

# Nons<sup>standard</sup> Foot & Ankle

## Nomenclature

- lexicon is expected to be known by all in profession
- diverse application creates issues
- + clinical, commercial, industrial, comparative and/or evolutionary
- many attempts made since 1890's

- focused term / definition based on discipline is counterproductive, as research is often cross-disciplinary
- + elements of hubris
- here we will identify common misconceptions

### Anatomical Descriptions

#### Persistence of Eponyms

- continuation of tradition of unifying logic
- eponym: use of name of discoverer
- linguistically difficult, carries a sense of membership and identity
- + creates exclusionary effect!!!

#### Regional Descriptions

- Distal element of lower limb
- + shank has problems
- \* element between knee and ankle
- \* sometimes includes ankle

- \* also description of shoe
- \* non-english description weird
- + solution? "cruis" in Latin = "leg" between ankle & knee
- + "femur" = Latin for "thigh"
- + "membrana inferius" or "membrana pelvinum" = "lower" or "pelvic membrane"
- Forefoot & Hindfoot
- + forefoot often same as hand in non-animal descriptions
- \* some own bother
- + "distalis pede" = distal foot
- + "proximales pede" = proximal foot

### Applying Anatomical Position

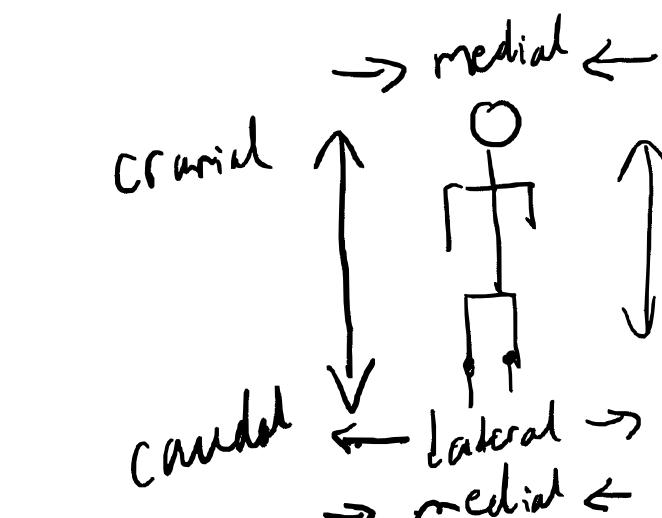
- assumed, no technical strong definition
- strong arm description to cross parallel bones.
- + lack of it for legs, feet position is rather vague.

- is foot parallel to leg or perpendicular?
- are feet parallel to each other or do they diverge at some angle?
- Tetrapoda = superclass of vertebrate animals with homologous foot & ankle structure
- + unguligrade: horses, cows, walk on phalanges supported by hoof
  - \* akin to ballerina "en pointe"
- + digitigrade
- + plantigrade = most reptiles, primates.
- \* full plantigrade = tuberosity from heel touching ground
- HAP legs parallel foot perpendicular most often to all species (↳ uniquely human)

