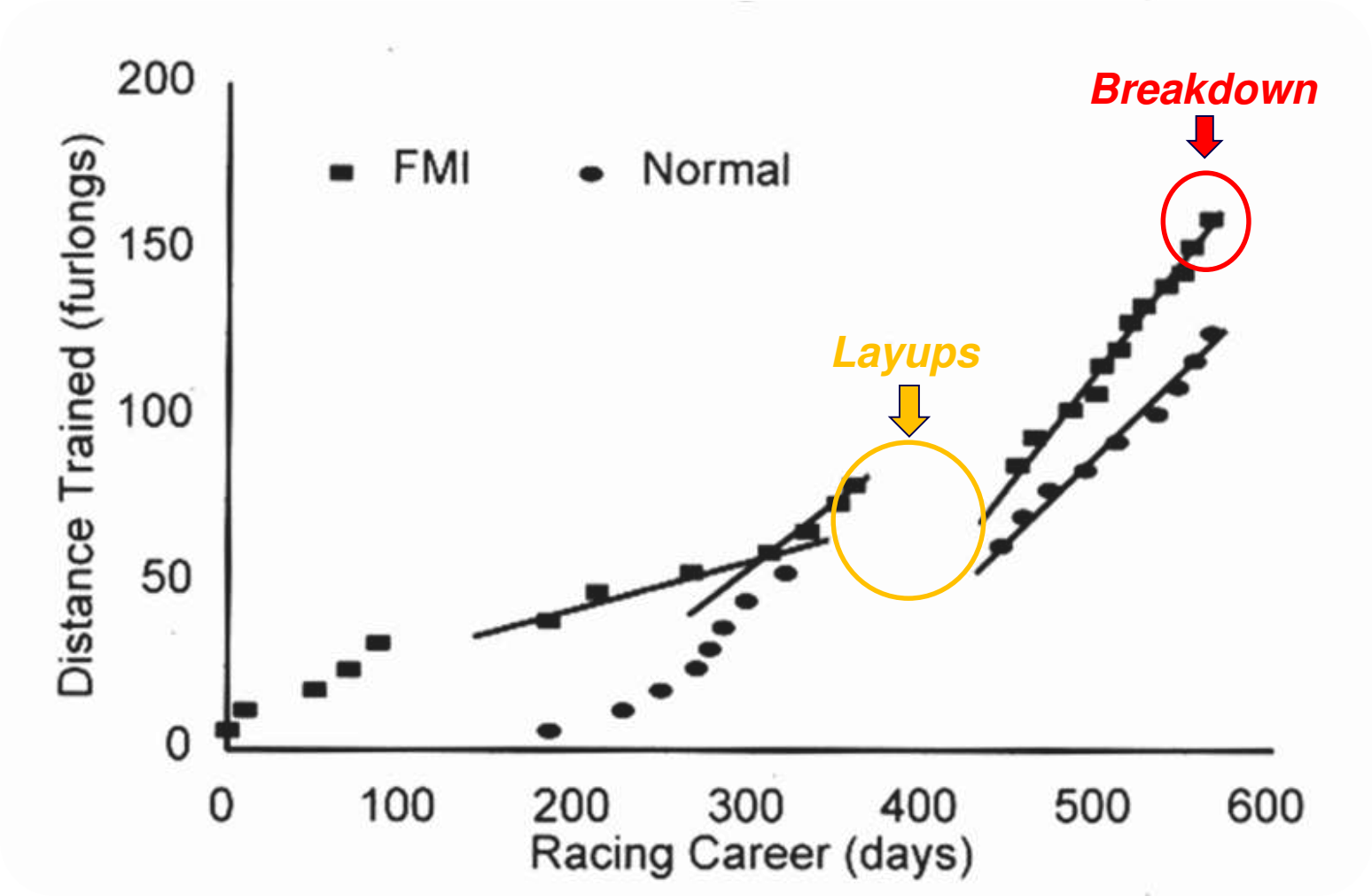


- ↓ stiffness
- ↓ strength
- then failure

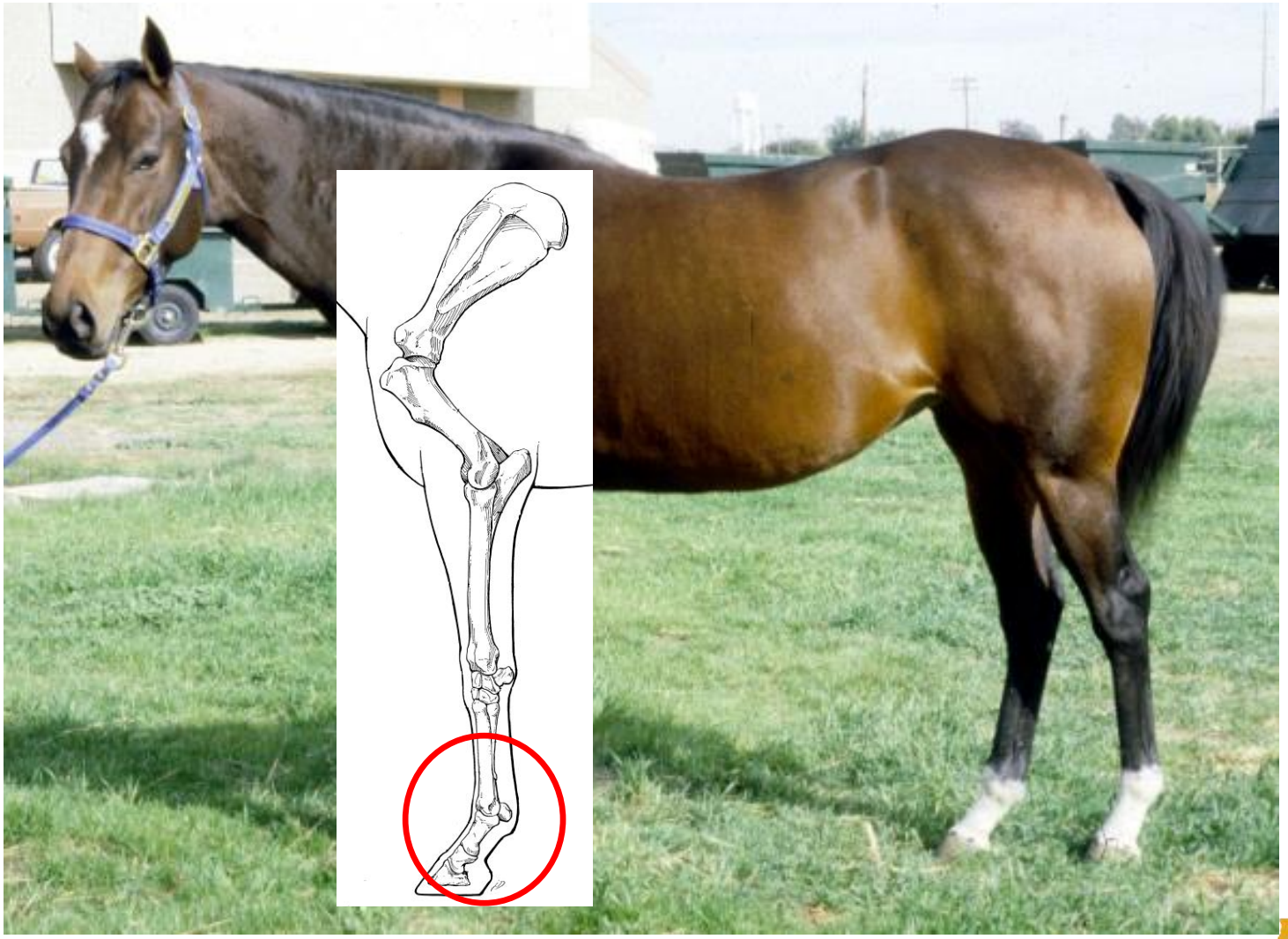
Damage accumulation affects risk of failure

- Number of load cycles
  - horse strides (distance)
  - over time (rate of distance accumulation)
- Magnitude of load per cycle
  - horse speed
  - hoof conformation
  - horseshoes
  - race surface

