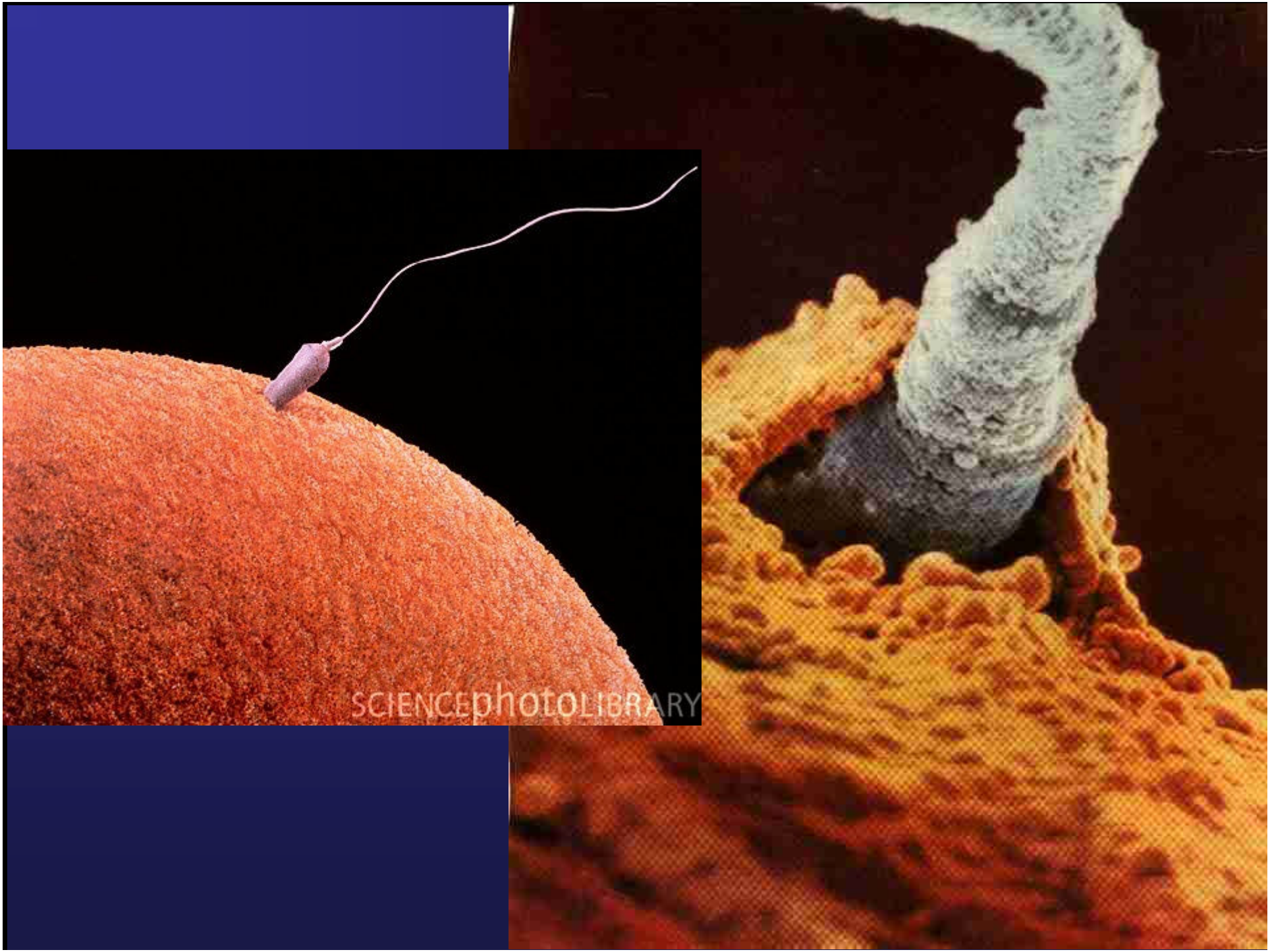
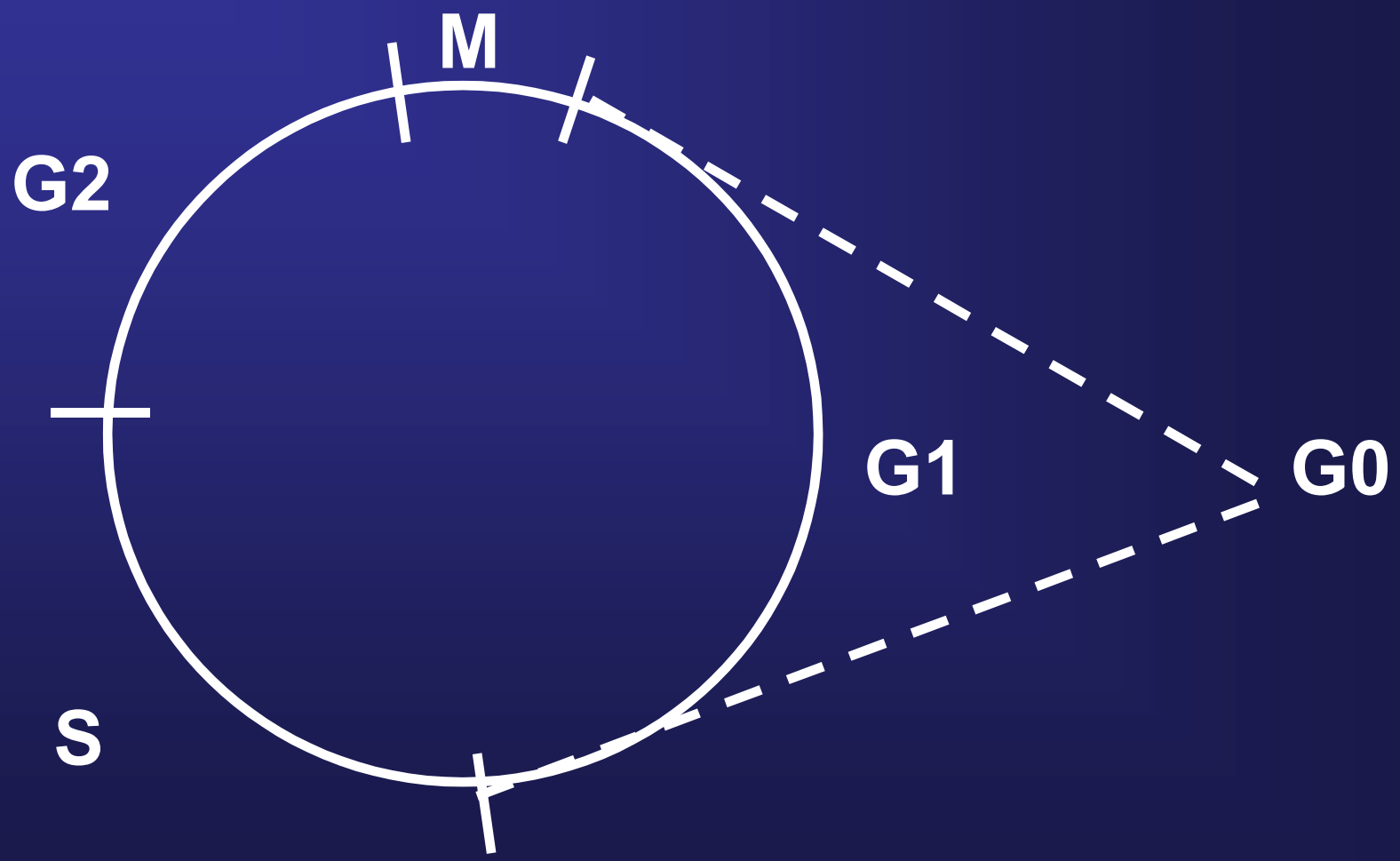
Growth and Development