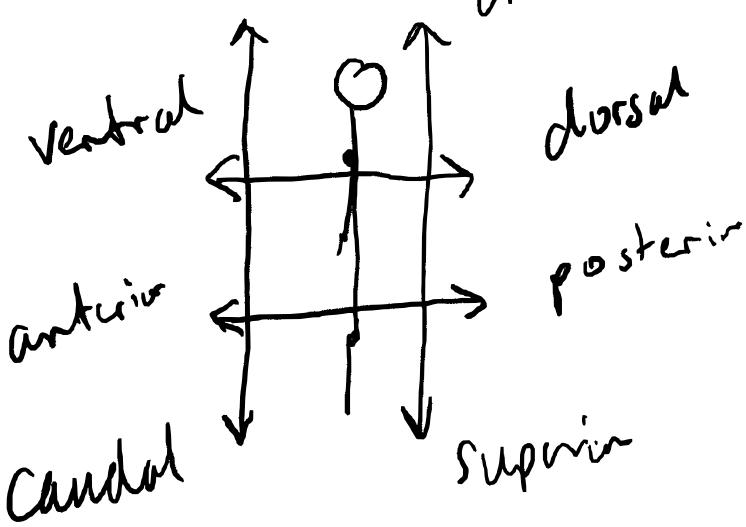
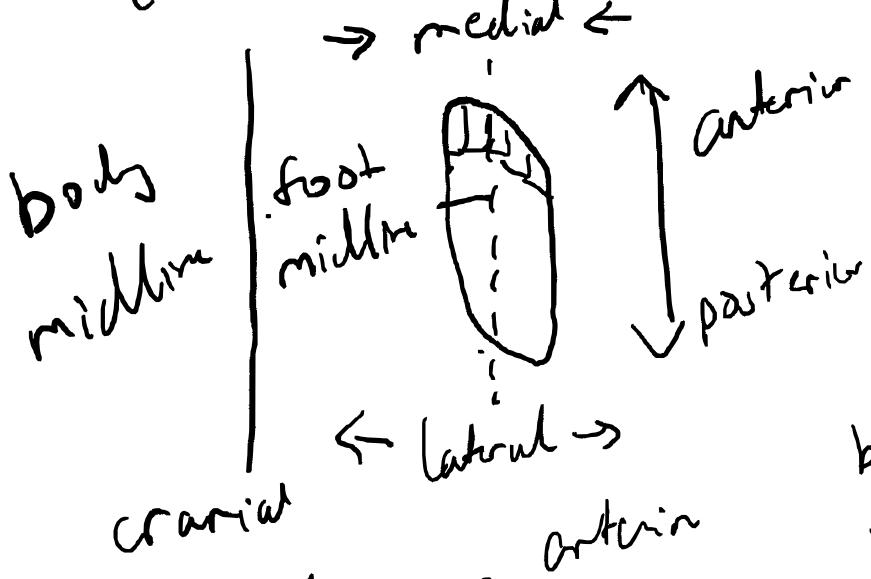
### Application Specific HAP

- Vague definition of foot placement does help studies collect data without immediately applying clinical eval
- LAP (leg anatomical position) local reference frame by ISB (International Society of Biomechanics)
- + uses malleoli and condyles of fib/tib

- Tibial torsion can be studied due to free foot frame



Same but  
with diff  
foot positions

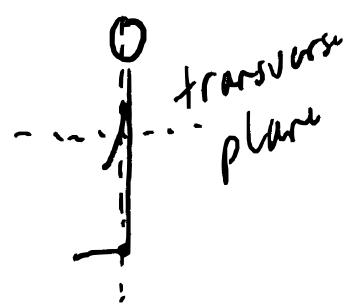


Same with  
b. foot  
position



- anterior-posterior is "free axis" as it is ~~relative~~  
to foot orientation. Cross product medial/lateral & inf/sur.