Training Intensity

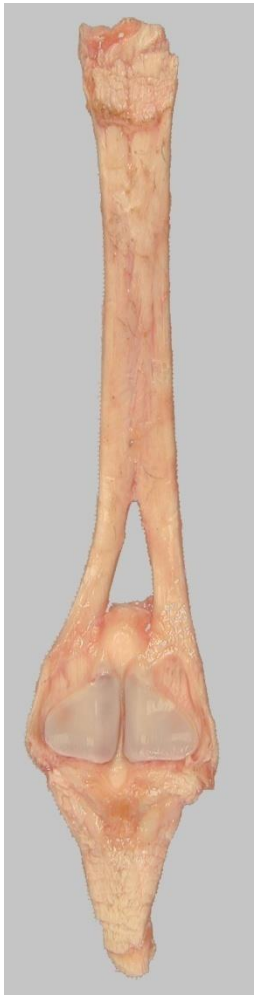


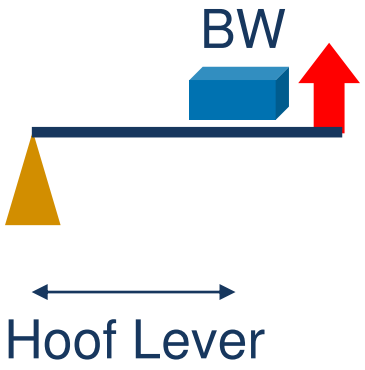
Fetlock Injuries

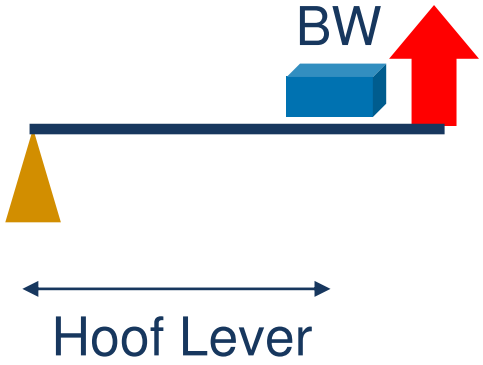


Load Magnitude

Courtesy of Mitch Taylor







Long toe / underrun heel

- Increases risk for fetlock injuries

Courtesy of Mitch Taylor

Kane, et al. AJVR 1996;57:1147-1152

Balch, et al. AAEP 2002;47:334-338

Traction Devices and Risk for Fetlock Breakdown

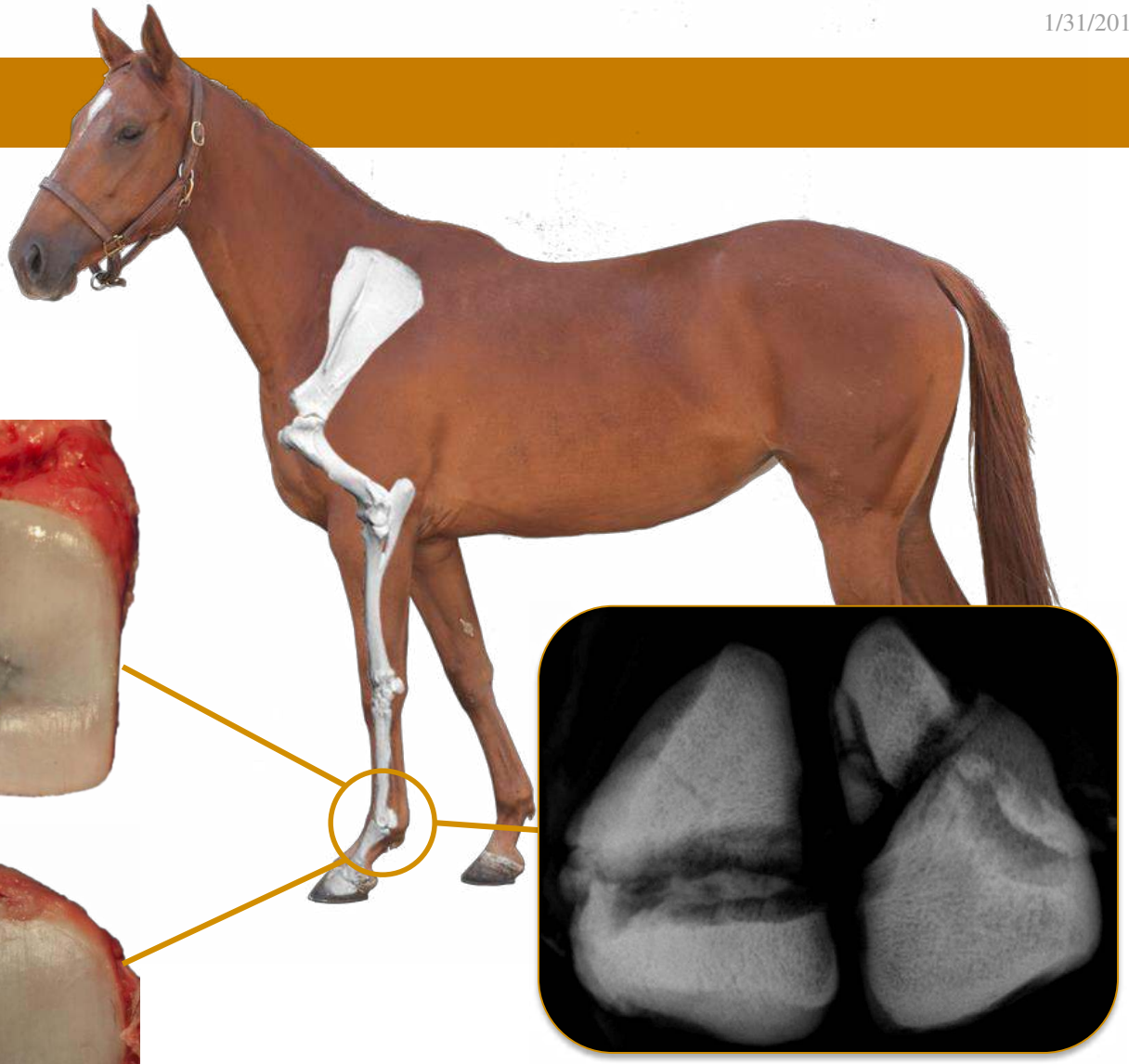
	OR*	95% CI
