Nutrition and Diet Formulation
Mouth and Jaw

• The order Rodentia is defined by the ability to gnaw and grind—through just about anything.
Dental Formula

Incisor

Diastema

Premolar (rabbits and guinea pigs only)

Molars

Peg teeth (Rabbit only)
Dental characteristics

Brachiodontic:
permanently-rooted
- Molars of rats, mice, and hamsters

• Hypsodontic:
open-rooted, continuously erupting
- Incisors of mice, rat, and hamsters
- All teeth of rabbits and guinea pigs

Labial surface (hard):
Enamel w/ iron

Lingual
Surface (soft):
Cementum & Dentin
(No enamel)

Incisors:
Occlusal surface wears to a chisel-like edge

Labial surface (hard):
Enamel w/ iron
Other Characteristics

• Jaw strength
  – Masseter muscles
  – Joint of jaw is articulated

• Salivary Glands
  – Sublingual and submandibular in neck
  – Parotid by masseter muscle
Cheek or buccal pouches

- Found in hamsters and some gerbils
- Mouth to scapula
- Thin walled, highly distensible
- Well vascularized
- Devoid of lymphatic tissue (immunopriveleged)
- Used to carry feed, bedding, young offspring
Stomach

• Cardiac region (grey/green)
  – Thin-walled
  – Aglandular
  – Guinea pigs lacks this area

• Limiting Ridge
  – Divides the 2 regions and prevents regurgitation

• Pyloric region (red)
  – Muscular
  – Glandular
    • Parietal cells secrete HCl (pH of 1-3)
    • Chief cells secrete pepsinogen

\[
\text{Pepsinogen} \xrightarrow{\text{HCl pH = 3}} \text{Pepsin} \xrightarrow{\text{Protein}} \text{Peptides}
\]
Pancreas

• Diffuse
  – Located between stomach and spleen and in the first loop of the duodenum
  – Denser and darker red than adipose tissue

• Exocrine (98%)—secretes into duodenum
  – Bicarbonate to neutralize stomach acid
  – Enzymes to break down starches

• Endocrine (2%)—Islets of Langerhans

Glucose (blood) $\xrightarrow{\text{Insulin}}$ Glycogen (liver)
Glucagon $\xleftarrow{\text{Insulin}}$ Glucose (blood)
Liver

• Energy storage—Glycogen
• Detoxification—Microsomal enzymes
  – Break down toxins into non-toxic components
  – Stimulated by aromatic aldehydes, inhibited by ammonia
• Formation of bile
  – Alkaline—neutralize HCl
  – Emulsifies fat to facilitate absorption
  – Stored in gallbladder except in the rat
  – Secreted into the duodenum via the Sphincter of Odii
Small Intestine

- Site of final breakdown of ingested material
- Site of absorption of nutrients into blood stream
- Muscular tube ~10 x body length
- Villi and microvilli increase surface area 6000-fold
Large Intestine

• Cecum
  – Junction between ileum and colon
  – Blind sac
  – Pseudoruminatation or post-gastric fermentation: Contains bacteria that breaks down fibrous components of diet. Byproducts include protein and vitamins

• Colon
  – Devoid of villi and microvilli
  – Functions to absorb water and maintain electrolyte balance
Coprophagy

- The practice of eating one’s own feces
- Necessary to utilize nutrients liberated by bacteria in cecum
- Juveniles eat adult feces to ingest symbiotic bacteria
- Prevention of coprophagy depresses growth rate in rats and mice by 15-25%
- Rabbits use 70-80% of plant protein; most highly developed mechanism
Rabbit Coprophagy

- Differentiation of feces
  - Hard feces are voided into bedding
  - Cecotrophs (soft feces) are produced for a short period ~4-8 hours after eating.
  - Cecotrophs are eaten directly from the anus and not prevented by wire-bottom caging

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<tr>
<th></th>
<th>Water</th>
<th>Protein</th>
<th>Fiber</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hard</td>
<td>18%</td>
<td>20%</td>
<td>47%</td>
</tr>
<tr>
<td>Soft</td>
<td>45%</td>
<td>40%</td>
<td>15%</td>
</tr>
</tbody>
</table>
Cecotrophs

Nutritional byproducts of bacterial digestion:
- Protein
- B Vitamins
- Vitamin K
- Trace minerals
- Short chain fatty acids (SCFA)