torso based  
coronal plane



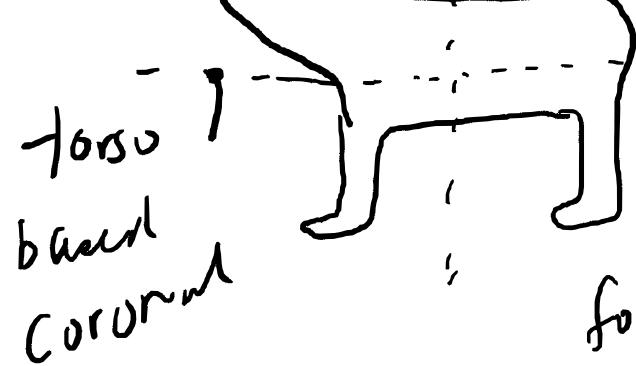
leg based  
coronal

leg  
based transverse

foot based  
Coronal

Plantigrade

torso based  
transverse



torso  
based  
Coronal

foot  
based transverse

leg based  
coronal

leg based  
transverse

Digitigrade

foot based  
transverse

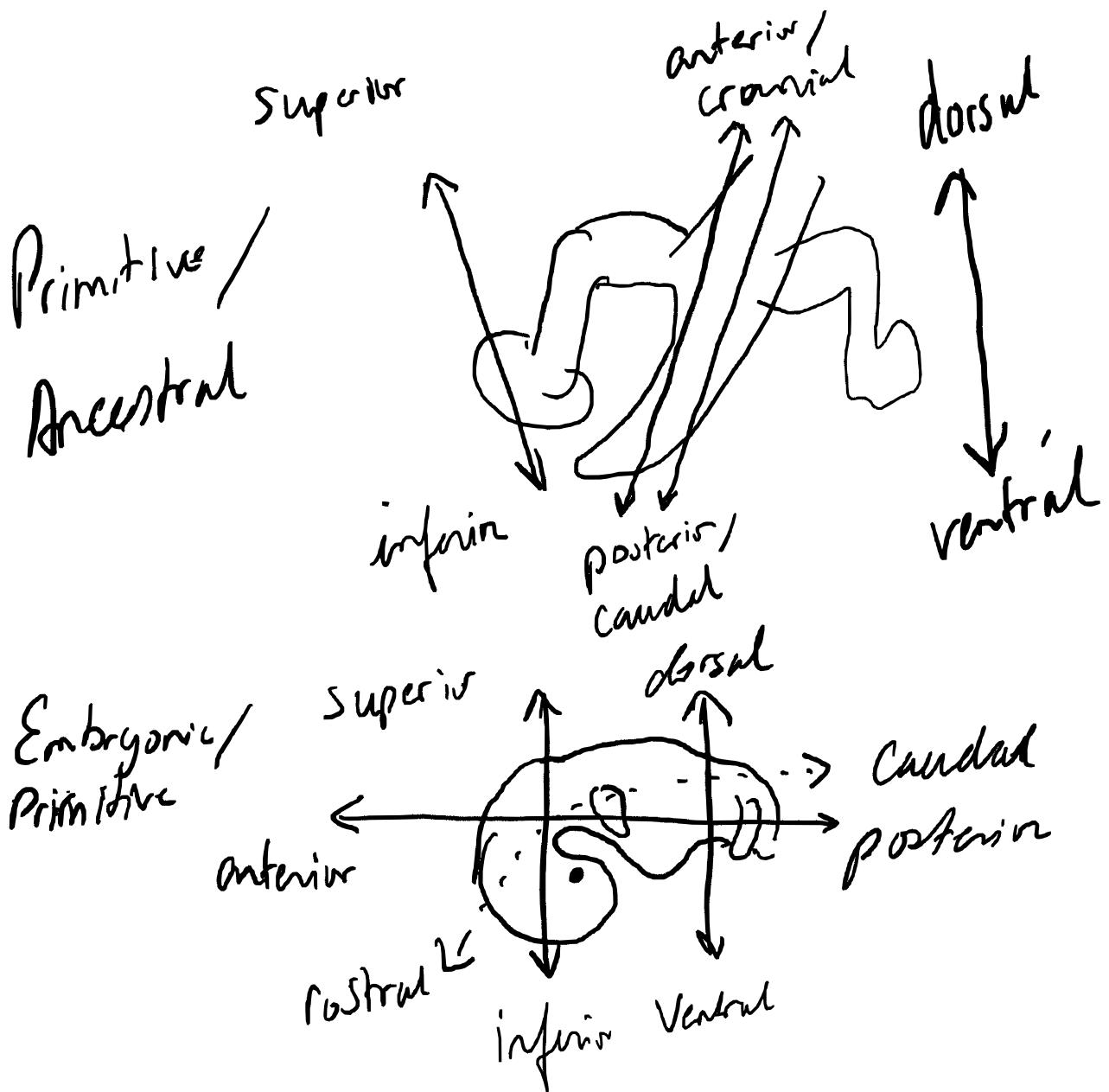
foot based  
coronal

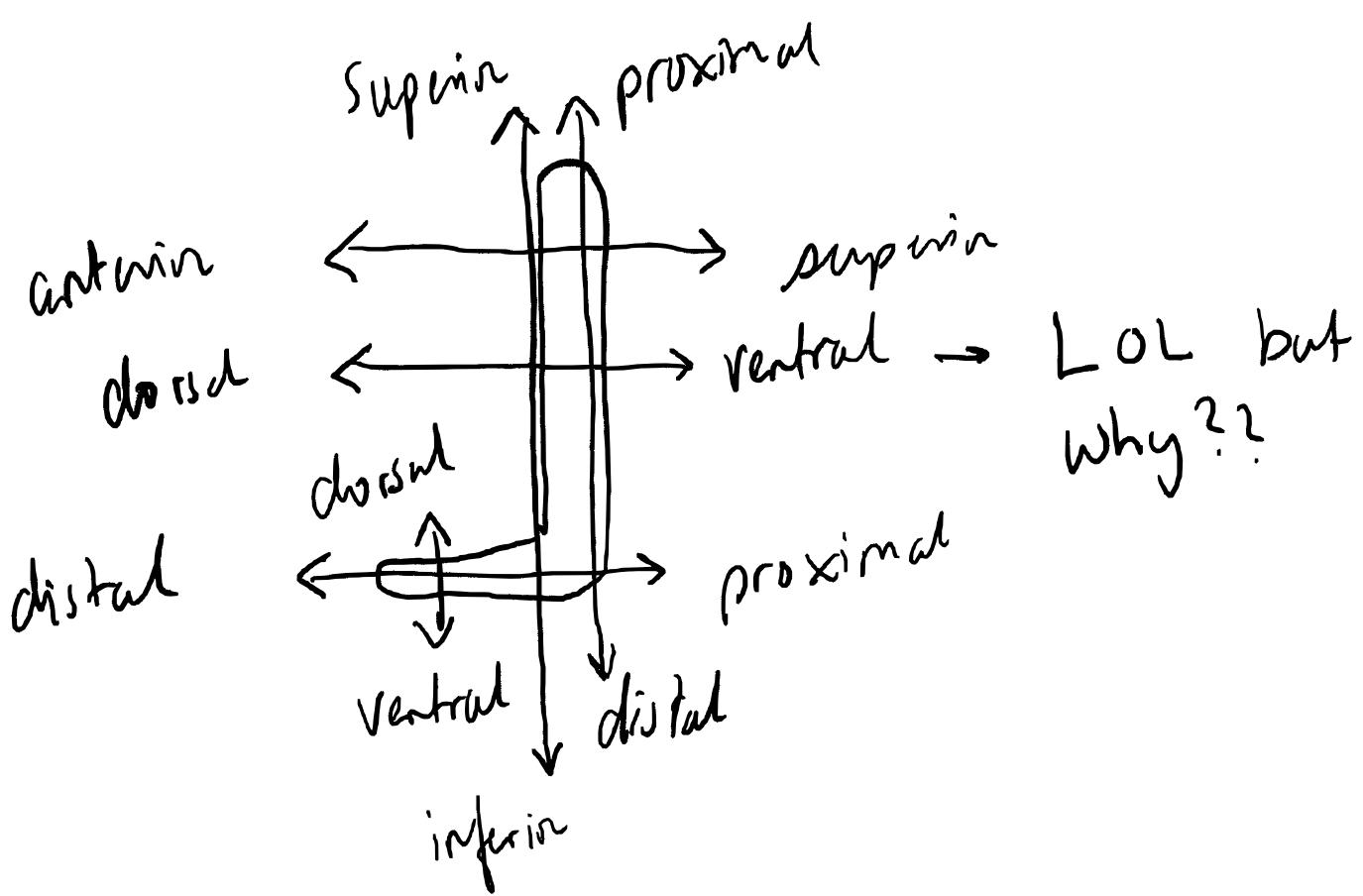
leg based transverse  
leg based coronal

