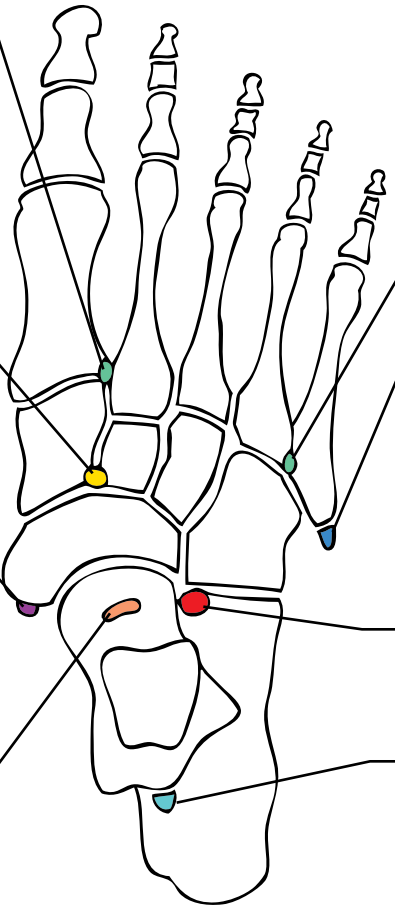
Accessory Bones
Dorsal View

Medial **Distal** **Lateral**

There are several frequently occurring accessory bones in the foot. It is important to be able to distinguish between an accessory bone and a fracture.

Accessory sesamoids are also found in the foot. An accessory sesamoid is located within a muscle tendon or joint capsule.



Os Intermetatarseum I
- an accessory bone located between the bases of 2 adjacent metatarsal bones
- most common are os intermetatarseum I (between the bases of the 1st and 2nd metatarsal bones) and os intermetatarseum IV (between the bases of the 4th and 5th metatarsal bones)

Os Intercuneiforme
- an accessory bone located dorsally between adjacent cuneiforms
- usually between the medial and intermediate cuneiform bones; os intercuneiforme I

Os Tibiale Externum
- an accessory sesamoid located within the tibialis posterior tendon at the plantar aspect of the navicular tuberosity
- best viewed on a lateral oblique radiograph of the foot
- generally also seen on a lateral radiograph of the foot

Os Supratalare
- an accessory bone located dorsal to the talar neck

Accessory Navicular
- an accessory bone located near the navicular tuberosity, usually large and often a visible prominence clinically
- may appear to articulate with the navicular tuberosity or as if it was a secondary center of ossification
- easily viewed on anteroposterior, lateral and lateral oblique radiographic views of the foot

Os Intermetatarseum V

Os Vesalianum
- an accessory sesamoid located within the tendon of peroneus brevis at its insertion on the 5th metatarsal tuberosity
- often is a secondary ossification center of the 5th metatarsal tuberosity that did not fuse
- most easily viewed on anteroposterior or medial oblique radiographic views of the foot