low toe grab[a]	6.5	1.2-34.1
regular toe grab[a]	15.6	2.8-87.1
rim[b]	0.3	0.1-0.9

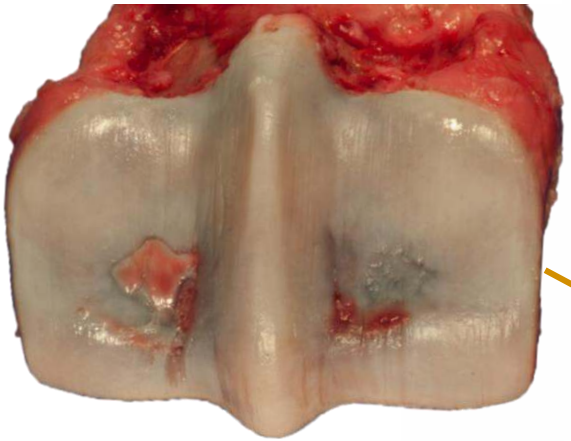
[a] compared to no toe grab

[b] compared to no rim

Kane, et al. AJVR 1996;57:1147-1152

Medication





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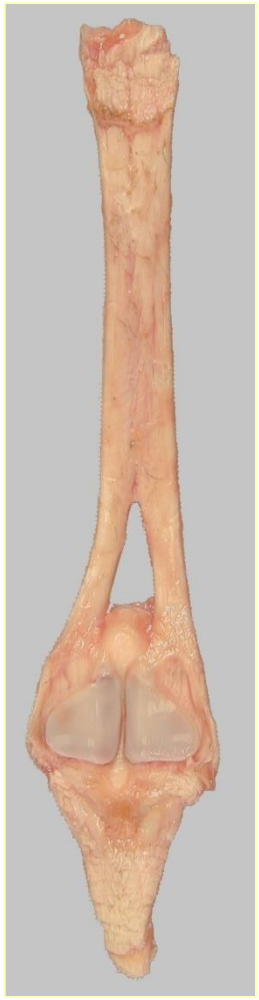
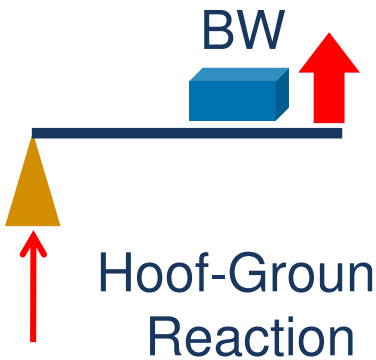
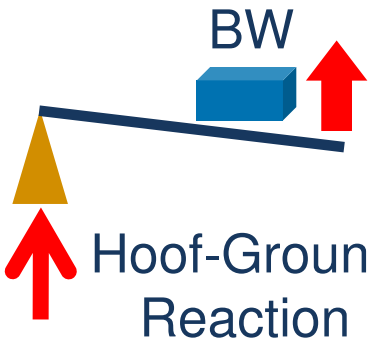
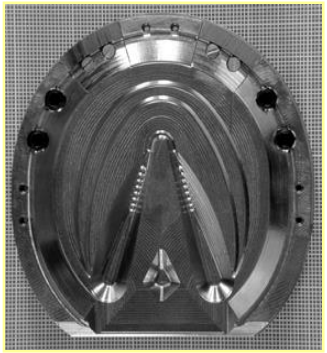
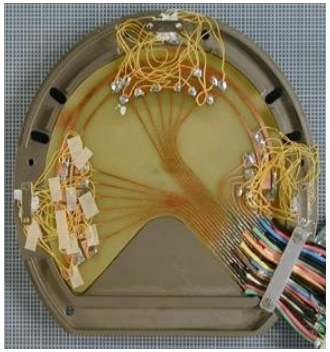