Differences in foot  
evolution & labeling  
Schemas

foot based  
coronal  
foot based  
transverse

Unguligrade



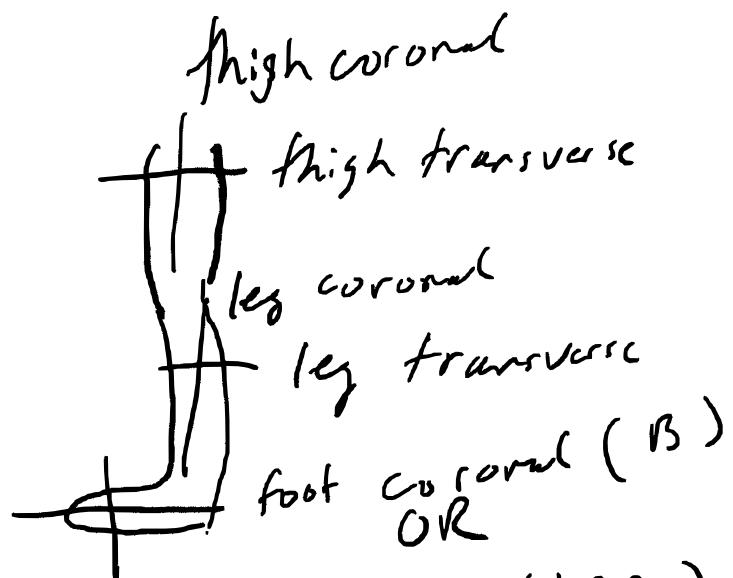


- research with just LAP neglect HAP or assumes common ground. BLIND SPOT
- worse when just FAP (foot) applied with no leg or body landmarks
  - + e.g.: human's work
- other places tough too, e.g. shoulder

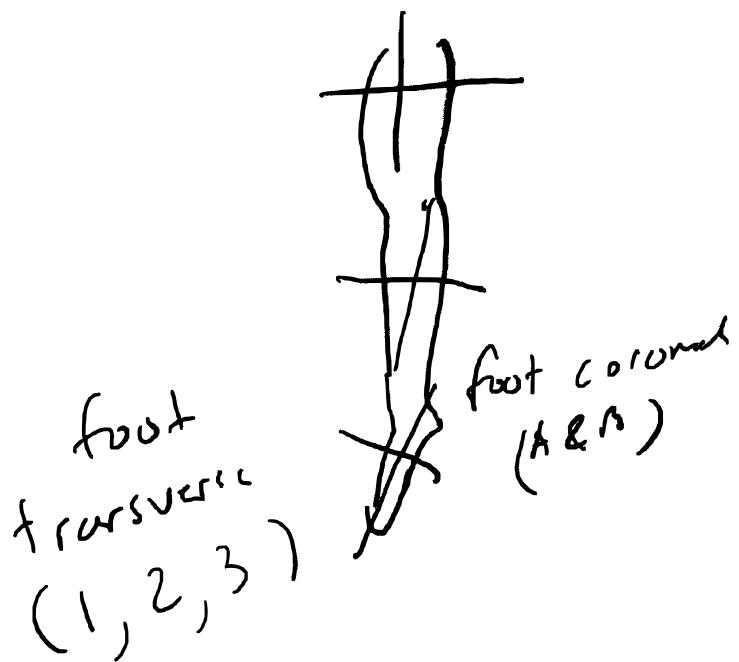
## Defining Directions, planes, axes

- posterior-anterior vs ventral dorsal
  - + anterior = front / forward travel
  - + Ventral = of the belly
  - + in most HAP's, treated synonymously
  - + non HAP, Superior/inferior = dorsal / ventral
  - \* foot dorsal associated with HAP superior, similar to embryology
  - \* Similar happens to heart & brain
- Anatomical Planes
  - + paramedian / parasagittal plane describes desidua LAP / FAP sagittal