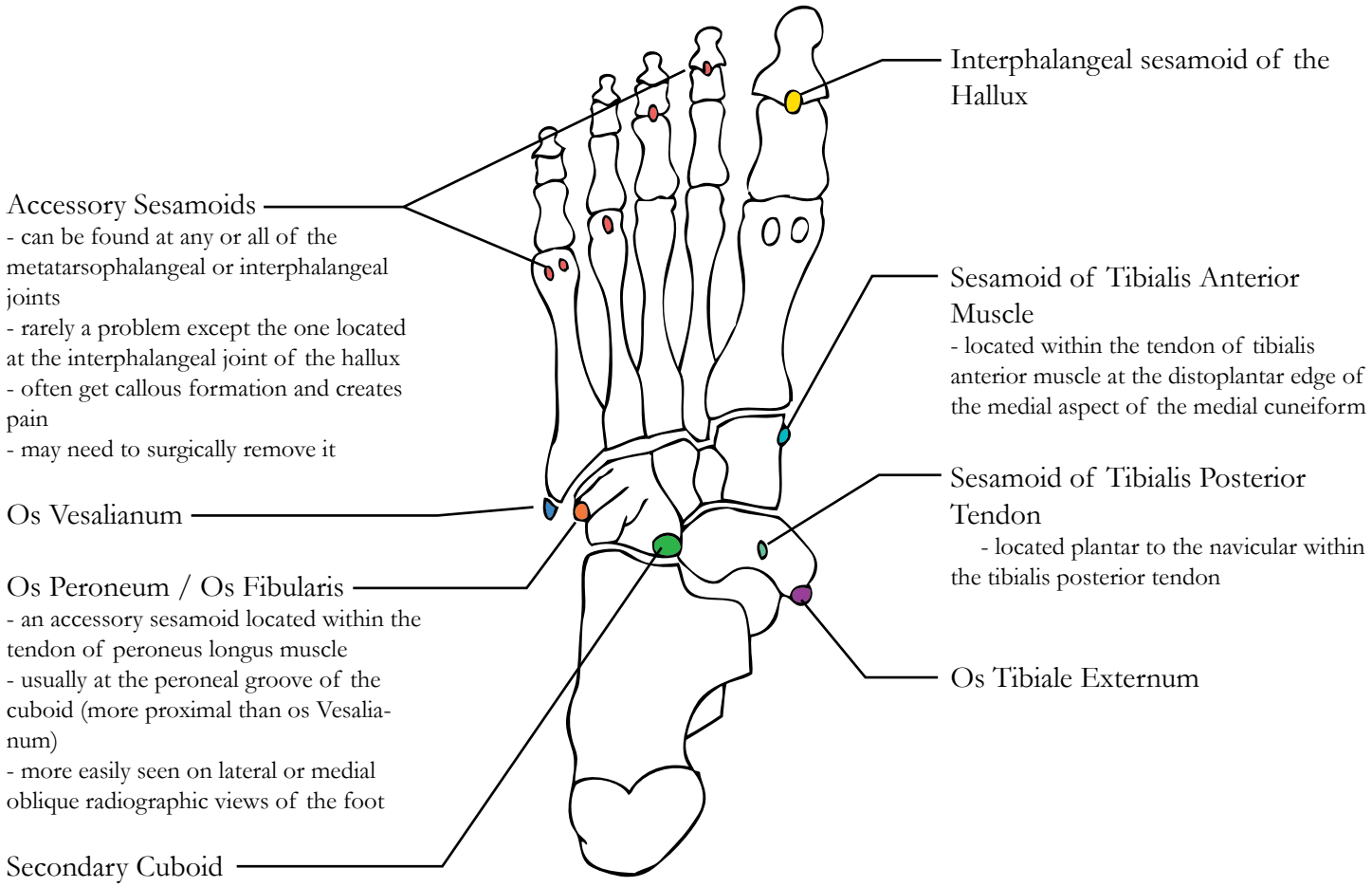
Secondary Calcaneus
- an accessory bone located dorsally at the anterior process of the calcaneus

Os Trigonum
- an accessory bone located at the posterior aspect of the talus
- often a secondary ossification center of the lateral tubercle of the talar posterior process that did not fuse
- most easily viewed on a lateral view radiograph of the foot or ankle

Proximal

Accessory Bones
Plantar View

Lateral **Distal** **Medial**



Accessory Sesamoids
- can be found at any or all of the metatarsophalangeal or interphalangeal joints
- rarely a problem except the one located at the interphalangeal joint of the hallux
- often get callous formation and creates pain
- may need to surgically remove it

Os Vesalianum

Os Peroneum / Os Fibularis
- an accessory sesamoid located within the tendon of peroneus longus muscle
- usually at the peroneal groove of the cuboid (more proximal than os Vesalianum)
- more easily seen on lateral or medial oblique radiographic views of the foot

Secondary Cuboid
- an accessory bone located plantarly at the calcaneal process of the cuboid

Interphalangeal sesamoid of the Hallux

Sesamoid of Tibialis Anterior Muscle
- located within the tendon of tibialis anterior muscle at the distoplantar edge of the medial aspect of the medial cuneiform

Sesamoid of Tibialis Posterior Tendon
- located plantar to the navicular within the tibialis posterior tendon

Os Tibiale Externum

Proximal

Limb Development
Embryonic Period (2 to 8 weeks in utero)
- Period of rapid development

Limb Buds
- Limb buds develop in a proximal to distal manner. The upper limb buds precede the lower limb buds in all areas of development by several days. This corresponds to the major development of the embryo which is from cephalad / proximal / superior to caudad / distal / inferior.