Mechanism
- Fibers moved into and out of cecum by parastalsis and antiparastalsis
- Cecotrophs are coated with mucilaginous membrane
- Attach to hairs around anus and swallowed without mastication
- Cecotrophs remain in mucus membrane until they pass through the stomach and reach the small intestine
Axenic Animals

• Axenics have no bacteria in cecum
• Diet must be supplemented
  – No protein or vitamin byproducts of bacteria
  – Decrease in calories liberated leads to decreased growth rate
• Fiber in diet must be reduced
  – Non-digestible fibers lead to enlarged cecum
  – Signs of compacted cecum
    • Decreased food consumption (anorexia)
    • Decreased defecation (constipation)
    • Death
Antibiotic toxicity

- Antibiotics kill off bacteria in cecum
  - Narrow spectrum antibiotics target gram +
  - Gram negative (E. coli) and spore-formers (Clostridium) overpopulate gut leading to enterocolitis
  - Signs of antibiotic toxicity
    - Decreased food consumption (anorexia)
    - Diarrhea
    - Dehydration
    - Death

- Prevention: Use a broad spectrum antibiotic
Natural Diet

• Omnivores: Mice, rats, hamsters, gerbils
  – Seeds and grains
  – Insects, eggs, small mammals

• Herbivores: Rabbits and guinea pigs
  – Grasses, hays, other vegetation
Feeding schedules

• *Ad lib*: Rodents
  – Group housed
  – Could benefit from restricted diet

• Meal fed: Rabbits
  – May feed ad lib with group housed
  – If singly-housed, require a restricted diet to prevent obesity

• Nocturnal animals eat at night

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*What’s known from literature?*
A literature study was done before designing the actual experiment. Only the most important aspects will be discussed in this article.

Rats are active during the dark phase. It is known that the animals consume eighty percent of their daily food intake during night. This is also shown in the following graph (Figure 1) where the mean food intake of rats over fourteen days is shown.

(Figure 1. Mean food intake of rats over 14 days (n=6))
Fasting Rodents

• Removal of feed may be required for some clinical or experimental procedures
• Varied effects
  – Fasting has a greater effect if it occurs when the animal would normally eat.
  – Rodents practice coprophagy so stomach won’t be empty
  – Rodents may eat bedding if hungry
  – Fasting of 6 hours empties the stomach; however, intestinal contents may remain relatively the same for 18 hours.
  – Fasting for 18 to 24 hours can cause 10 to 20% loss in body weight.
  – Fasting changes the basal metabolic rate
  – Fasting causes stress and aggression
Guidelines to fasting rodents

• Fasting must be justified in the experimental protocol
• Do a pilot study to determine if it's required and for how long.
• Maximum periods
  – 12 to 16 hours for rats
  – 6 hours for mice
• Do not restrict water
• Look for alternatives
  – Fast during the day for nocturnal species
  – Restrict feed rather than removing it
  – Gradually acclimate animals to fasting
  – Provide a sugar solution to decrease feelings of hunger.
Water

- Should be provided *ad lib* unless withheld for approved experimental purposes.
- Food and water consumption vary in parallel.
- Water requirements increase 9 to 10-fold during lactation.
- Must be potable.
- May be:
  - Deionized
  - Sterilized
  - Chlorinated
  - Acidified
Water Bottles

- Heavy and labor intensive.
- Easier to tell if the animal isn’t drinking.
- Can add drugs or experimental liquids.

Use:

- Always leave a space between the top of the water and the stopper
- Sipper tubes need to be long for smaller or less mobile animals but not touching the bedding.
- Check for high as well as low water level.
Automatic Water Systems

• Less labor intensive alternative.
• Infinite supply of drinking water but also an infinite supply of leaking water.
• Much harder to include additives.