- + functional, not geometric, median
- + coronal separates anterior/posterior OR ventral/dorsal (B) (A)
- + transverse separates superior/inferior (1) OR cranial/caudal (2) OR proximal/distal (3)
- + not easy single plane description works
- \* leg parallel looks great from planes but you forget the flip in directions



high coronal  
thigh transverse  
leg coronal  
leg transverse  
foot coronal (B)  
OR  
foot coronal transverse (1 & 2)  
(A) OR  
transverse (3)

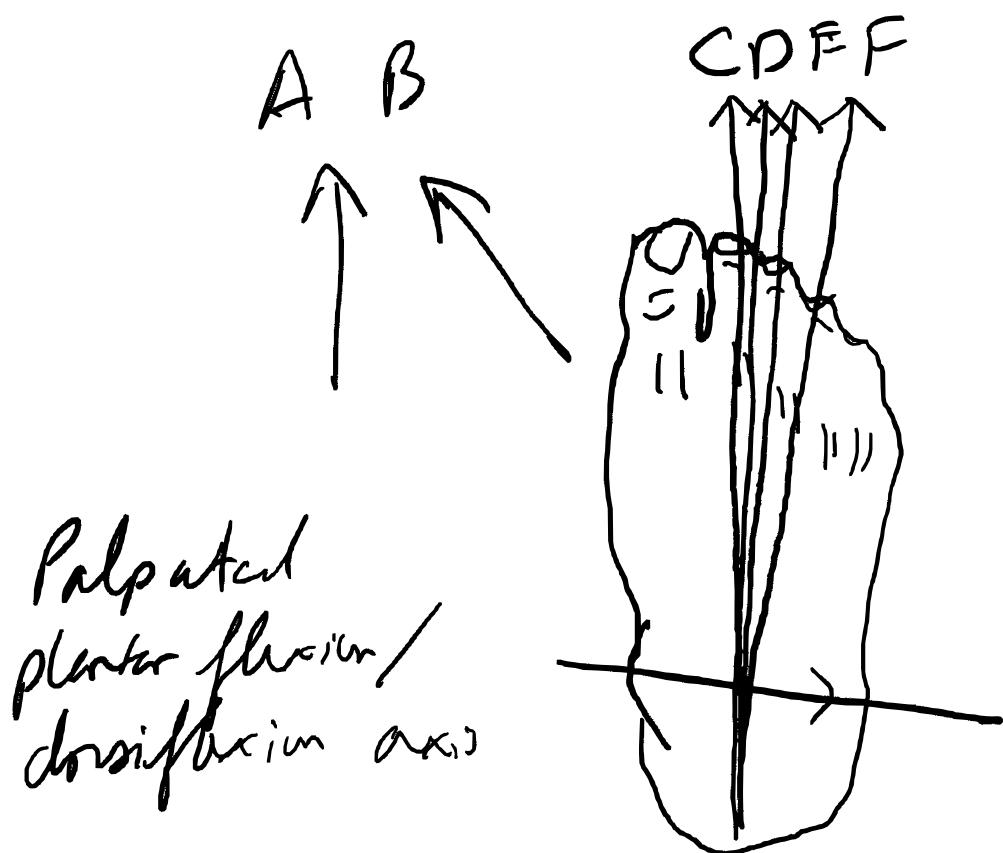


motions described often used antithetical  
definitions of motion

- Foot midline
- + definition of angle varies, creating problems
- + "valgus" = away from midline
- \* hallux valgus: which midline? which joint
- \* if to foot midline, which is often the case for foot issues, it is 1<sup>st</sup> MTP that is in valgus, not proximal phalange
- \* such a simple condition, so difficult to name

## Foot Motions

- Defining motion is done in Gray's Anatomy as such:
  - + flexion/extension  $\perp$  to sagittal plane
  - + ad/abduction  $\perp$  to coronal plane
  - + lateral/medial rotation  $\perp$  transverse
- obv. difficult because of prev. def. issues