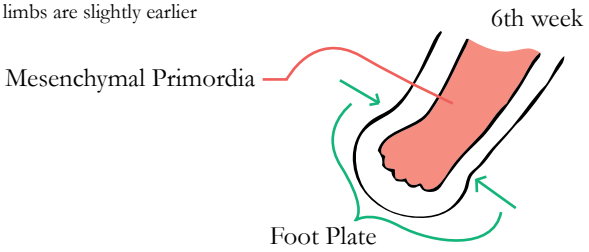
4th Intrauterine Week
Limb Buds Appear
- upper and lower limb buds appear on the ventrolateral aspect of the embryo
- develop initially in a lateral direction
- upper limb buds precede lower limb buds
- early and late 4th week, respectively
- small flipper-like projections
- pre-axial border is cephalad and post-axial border is caudad
- small masses of mesenchyme derived from mesoderm covered by ectoderm
- mesenchyme contains the developmental information or "blueprints" for the limb

Apical Ectodermal Ridge
- a longitudinal ridge of tissue on the distal end of each limb bud
- induces continued development of the limb (causes the limb to continue forming) by interaction with the mesenchyme in the limb buds
- if defective, limb may not develop or may develop partially

6th Intrauterine Week
Elbow, Wrist, Knee and Ankle become recognizable
- upper limb regions are slightly earlier limb development, embryonic development, 6th week, con't

Digital Rays of the Hand Plate Develop
- condensations of mesenchyme which are ridges that become digits
- each digital ray retains part of the apical ectodermal ridge which induces further development
- pollex (thumb) is at the pre-axial border

Limbs Extend Ventrally (Adduct)
- move from a more lateral position to a more anterior position late in this week
- hands and feet move to near each other at the ventral aspect
- upper limbs are slightly earlier

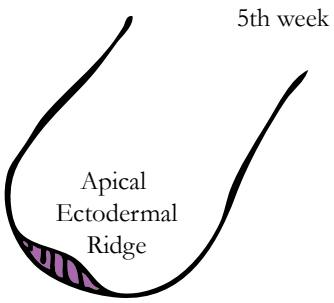


8th Intrauterine Week
- limb rotations continue through the 8th week

Fetal Position is attained
- occurs by the end of the eighth week
- limb rotations continue through the 8th week and end in the fetal position
- planta of feet approximate each other
- pre-axial (tibial) borders of leg and foot are cephalad and post-axial (fibular) borders are caudad
- lower limb is externally rotated and foot is plantar flexed
- pedal digits are splayed

Digits become free
- separated from each other as the mesenchyme between them degenerates
- still occurs sooner in the hand

5th Intrauterine Week
Hand and Foot Plates Develop
- are flattened, paddle-shaped areas at the distal end of the limb buds which are marked by a proximal constriction
- apical ectodermal ridge is present at end of each hand/foot plate
- hand plate develops slightly earlier

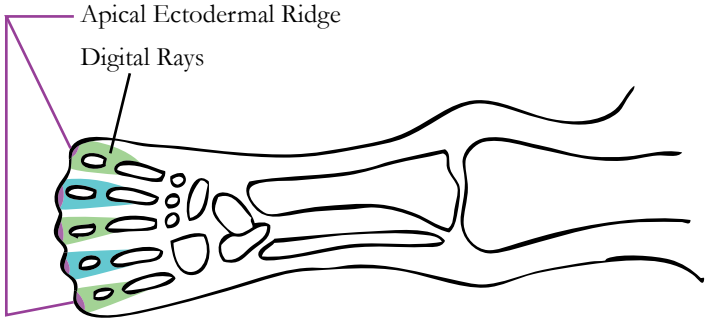


7th Intrauterine Week
Digital Rays of the Foot Plate Develop
- condensations of mesenchyme which are ridges that become toes
- each digital ray retains part of the apical ectodermal ridge which induces further development
- hallux is at the pre-axial border