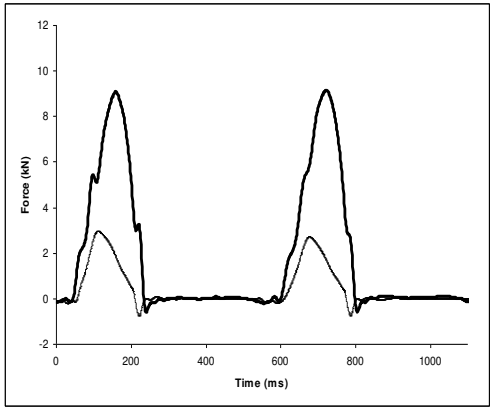


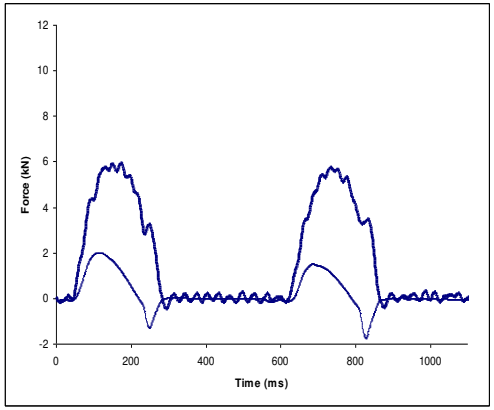
Limb loading

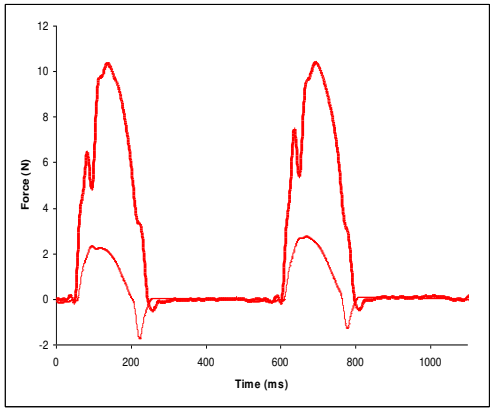




Load transferred to hoof varies with surface



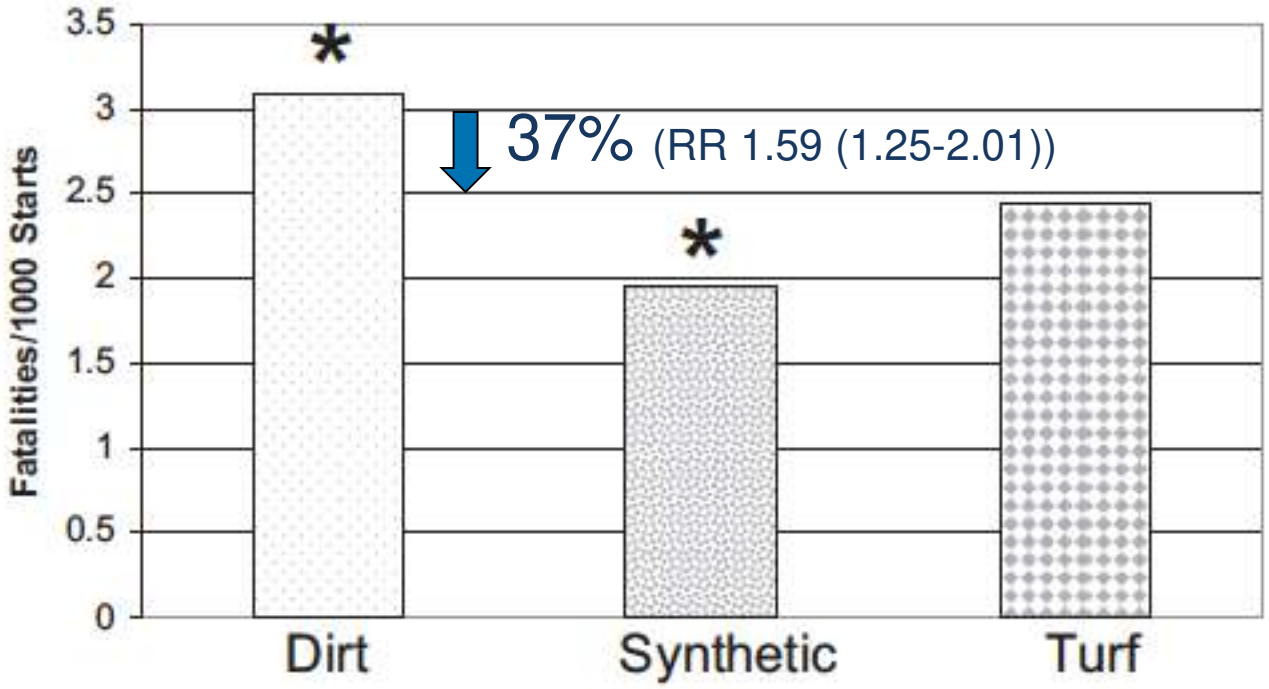




