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
The Cell Cycle

G2

M

G1

S

G0
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 centrioles. The chromosomes attach to the spindle fibers. At metaphase, the chromosomes align at the equator of the cell. Anaphase is characterized by the separation of the duplicated chromosomes (called chromatids) and their movement to opposite poles. Telophase sees the chromosomes reach the mitotic poles and the cell begins to pinch in.
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
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 myotubes, 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

- **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
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

Step 1: Transcription

- DNA double helix
- RNA polymerase
- RNA nucleotides
- Messenger RNA leaves nucleus

Step 2: Translation

- Transfer RNA
- Amino acids
- Ribosomal RNA
- Anticodon
- Proteins
- Polypeptide chain
- Ribosome
- Messenger RNA
- Codon
- Transfer RNA with amino acid

Nuclear membrane
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=983lhh20rGY
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
<table>
<thead>
<tr>
<th>Breed</th>
<th>Fiber Number</th>
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<tbody>
<tr>
<td>Pietrain</td>
<td>1,078,000</td>
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<tr>
<td>Duroc (high fat line)</td>
<td>659,000</td>
</tr>
<tr>
<td>Duroc (high lean line)</td>
<td>802,000</td>
</tr>
<tr>
<td>Landrace</td>
<td>988,000</td>
</tr>
<tr>
<td>Yorkshire (high fat line)</td>
<td>738,000</td>
</tr>
<tr>
<td>Yorkshire (high lean line)</td>
<td>797,000</td>
</tr>
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</table>
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
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

<table>
<thead>
<tr>
<th>Diet</th>
<th>Ab Lib</th>
<th>R1</th>
<th>R2</th>
<th>% Diff.</th>
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<tbody>
<tr>
<td>Fiber Size</td>
<td>3824 µm²</td>
<td>3024 µm²</td>
<td>3024 µm²</td>
<td>-21</td>
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<tr>
<td>Dietary Protein</td>
<td>LM</td>
<td>SM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11%</td>
<td>3002 µm²</td>
<td>2645 µm²</td>
<td>R1 = 1.64kg/d</td>
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</tr>
<tr>
<td>15%</td>
<td>3324 µm²</td>
<td>3732 µm²</td>
<td>R2 = 1.38kg/d</td>
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</tr>
</tbody>
</table>

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, Isoproterenol, and Clenbuteral (illegal)
• PST (Porcine Somatotropin; not approved)
Questions??