Limb Rotation Begins
- knee and elbow both initially face laterally
- upper and lower limbs rotate in opposite directions
- upper limbs are slightly earlier

Upper Limb Rotation
- rotates laterally / externally so that the elbow moves from a laterally directed position to an inferiorly directed or caudal position

Lower Limb Rotation
- rotates medially / internally so that the knee moves from a laterally directed position to a superiorly directed or cephalic position



Limb Development

B. **Skeletal Formation**
- begins in the 4th to 5th intrauterine week
- bones develop in mesenchyme or cartilage
- intramembranous ossification occurs in mesenchyme; tufts of distal phalanges
- intracartilaginous ossification occurs in cartilage after chondrification
- also occurs in a proximal to distal fashion and as the limb bud is forming
- continues throughout intrauterine development into adulthood when the last skeletal elements fuse

1. **Mesenchymal Stage**
- apical ectodermal ridge promotes growth and differentiation of the limb bud mesenchyme
- the mesenchymal models of the limb bones form

a. *Mesenchymal Primordia*
- condensations of mesenchyme in the limb bud
- begins as a solid mass of tissue in the center of the developing limb, then differentiates
- will become the bones and joints of the limb

2. **Cartilaginous Stage**
- the mesenchymal models of most limb bones undergo chondrification to become the cartilage templates of the bones
- navicular is the last tarsal bone to condrify
- order is different than for ossification

a. *Joint Formation Begins*
- in the areas between the newly chondrified bone models
- appear as areas where the mesenchymal primordia did not differentiate
- differentiation of this portion of the mesenchymal primordia depends upon the type of joint being formed

i. Fibrous Joint / Synfibrosis
- becomes collagen

ii. Cartilaginous Joint / Synchondrosis
- becomes modified hyaline cartilage

iii. Synovial Joint
- becomes trilaminar (an intermediate zone between 2 dense zones)
- the model for the joint space and the epiphyses which will form the various structures

3. **Osseous Stage**
- the chondrified bone models begin ossification at the area of the primary centers
- this is the point when bones begin to show up on radiographs
- many morphologic changes occur as the bones continue to ossify and positional changes occur

C. **Muscular Formation and Innervation**
- both occur in a proximal to distal manner

1. **Limb Muscles Masses Develop**
   - from the mesenchyme around the developing bones
   - during the 4th through 7th intrauterine weeks as the limbs are forming
   - muscle masses enlarge by mitosis (adding new cells) until the mid-fetal period (near 22 weeks gestation) after which the fibers only increase in size
   - 2 muscle masses per limb

   a. *Ventral Mass / Flexor Mass*
      - located ventrally / anteriorly before limb rotation in all 4 limbs
      - located anteriorly in the upper limb after limb rotation (anatomic position)
      - located posteriorly in the lower limb after limb rotation; in the lower limb girdle, it is still anterior

   b. *Dorsal Mass / Extensor Mass*
      - located dorsally / posteriorly before limb rotation in all 4 limbs
      - located posteriorly in the upper limb after limb rotation
      - located anteriorly in the lower limb after limb rotation; in the lower limb girdle, it is still posterior

2. **Innervation of the Limbs**
   - begins near 4 weeks gestation, prior to limb rotations; so dermatomes spiral
   - nerves arise from ectoderm
   - ventral rami from the spinal cord segments adjacent to the limb buds grow into the limb bud mesenchyme and migrate along the developing limbs
   - T-12 through S-4 for the lower limb
   - as a muscle group becomes discernible, the nerves send branches to supply them

Limb Development
Vascular Supply

- large vessels of the embryo begin as capillary plexuses
- blood flow causes vessels to enlarge or degenerate
- causes constant change
- supply and demand system can cause anomalies
- adult pattern is reached by the end of the 8th intrauterine week