Race Surface

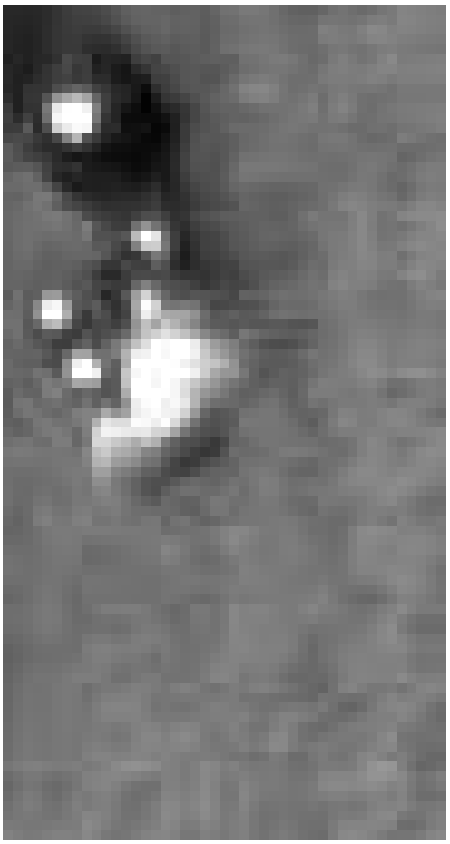
Fatality Rates at California Racetracks

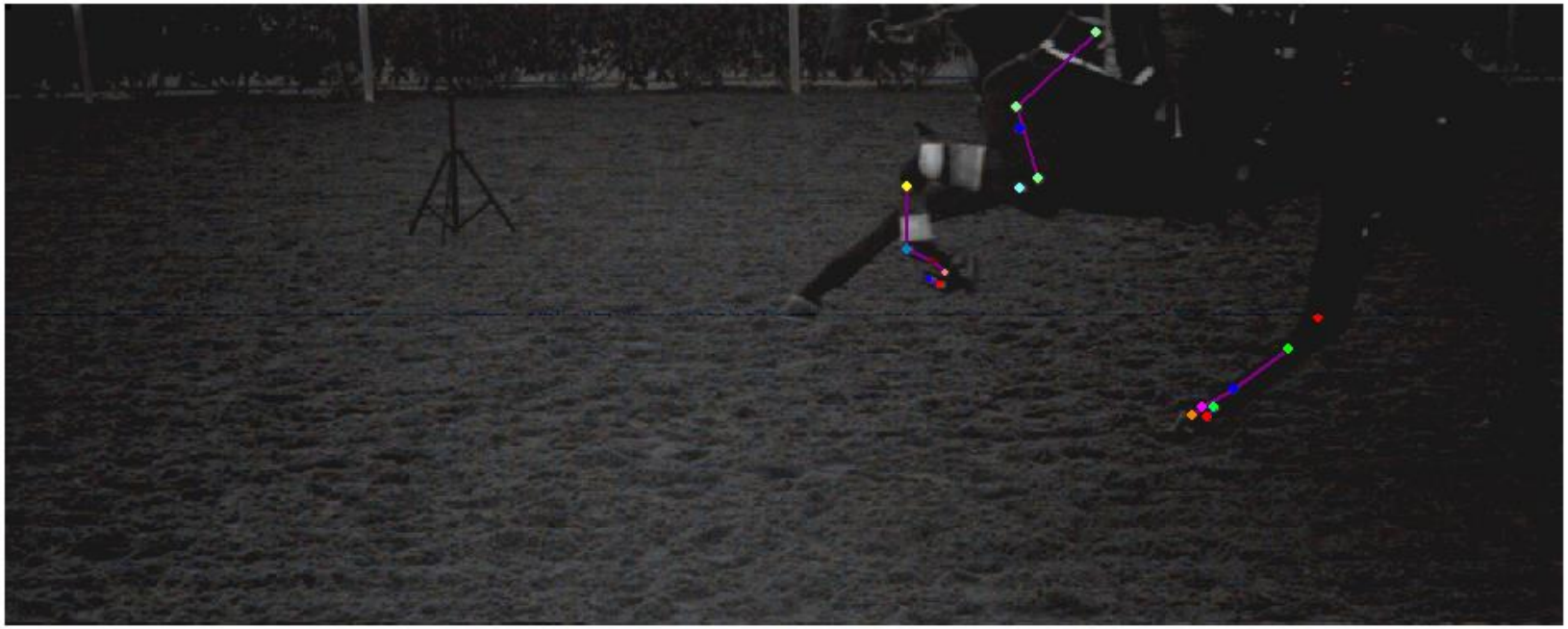
Rick M. Arthur, DVM AAEP PROCEEDINGS / Vol. 56 / 2010