Objectives

- Be able to:
  - Discuss the cell cycle
  - Discuss the growth of muscle pre- and postnatal
  - Describe the two types of growth
  - Discuss how genetics, nutrition, hormones, etc affect growth


SCIENCEphotoLIBRARY

The Cell Cycle



Cell Cycle

- G1 (Gap 1)
  - 3 to 12 hours in length
  - Respond to cues from the environment
  - External cues – Growth factors that signal the cell to stay in G1 or continue to through the cell cycle
  - Examples of mitogens: Fibroblast growth factors, Insulin-like growth factors I & II, testosterone, & Transforming growth factors
  - Or remain in G1 phase
- S-phase
  - 4.1 to 4.3 hours in length
  - DNA replication

The Cell Cycle

- G2 (Gap 2)
  - 2.4 to 2.5 hours
  - Intracellular structure remodels itself to prepare for the physical division of the cell
- M-phase (mitosis)
  - Shortest 0.8 hours
  - Cell splits and returns to G1
- G0
  - Cells become quiescent
  - Satellite Cells

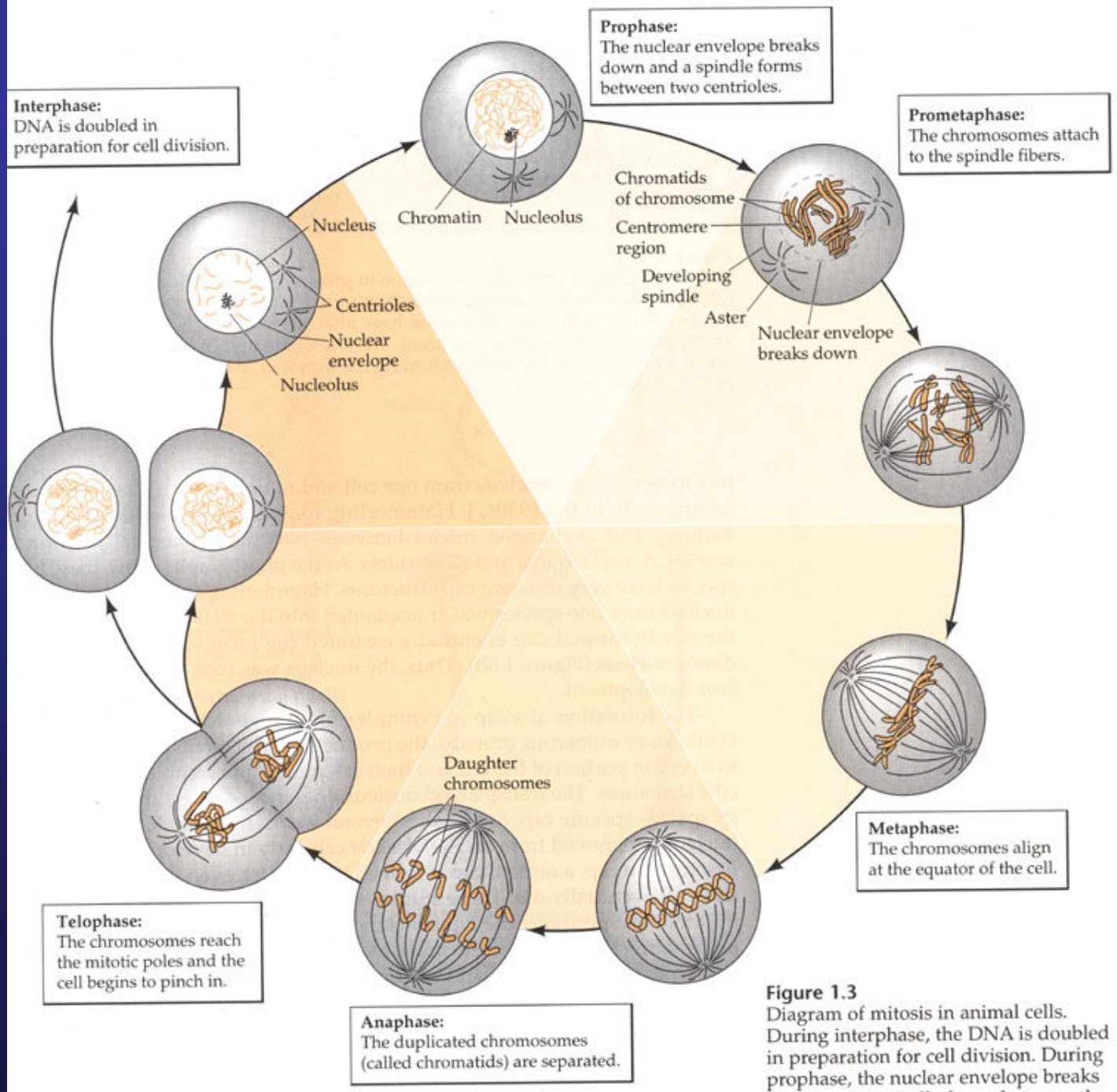
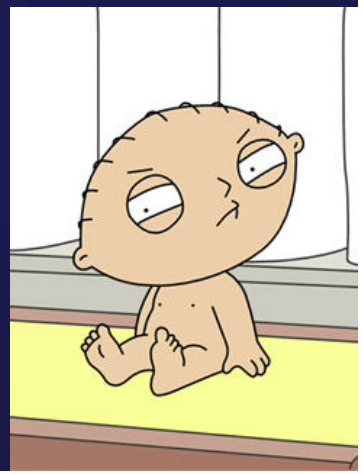
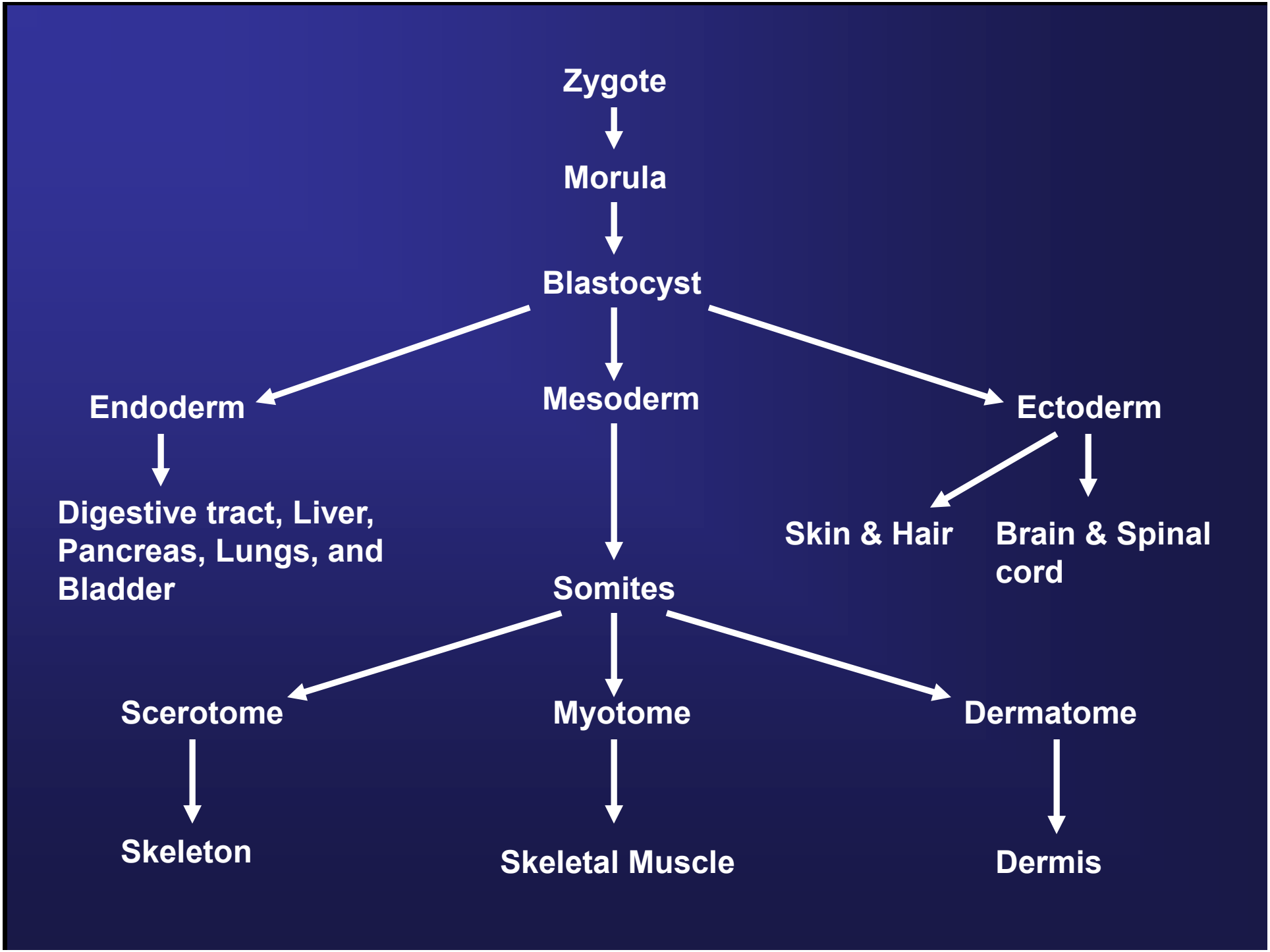