Axis Artery

- begins as a capillary plexus from the umbilical artery
- main supply to the developing limb
- passes along dorsal (posterior) aspect of the developing limb and forms a plantar network
- several branches pass into the mesenchymal skeleton, one forms a dorsal network

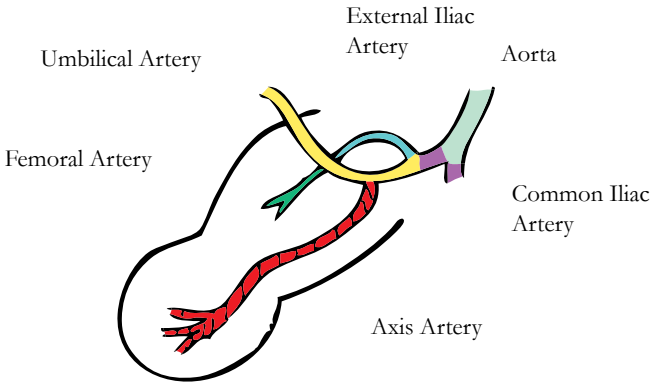
Remnants of the Axis Artery

- in the adult
  - internal iliac artery
  - popliteal artery
  - peroneal artery

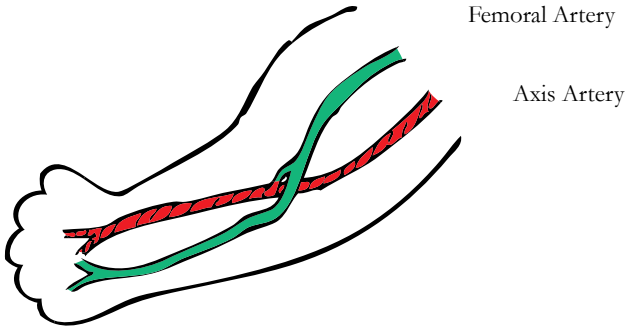
Femoral Artery

- an extension of the newly formed external iliac artery
- passes down the anterior aspect of the lower limb and ends on the dorsum of the foot
- many points of communication with axis artery

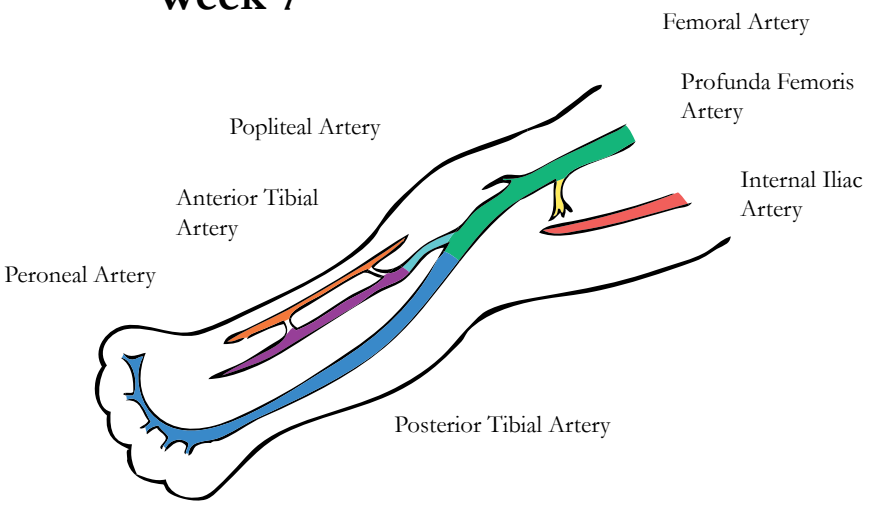
Week 5



Week 6-7



Week 7



FETAL DEVELOPMENT; 9 weeks in utero to birth

A. **Primary Centers of Ossification**
- continue to appear

B. **Circulation Pattern Changes**
- arteries become larger to meet the demand

C. **Nail Formation**
- nails of the toes begin forming in the 9th fetal or intrauterine week and are completely formed by the 12th fetal week
- hands still precede feet