A: sagittal plane with forward toes

B : sagittal plane with outward toes

C: middle def. that splits 2<sup>nd</sup> digit, "functional axis". Pedal dorsal interossei reflect outward 2<sup>nd</sup> digit

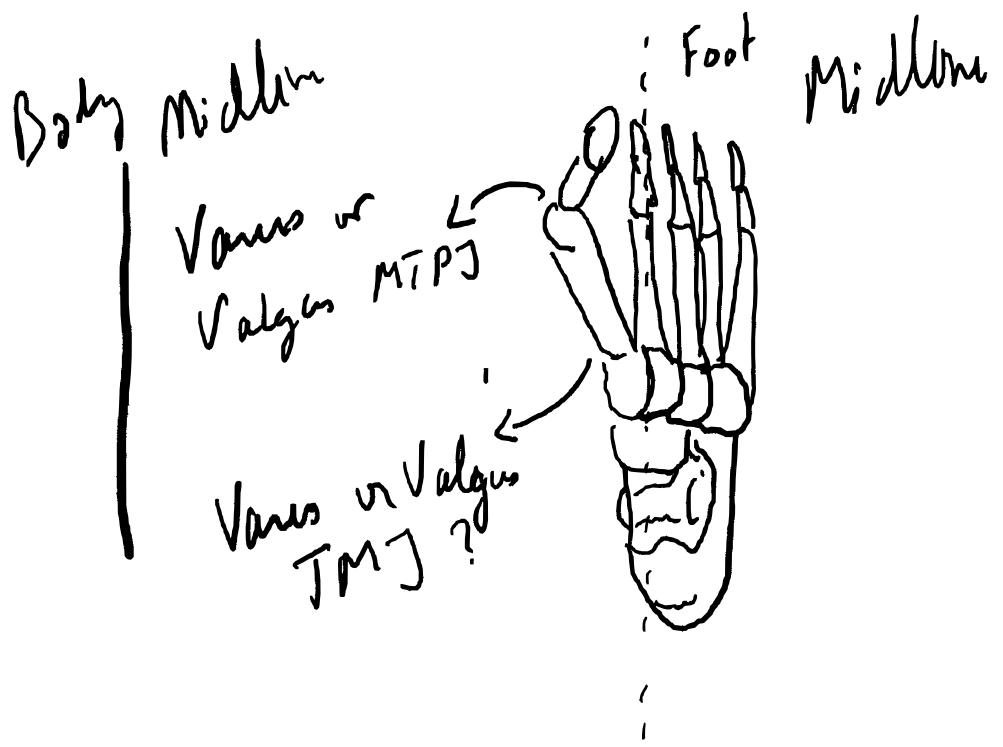
D: between 2<sup>nd</sup>/3<sup>rd</sup> in Drman's work

E: Split 3<sup>rd</sup>, most geometric split

F: bisection of malleoli defining flexion/extension axis

- Flexion/Extension

+ flexion: bring distal structures to ventral surface



- + extension: same, to dorsal surface
- + embryonic def.: along with neurological org.
- \* e.g. all ventral division nerves innervate depressors (foot/ankle flexors), all dorsal division nerves innervate elevators
- + NOT FOLLOWED IN PRACTICE
- \* when defined kinematically, always occurs about local medial/lateral axis
- \* variation amongst individuals local kinematic frame inside anatomic position
- \* NOT ALWAYS THE SAME

- Ad/Abduction vs Ext/Internal rotation
- + adduction = rotation of segment along coronal plane to midline. Ab = opposite
- + phalanges of foot ab/adduction occurs about foot midline.
  - \* in II HAP, transverse plane motion.
  - \* in II HAP, coronal
- + RHR says abduction of hallux is positive.  
Then little toe abduction is negative
- + External/Internal rotation often defined long axis of limb.
- \* Often confused if referring motion to body midline or foot midline
- \* in this book, movement about the talocalcaneal joint & subtalar = external/internal rotation for toe/out whole foot motions & complexity
- Cannot isolate muscle actions + consequences
- Plantarflexion - Dorsiflexion
- + often seems synonymous with flexion/extension