Figure 1.3
Diagram of mitosis in animal cells. During interphase, the DNA is doubled in preparation for cell division. During prophase, the nuclear envelope breaks down and a spindle forms between the

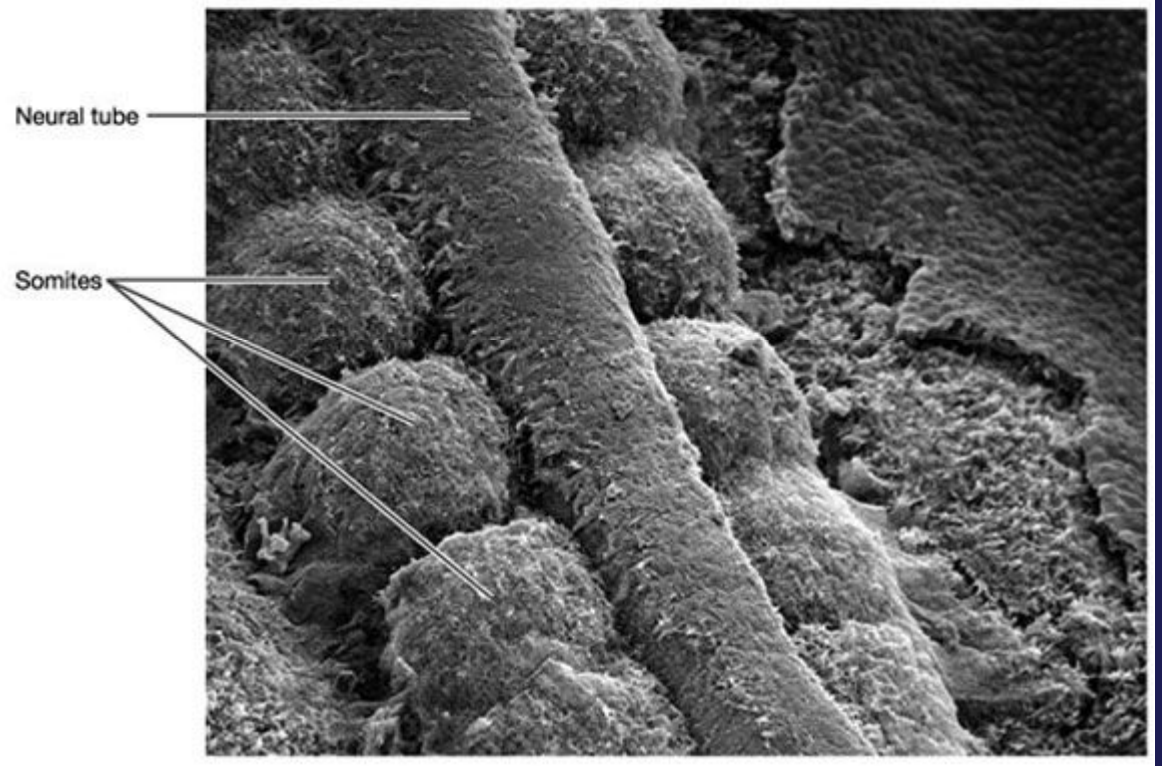
Prenatal Development

- Ovum Phase
  - Shortest phase (11 to 14 d)
  - Cleavage – massive increase in cell number & decrease in cell size
  - Increase in DNA, with no protein synthesis
  - Fertilization to implantation
- Embryonic Phase
  - Formation of the ectoderm, mesoderm, & endoderm
  - Starts of take form
- Fetal Phase
  - Starts to look like something
  - Organ and tissue development
  - Grow, grow, grow




Zygote
Morula
Blastocyst
Endoderm
Mesoderm
Ectoderm
Digestive tract, Liver, Pancreas, Lungs, and Bladder
Skin & Hair
Brain & Spinal cord
Somites
Scerotome
Myotome
Dermatome
Skeleton
Skeletal Muscle
Dermis

SOMITES: segmented mesodermal tissue along neural tube, which gives rise to vertebral column, voluntary muscle, connective tissue, skin.



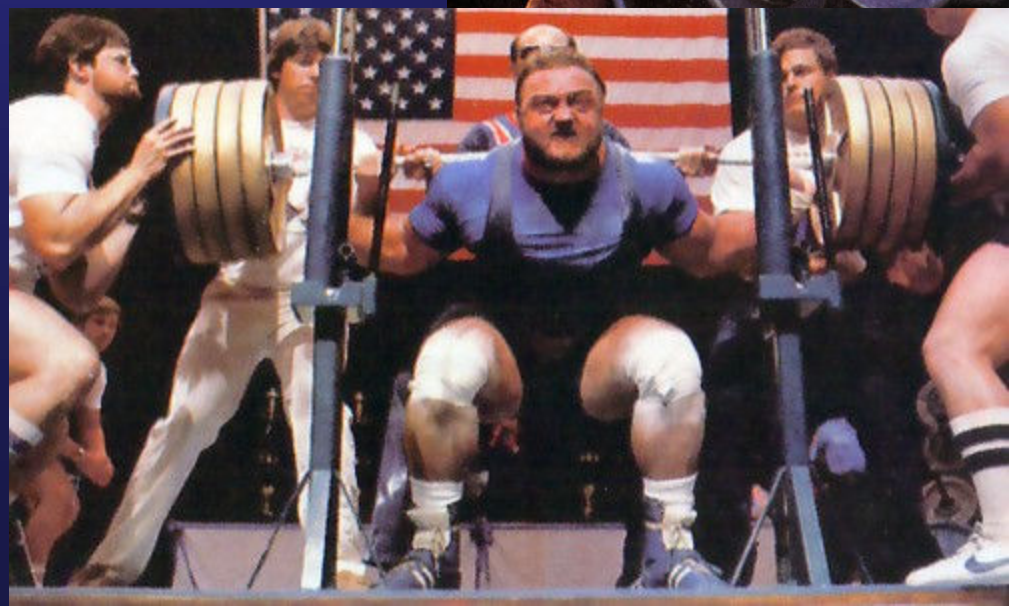
What's the difference?

Gestation = 19 – 21 days

Gestation = 22 months (660 d)

Myogenesis

- Myo = Muscle
- Genesis = Coming to being
- Two types of growth
  - Hypertrophy – increase in cell size
  - Hyperplasia – increase in cell number

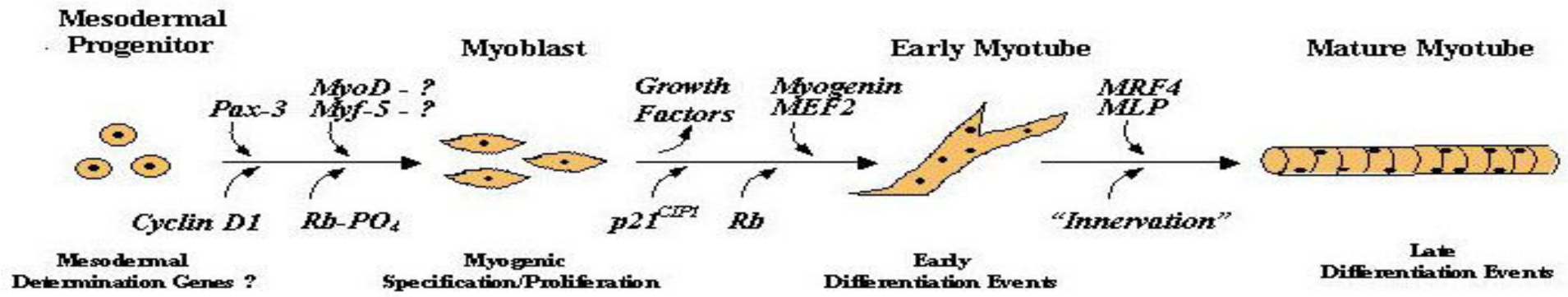


Muscle Cells

- Cells that are designed for a specific type of tissue or structure are called *Determined* or *Committed* cells
- Myoblasts (muscle regulatory genes)
  - Capable of making new myoblasts
  - DO NOT CONTAIN CONTRACTILE PROTEINS