III. **INFANCY; birth to 1.5 or 2 years**
- lower limb positional (soft tissue) changes occur
- hips begin internally rotating, in part due to muscular control
- overall development is monitored by motor milestones
  - ie: rolling, sitting, standing, walking, talking

IV. **CHILDHOOD; 1.5 or 2 years to 13 years**
- significant changes in lower limb positions (due to soft tissue control) occur until 6 years of age
- torsional changes in the bones occur until about 13 years of age

	birth	**6 years**
hips	60 degrees external	10 degrees external

- internally rotating, many soft tissue changes, some osseous changes in the femoral head and neck

knees	external	on frontal plane

- due to hip rotation initially, and then femoral torsion (angle of declination)

ankles	0 degrees	~15 degrees external

- (tibiofibular torsion) knee with respect to the ankle, due to external tibial torsion

heel	7 degrees everted	vertical

- vertical bisection of the heel with respect to the floor
- due to torsional changes in the head and neck of the talus as well as to increased ossification of the pedal bones

angle of gait	45 degrees abducted	~15 degrees abducted

- foot bisection with respect to the line of progression
- due to hip rotations, femoral torsion, tibial torsion and talar torsion

base of gait	shoulder width	1.5 to 3 inches

- distance between the medial malleoli
- due to higher center of gravity in infancy;
  adult - just anterior to S-2 vertebra
  infant - near the umbilicus (T-12 - L-2)

V. **DISTURBANCES in limb development**
- can occur at any time during the development of the limbs, may be hereditary or environmental

A. **Failure to Differentiate**

1. **Synostosis**
   - failure of mesenchymal primordia to differentiate
   - several possibilities in the foot
   - most frequent talus and calcaneus
   - not treated unless symptomatic
   - may be treated conservatively or surgically

2. **Syndactyly**

   a. *Cutaneous Syndactyly*
      - failure of mesenchyme between digits to degenerate
      - causes webbed digits, complete or partial
      - surgically separated if problematic
      - usually a problem in the hand as fingers have much independent motion and are more used
      - usually a cosmetic problem only for feet (little functional problem)

   b. *Osseous Syndactyly*
      - failure of mesenchymal primordia to differentiate
      - notches between digital rays do not form

B. **Failure to Form**

1. **Amelia**
   - low incidence
   - failure of limb to develop
   - may be one or more limbs
   - absence of all limbs seen most often when pregnant women took thalidomide for nausea; no longer used for this, but is being used for parkinson's disease
   - upper limb involvement, may use prostheses
   - lower limb involvement, usually use prostheses

2. **Meromelia**
   - low incidence; old term hemimelia
   - limb(s) partially absent
   - can occur at any level from digits to parts of limbs
   - upper limb involvement, may use prostheses
   - lower limb involvement, usually use prostheses

   a. *Congenital Absence of Bones*
      - usually are genetic factors

      i. Fifth Metatarsal
         - low incidence

- often no functional problems

ii. Fibula
- low incidence
- problem with ankle stability
- could probably use a knee-ankle-foot orthosis or fuse the ankle joint or perform a below-the-knee amputation

b. *Cleft Hand / Cleft Foot (Lobster Claw Hand/Foot)*
- low incidence; old term ectrodactyly
- usually surgically corrected due to associated functional problems
- very difficult surgery, often done in stages (2-3 separate surgeries)
  - depends upon which bones or other structures are absent

C. **Duplication of Parts**
- often hereditary conditions

1. **Polydactyly**
- formation of extra digits/parts of digits
- more common in cultures with less genetic diversity (limited number of people in the community with no outside marriages)
- usually surgically corrected
  - even for feet is a problem due to fit of shoes
- may also have extra metatarsal bones (polymetatarsia)
- in upper limb, usually medial or lateral (pre-axial or post-axial)
- in lower limb, usually lateral (post-axial)

D. **Enlargement of Parts**

1. **Macrodactyly**
- enlargement of a digit or digits
- possibly due to vascular excess in a localized area (supply and demand failed)