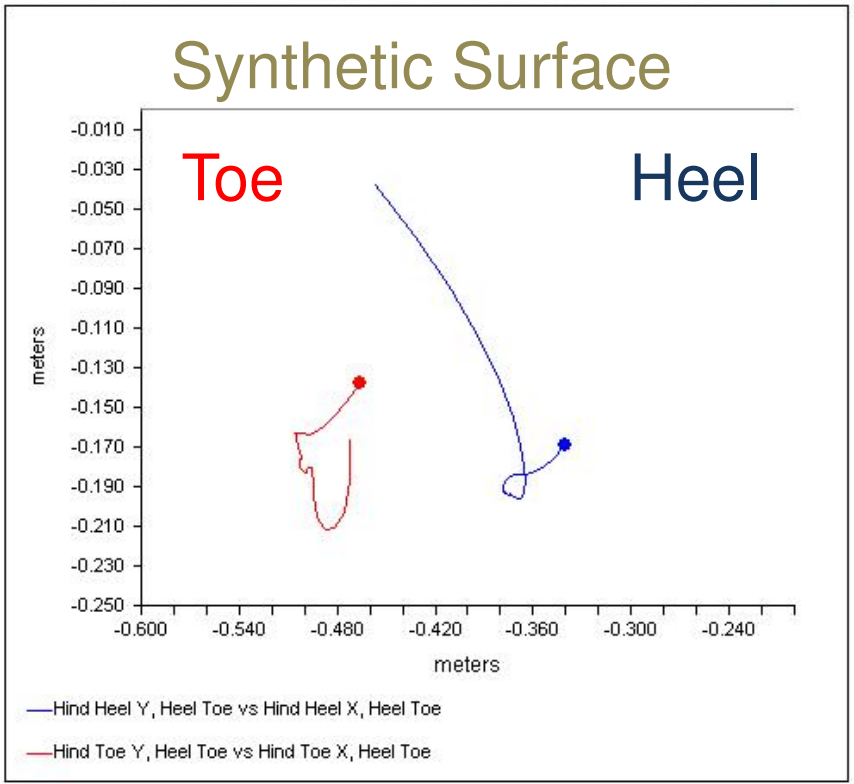


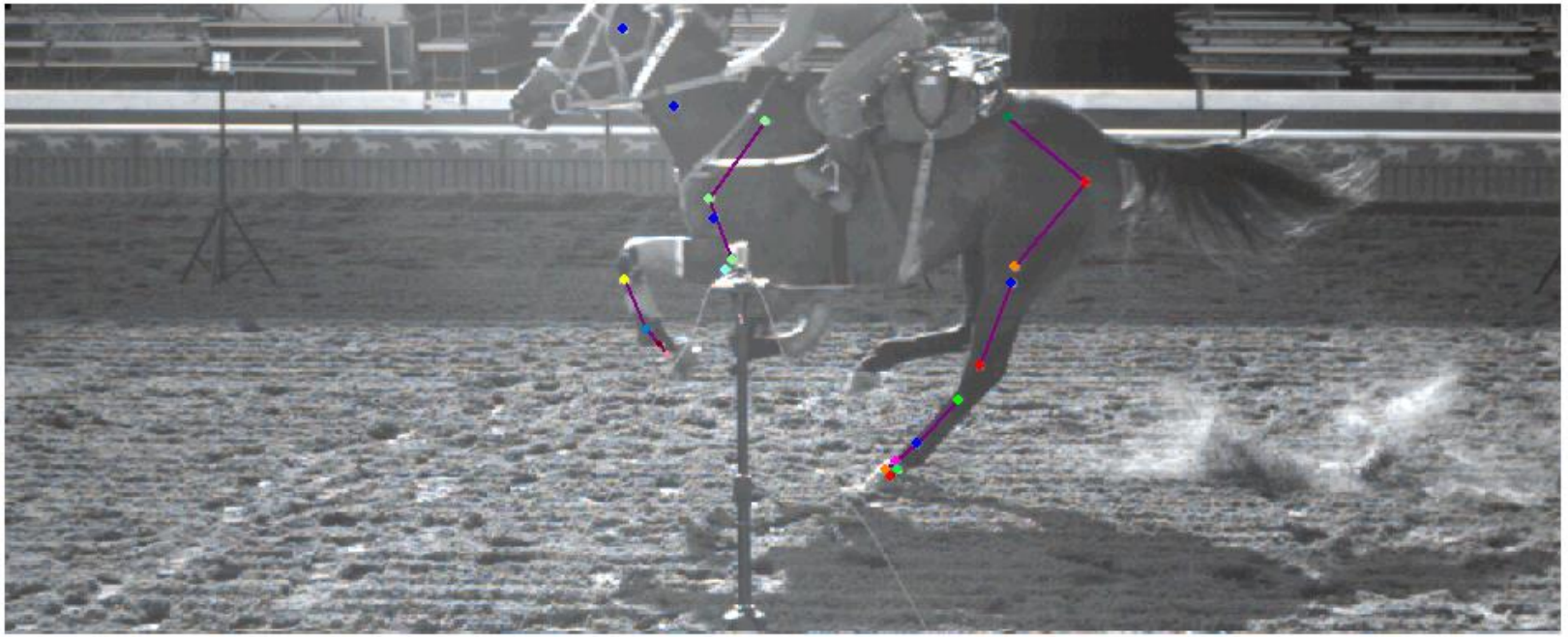
2004-2009: HP, DM, GGF, SA converted from dirt to synthetic surfaces