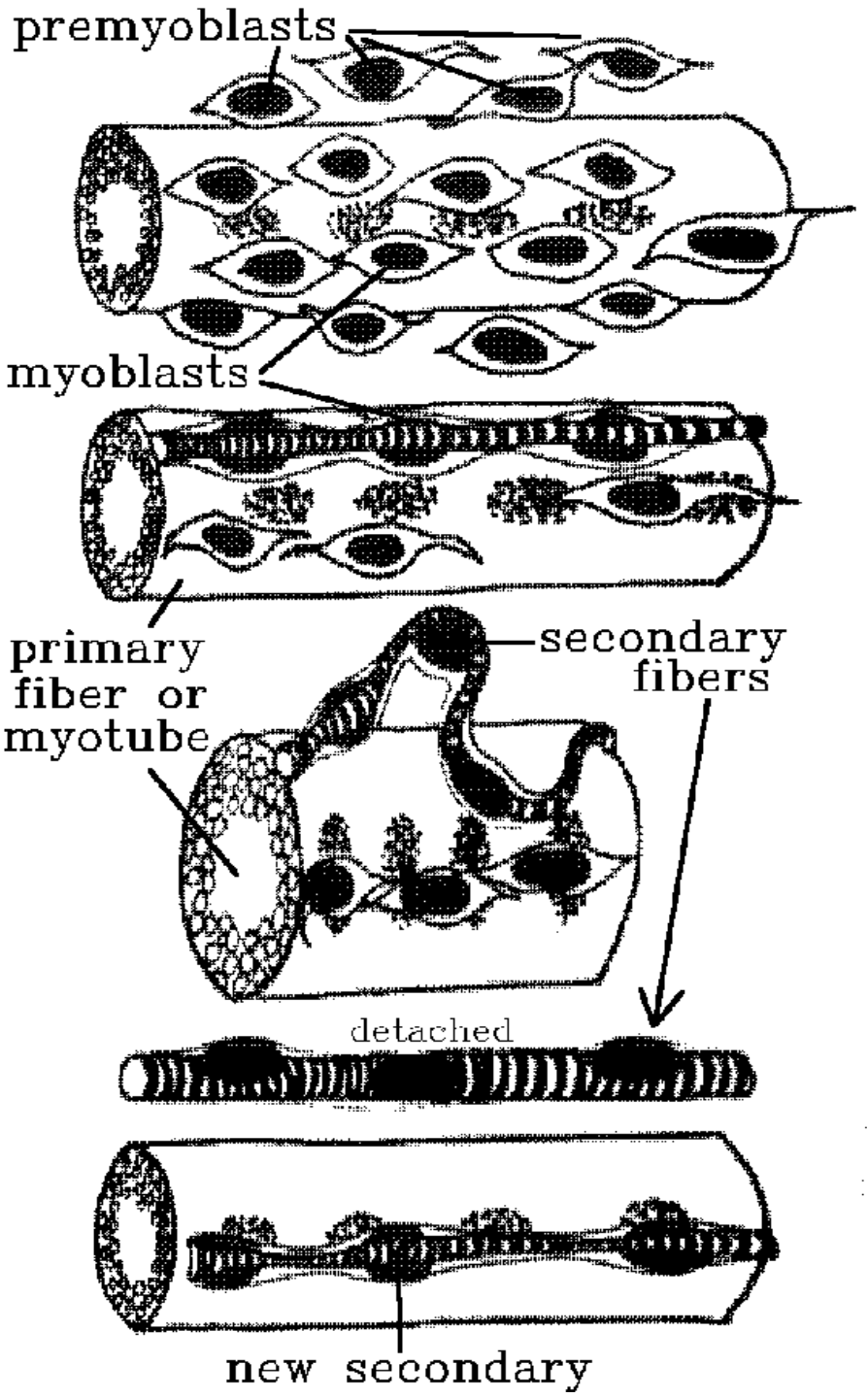
Muscle Cells

- Differentiate
- Stop dividing
- Align
- Membranes fuse to form an immature muscle fiber
  - Myotube



Myotube

- Scaffolding for the formation of muscle fibers
- Myoblasts will align themselves along the Primary Myotube
  - More Primary mytubes, more muscle
- Fuse together to form Secondary Myotubes
- Innervation occurs
- Splinter away
- Forming myofibers

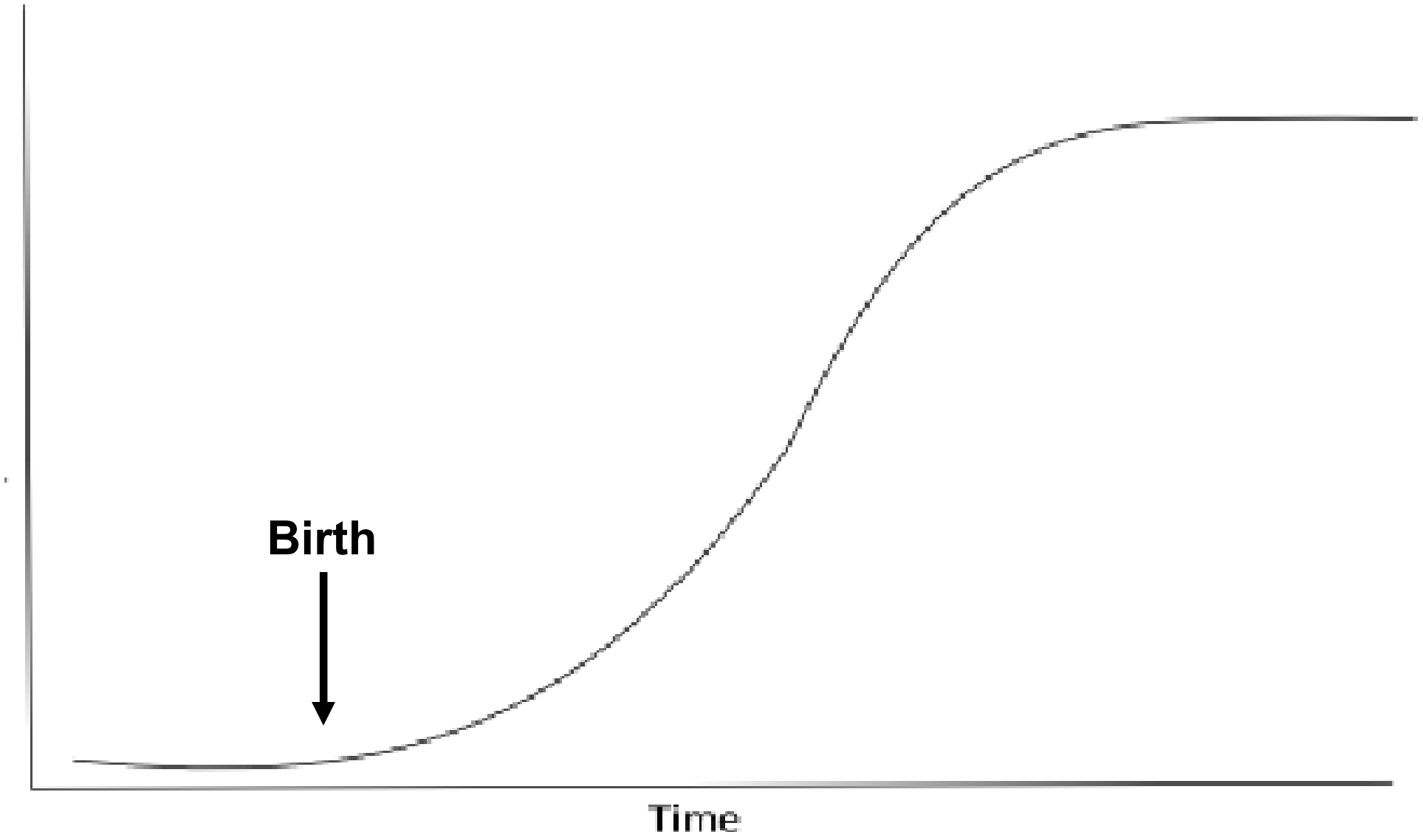


Myogenesis

- All of this occurs during the first 2/3 of prenatal development
- Pigs = First 90 to 95 d post conception
- After remains unchanged for the rest of your life
- This means you have the same number of muscle fibers now as when you were born!