- + Triceps Sural group pull via calcaneus
  - + cascade of ligament strain due to motion of tarsal joints
  - + FHL, FHB, TP create oblique medial twist due to wrap around medial malleolus
  - + PL, PB create lateral flex moment, small
  - + Plantar flexion defined by Jenkins: action of all posterior compartment muscle in foot. Dorsi flexion = anterior compartment.
- \* foot twist part of it, particularly inward twist
- \* outward foot twist needs separate term
- + most kinematic studies assume all rotation about talocrural, and often twist occur in other, unspecified joints
- Inversion/Eversion

- + 45% published literature agree it is a rotation about the long axis so the sole faces medial/laterally
- + 21% say subtalar movement so sole of hind foot faces medial/lateral
- + anatomical plane definition makes inversion/eversion either an abduction/adduction in coronal or transversus ER/IR
- + Using II foot HAP, ab/add action thanks to tibialis posterior and peroneals
- \* However, FHL, FHB provide medial twist to
- + 2<sup>nd</sup> definition suggests separation of movement between fore and hind foot, distal vs proximal action
- + further complications include onctatarsal/phalangeal actions and then foot influence
  - \* e.g. extended hallux medial border lifts up, inversion of forefoot.

- Pronation / Supination
  - + only defined w.r.t. radius/ulna rotation
  - + abuse in foot definition
  - + most popular is a movement of subtalar joint oblique to all planes, involving all actions (dorsi/plantar flexion, eversion/inversion, adduction/abduction)
- \* definition can be cleaned up with identification of planes and assumptions
- + DOES NOT ACCURATELY DESCRIBE motion
- \* what is overpronation?
- \* equal extra motion from all actions? just one?
- \* results in impressions, not useful for outcomes
- + 2<sup>nd</sup> popular definition = inversion/eversion
- \* BASICALLY, nobody can say for sure what the hell has happened, but the foot looks different
- + Only plantaris, solitus, and gastrocnemius are extrinsic connectors to calcaneus to "twist" hindfoot
- \* few intrinsic muscles connect, very limited pivoting force capacity

- + cannot be considered normal function, must be a result of other function
- + does it even deserve to be an action??

## Terminological Implications of Mathematical Choices

- rotation matrices suffer from definition of initial planes & order of angular rotations
- X, Y, Z rotation values (Cardan / Tait - Bryan angles, subset of Euler) combined into lot of 6 diff. sequences
- kinematic impact of order has impact
- + often values interpreted in isolation without knowing order
- + Woltring suggests "attitude" vector, independent of sequence for rotations.
- + how adoption
- great lack of mathematical understanding and validity

# Effect of foot orientation based on rotation expression

Rotation Axis	Anterior foot orientation	Lateral foot orientation
X (radial/lateral)	15°	2°
Y (posterior/anterior)	18°	23°
Z (inferior/Superior)	5°	40°

XYZ  
 decompr            rotation 33°      

new XY Z  
decomp

Rotation Matrix :

$$\begin{bmatrix} 0.66 & -0.56 & 0.50 \\ 0.24 & 0.61 & -0.30 \\ -0.14 & 0.56 & 0.81 \end{bmatrix}$$

Square	X	Y	Z
X Y Z	20	30	40.0
X Z Y	42.8	37.0	33.8
Y X Z	17.2	31.6	50.3
Y Z X	25.9	11.9	47.3
Z X Y	34.3	9.8	42.4
Z Y X	34.3	8.1	47.9
Attitude	29.2	21.8	43.9

## Conclusion

- communication is hard
- no serious standard
- publishers glossary?
  - + acceptable eponyms
- + limb segment names (Lag, Shank, Halker, etc)
- + anatomical positioning of foot, foot + leg
- + plane definitions
- + movement definition, whole foot or joint sp.
- + rot. sequence. Either universal or joint spec.