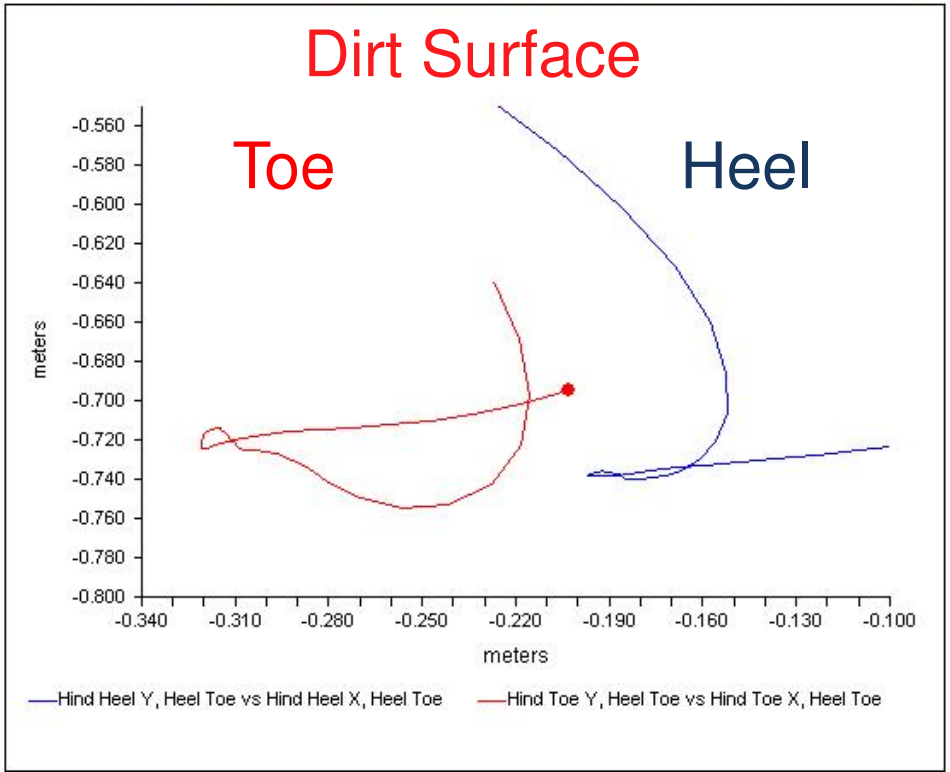
Race Surface

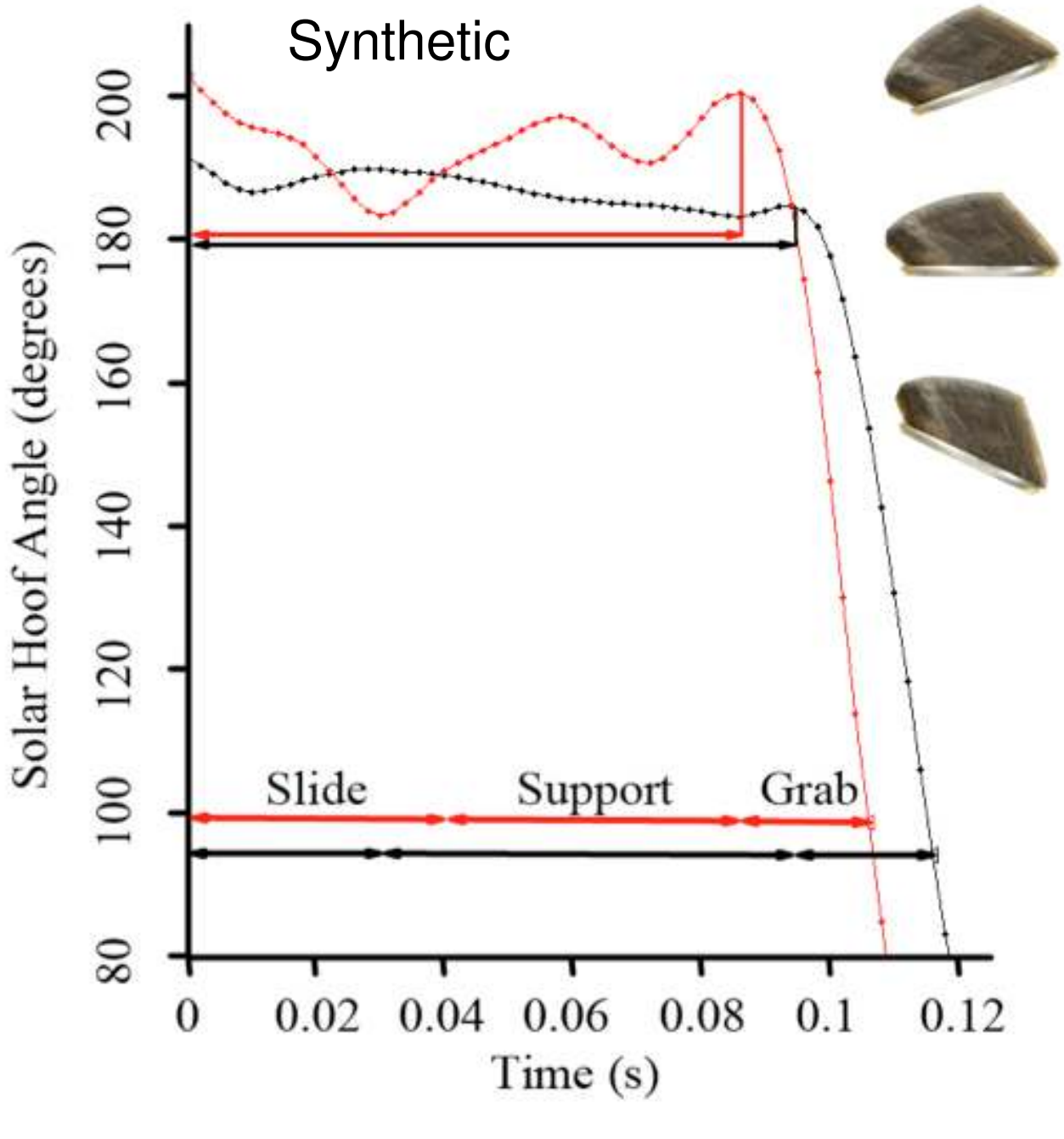


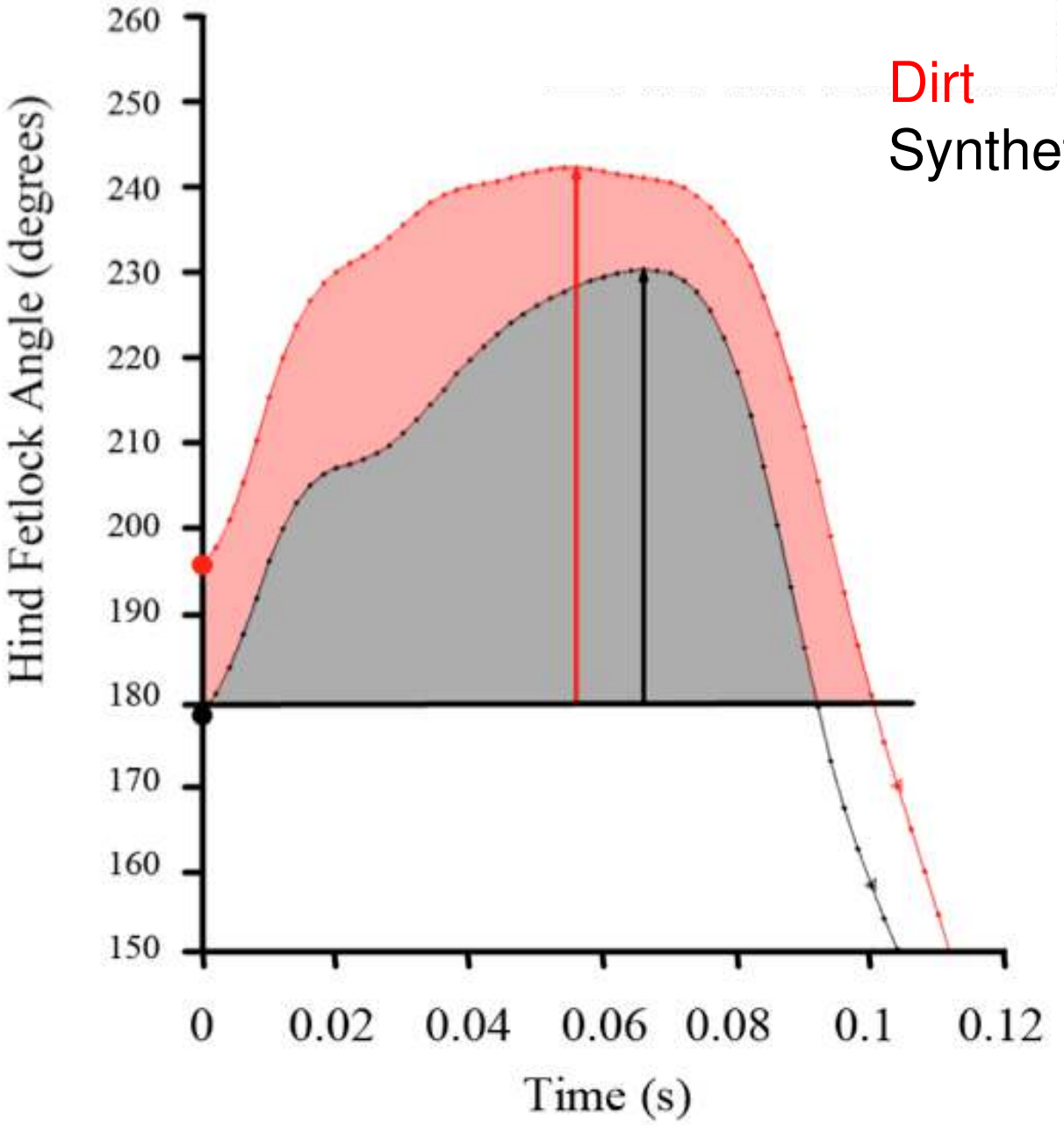



Synthetic Surface
Toe
Heel
-0.010
-0.030
-0.050
-0.070
-0.090
-0.110
-0.130
-0.150
-0.170
-0.190
-0.210
-0.230
-0.250
meters
-0.600
-0.540
-0.480
-0.420
-0.360
-0.300
-0.240
meters
Hind Heel Y, Heel Toe vs Hind Heel X, Heel Toe
Hind Toe Y, Heel Toe vs Hind Toe X, Heel Toe




Dirt Surface
Toe
Heel
-0.560
-0.580
-0.600
-0.620
-0.640
-0.660
-0.680
-0.700
-0.720
-0.740
-0.760
-0.780
-0.800
meters
-0.340
-0.310
-0.280
-0.250
-0.220
-0.190
-0.160
-0.130
-0.100
meters
Hind Heel Y, Heel Toe vs Hind Heel X, Heel Toe
Hind Toe Y, Heel Toe vs Hind Toe X, Heel Toe


Dirt
Synthetic
Solar Hoof Angle (degrees)
200
180
160
140
120
100
80
Slide
Support
Grab
0
0.02
0.04
0.06
0.08
0.1
0.12