How do I get from here to there?

Growth



Growth

- Determinate Growth
  - Mammals
  - Grow to a given size (mature size)
- Indeterminate Growth
  - Fish
  - No predetermined size
  - Will grow to available nutrients and environment
  - Can create new muscle fibers after hatching

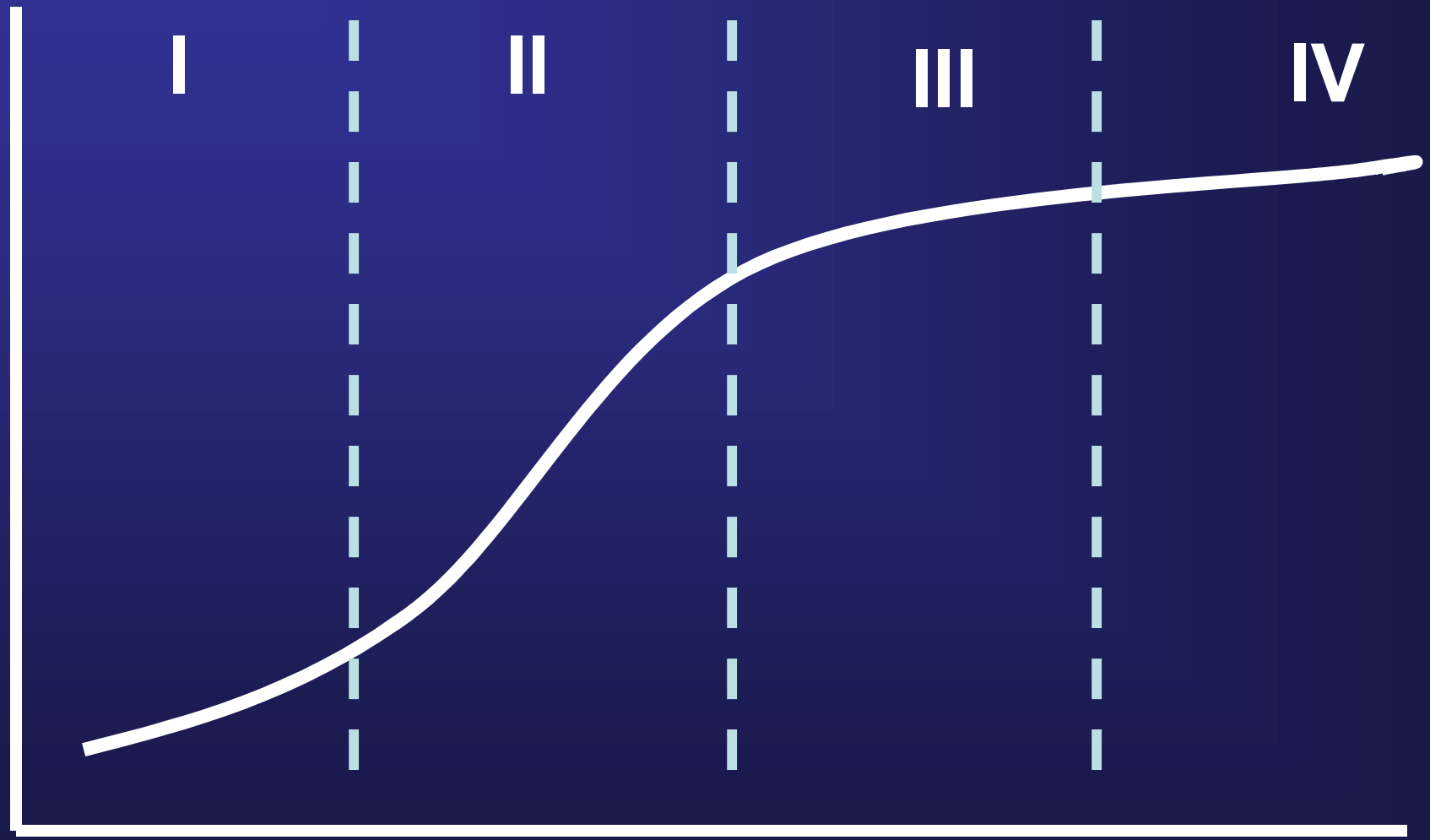
Postnatal Growth

- Phase I
  - 15 to 20% of total growth
  - Slow growth of all tissues
  - Organs > Bone > Muscle
- Phase II
  - ~75% of total growth
  - Organ & bone growth complete
  - Muscle hitting maximal growth
  - Fat accumulates slowly

Postnatal Growth

- **Phase III**
  - 80 to 90% of growth complete
  - 80 to 90% of muscle is deposited
  - Rapid accumulation of fat
- **Phase IV**
  - 90 to 95% of additional growth is fat
  - 5 to 10% of gain is muscle