Time (s)


Dirt
Synthetic
Hind Fetlock Angle (degrees)
260
250
240
230
220
210
200
190
180
170
160
150
0
0.02
0.04
0.06
0.08
0.1
0.12
Time (s)

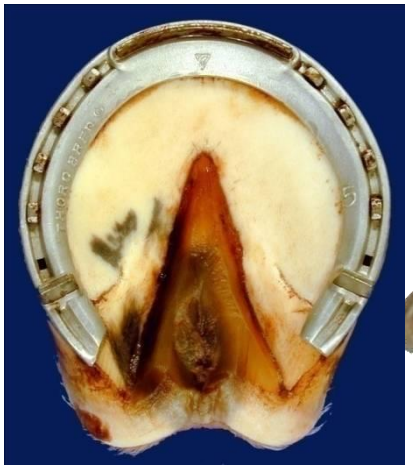
- Bone alters it's size and shape in very specific ways to training and to inactivity
- Bone adapts specifically to the job it performs
- Bone is actively being repaired throughout life
- A transient period of enhanced weakness may follow injury during repair

Race between 2 rates:

- Rate of damage accumulation
- Rate of damage repair

- Exercise intensity and schedule
- Hoof conformation and shoeing
- Surface materials and management

Many OPPORTUNITIES for injury prevention



Training intensity
Horseshoe appliances

Hoof conformation
Race surfaces
…

Injuries are mu

CHRB RACING SAFETY PROGRAM

Horses, Horsemen and Horsewomen