Growth Phases



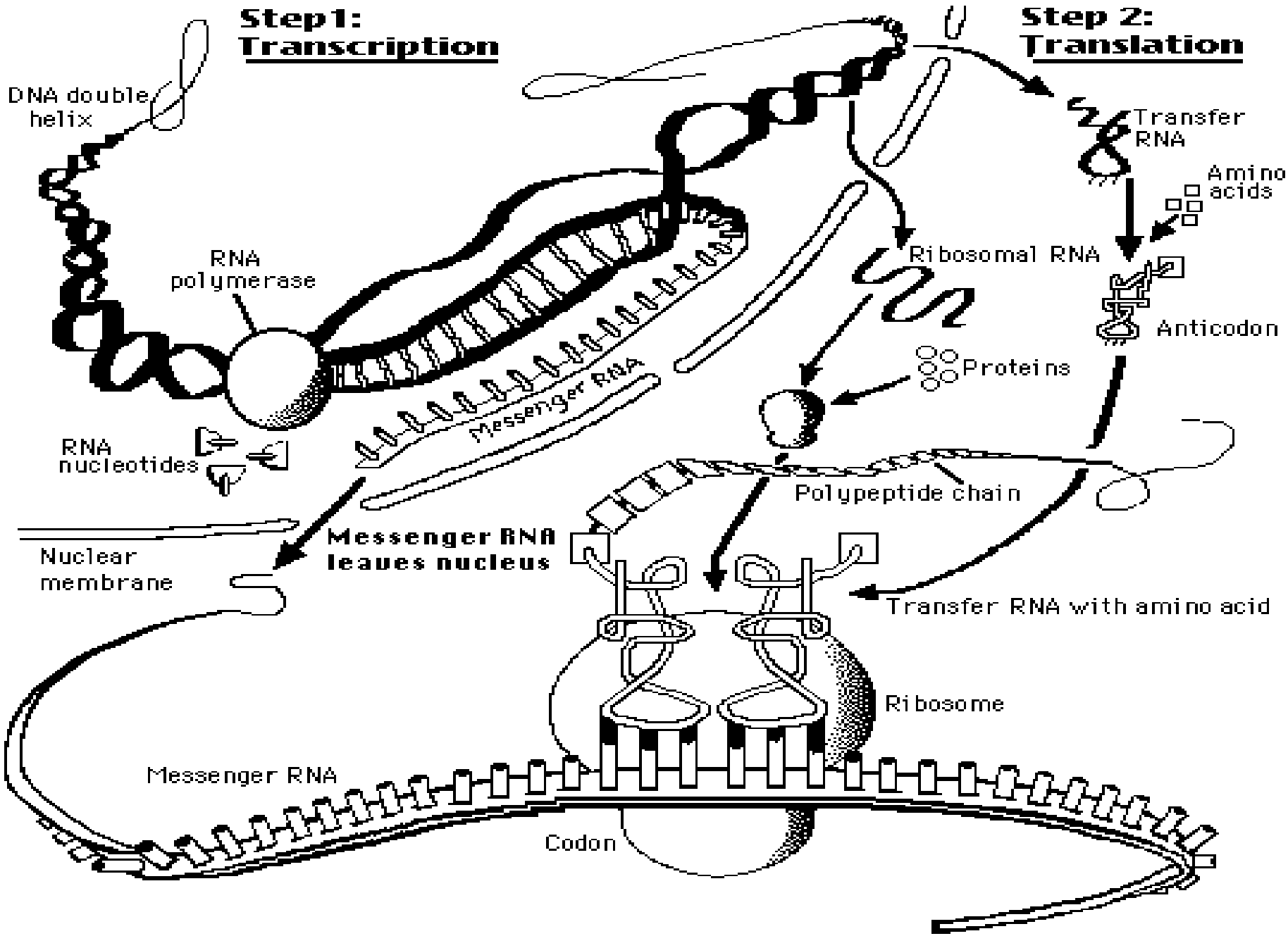
Muscle Growth

- Increase in Muscle Fiber size
- Radial and Longitudinal
- Radial
  - Fibers will split to form new myofibrils
  - Work – induced hypertrophy or Exercise – induced hypertrophy
  - 10 to 20 µm to 50 – 80 µm

Muscle Growth

- **Longitudinal Muscle Growth**
  - **Stretch – induced hypertrophy**
  - **Bone growth**
  - **Growth occurs at the ends of the muscle not in the middle**
  - **Add Sarcomeres (talk about what these are at a later date)**
- **What else do we need to make muscles grow big and strong?**

PROTEIN SYNTHESIS



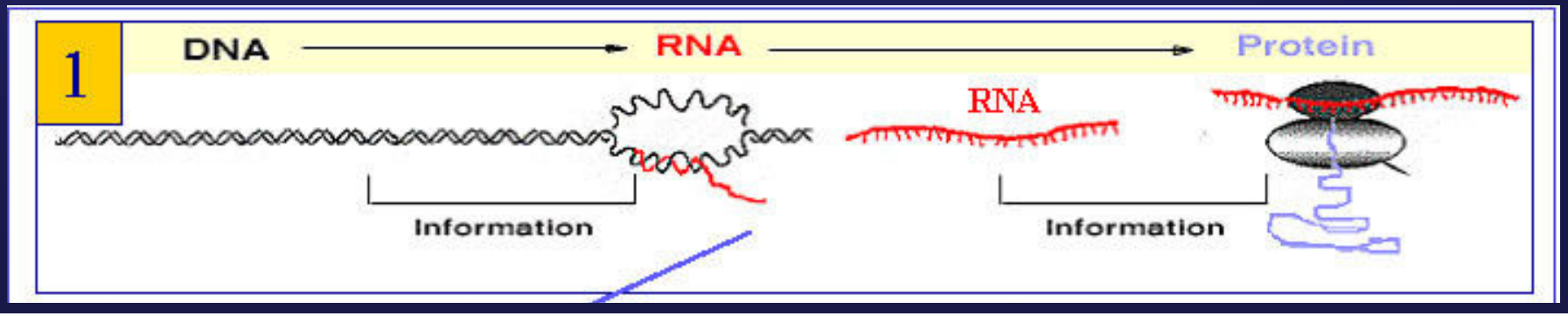
Protein Synthesis and Degradation

- **Protein Turnover = process of building protein, the replacing it with newly synthesized protein**
- **Protein Accretion = more synthesis than degradation**
- **Atrophy = more degradation than synthesis**

http://www.youtube.com/watch?v=983Ihh20rGY

Protein Synthesis

- Protein synthesis = turning amino acids into protein
- Involves:
  - Transcribing DNA into Messenger RNA
  - Move mRNA out of the nucleus into the cytoplasm
  - Translate mRNA into Protein
  - Positioning of new protein to specific location



Protein Degradation

- Protein degradation = aka proteolysis, breaking down proteins into peptides and amino acids
- How?
  - Lysosomal System
    - Responsible for 25 – 30%
    - Sarcoplasmic Proteins
  - Calpain System
    - Majority of the Protein Degradation
    - Postmortum Tenderness
  - Ubiquitin – proteosome proteolytic pathway
    - Binds to Proteins
    - Once bound, Protein is targeted for degradation

Satellite Cells

Satellite Cells

- Differentiate and enter the cell
- Create more DNA UNITS
- More protein synthesis
- More protein synthesis
- More protein synthesis
- Hypertrophy
- However, there is a recent new hypothesis!

What else affects muscle growth?

- Genetics
- Nutrition
- Hormones
  - Sex
  - Age
- Growth Promotants

Breed Differences

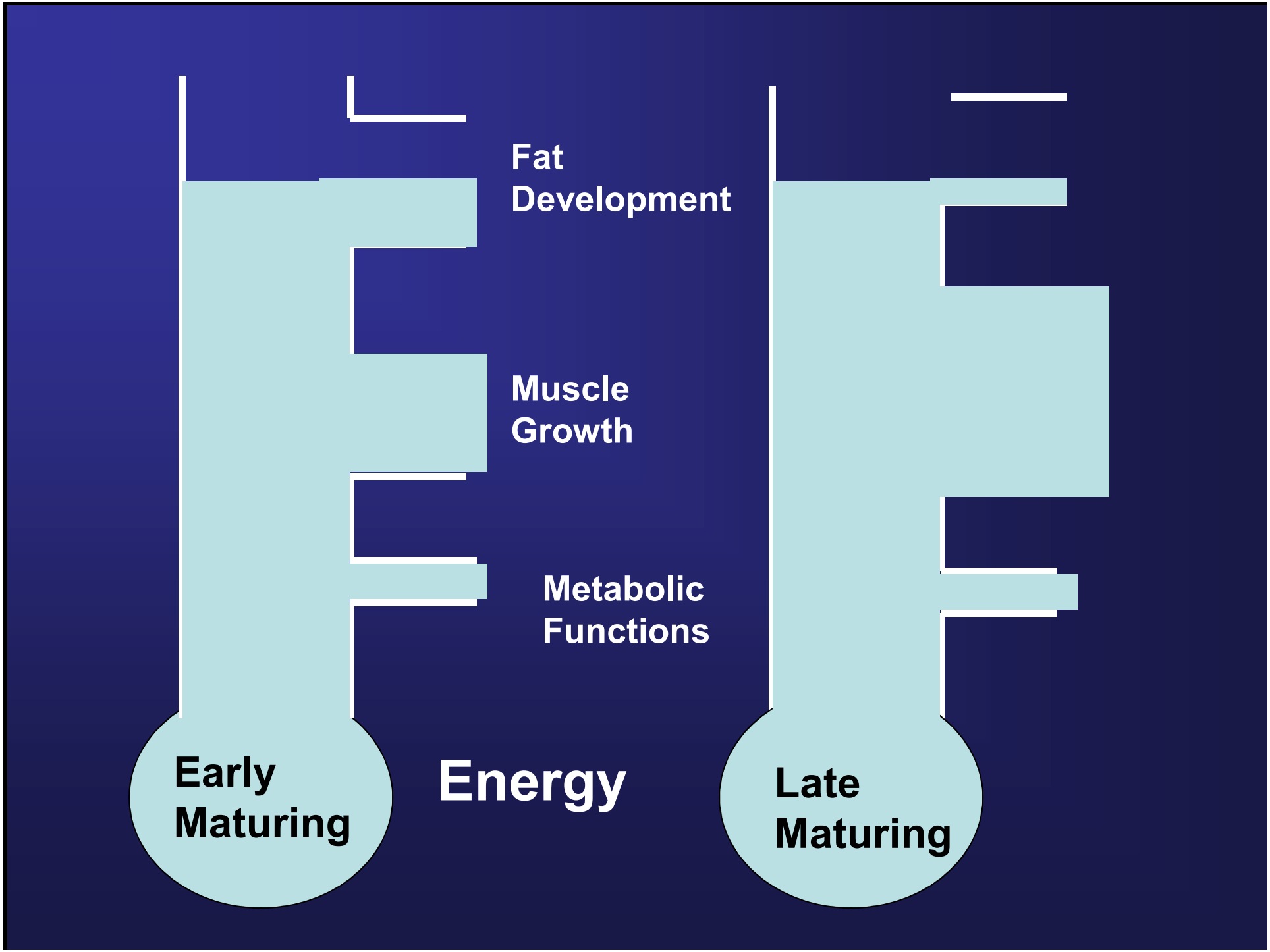
Breed	Fiber Number
Pietrain	1,078,000
Duroc (high fat line)	659,000
Duroc (high lean line)	802,000
Landrace	988,000
Yorkshire (high fat line)	738,000
Yorkshire (high lean line)	797,000

Genetics

- Double Muscled
- Belgian Blue & Piedmontese
- Callipyge Sheep
- Increase in muscle cell size
- Mutation or complete deletion of the Myostatin gene

More on Genetics

- Late maturing vs Early maturing animals
- Late Maturing (aka large frame) require longer time to reach compositional maturity
- Early Maturing (aka small frame) reach compositional maturity earlier than large frame


Fat
Development
Muscle
Growth
Metabolic
Functions
Early
Maturing
Energy
Late
Maturing

Nutrition

- Genetic propensity nor added growth promotants are a substitute for good nutrition
- Mothers nutrition is important
  - Poor nutrition can alter the muscle fiber number
  - Example; Runts. If they live, they will be fatter with less muscle when compared to littermates at same age and weight

Nutritional Effects

Diet	Ab Lib	R1	R2	% Diff.
Fiber Size	3824 μm^2	3024 μm^2	3024 μm^2	-21

Dietary Protein	LM	SM
11%	3002 μm^2	2645 μm^2
15%	3324 μm^2	3732 μm^2

R1 = 1.64kg/d

R2 = 1.38kg/d

LM = Longissimus

SM = Semimembranosus

Hormones

- Sex hormones
  - Testosterone (other androgens such as androstenone and adrenal androgens)
    - Increases bone growth
    - Shortens G1 phase
    - Increase protein synthesis
  - Estrogen
    - Facilitates fat deposition
    - Stimulate muscle growth
    - Very anabolic in ruminants
- Growth Hormone or Somatotropin
  - Major action is to the production of Insulin – like Growth Factor I
  - Increase protein synthesis and decrease protein degradation
  - Increases lipolysis; mobilizes fatty acid from adipocytes

Hormones

- **Insulin**
  - Increases storage of:
    - Glucose = Glycogen
    - Fatty Acids = Triglyceride
    - Amino Acid = protein
- **Leptin**
  - Decrease food intake
  - Increase energy expenditure
  - Decrease fat mass

Growth Promotants

- Increase muscle cell size
- Beef Implants
  - Trenbolone Acetate
  - Estradiols
- Pigs and Cattle
  - Ractopamine hydrochloride
  - Paylean and Optaflex
- Cimaterol, Isoproternol, and Clenbuteral (illegal)
- PST (Porcine Somatotropin; not approved)

Questions??