Use:
  – Automatic watering systems need to be flushed regularly to prevent biofilm.
  – Water valves should be checked regularly to be sure they are working properly.
Hydropac Water System

• Disposable plastic bag
• Disposable water valve
• Advantage
  – Like a water bottle but lighter
  – Easy to store
  – Can include additives
• Disadvantage
  – High start-up costs
  – Takes a lot of practice to fit valves into bags
## Types of Diets

<table>
<thead>
<tr>
<th></th>
<th>Natural Product Diet</th>
<th>Purified Diet</th>
<th>Chemically Defined Diet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Composition</td>
<td>Little post-harvest processing</td>
<td>Purified ingredients</td>
<td>Products of digestion</td>
</tr>
<tr>
<td>CHO</td>
<td>Corn, Wheat</td>
<td>Corn starch</td>
<td>Mono/Disaccharide</td>
</tr>
<tr>
<td>Protein</td>
<td>Dried milk, Brewer's yeast</td>
<td>Casein, Lactalbumin</td>
<td>Amino acids</td>
</tr>
<tr>
<td>Fat</td>
<td>Corn oil</td>
<td>Corn oil</td>
<td>Triglycerides</td>
</tr>
</tbody>
</table>
### Ingredient Comparisons

<table>
<thead>
<tr>
<th>Rodent (Purina 5008 Formulab)</th>
<th>Rabbit (Teklad Global Rabbit Diet)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Major Ingredients</strong></td>
<td><strong>Major Ingredients</strong></td>
</tr>
<tr>
<td>(in descending order of inclusion)</td>
<td>(in descending order of inclusion)</td>
</tr>
<tr>
<td><strong>ME</strong> (Kcal/g)</td>
<td><strong>Crude Fiber</strong></td>
</tr>
<tr>
<td>Ground corn</td>
<td>3.4</td>
</tr>
<tr>
<td>Soybean meal</td>
<td>2.4</td>
</tr>
<tr>
<td>Ground wheat</td>
<td>3.1</td>
</tr>
<tr>
<td>Fish meal</td>
<td>2.6</td>
</tr>
<tr>
<td>Wheat Midlings</td>
<td>4.5</td>
</tr>
<tr>
<td>Animal fat</td>
<td>9.4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Diet totals</th>
<th>Diet totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Crude protein</td>
<td>23.0</td>
</tr>
<tr>
<td>% Crude fiber</td>
<td>6.5</td>
</tr>
<tr>
<td>% Fat</td>
<td>3.3</td>
</tr>
</tbody>
</table>
# Natural Product Diet

**NUTRIENT COMPOSITION OF NATURAL PRODUCT DIETS**

<table>
<thead>
<tr>
<th></th>
<th>Rodent</th>
<th>Mouse</th>
<th>Mouse</th>
<th>Rat</th>
<th>GP</th>
<th>Rabbit</th>
<th>Rabbit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5008</td>
<td>5015</td>
<td>5021</td>
<td>5012</td>
<td>5025</td>
<td>5321</td>
<td>5326</td>
</tr>
<tr>
<td></td>
<td>Lifecycle</td>
<td>Lifecycle</td>
<td>Autoclave</td>
<td>Lifecycle</td>
<td>Lifecycle</td>
<td>Breeder</td>
<td>Stock</td>
</tr>
<tr>
<td>Protein (%)</td>
<td>23.5</td>
<td>17.5</td>
<td>21.0</td>
<td>22.5</td>
<td>18.5</td>
<td>16.2</td>
<td>14.5</td>
</tr>
<tr>
<td>Fat (%)</td>
<td>6.5</td>
<td>11.0</td>
<td>9.0</td>
<td>9.0</td>
<td>4.0</td>
<td>2.5</td>
<td>1.7</td>
</tr>
<tr>
<td>Fiber (%)</td>
<td>3.8</td>
<td>2.5</td>
<td>4.1</td>
<td>4.1</td>
<td>11.5</td>
<td>13.5</td>
<td>22</td>
</tr>
<tr>
<td>Lysine (%)</td>
<td>1.4</td>
<td>0.9</td>
<td>1.3</td>
<td>1.4</td>
<td>1.0</td>
<td>0.8</td>
<td>0.7</td>
</tr>
<tr>
<td>Methionine (%)</td>
<td>0.4</td>
<td>0.4</td>
<td>0.5</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
<td>0.3</td>
</tr>
<tr>
<td>Vit A (IU/g)</td>
<td>15.0</td>
<td>30.0</td>
<td>44.0</td>
<td>12.0</td>
<td>30.0</td>
<td>20.0</td>
<td>20.0</td>
</tr>
<tr>
<td>Thiamin, ppm</td>
<td>15.1</td>
<td>5.5</td>
<td>85.0</td>
<td>10.9</td>
<td>5.5</td>
<td>3.5</td>
<td>2.8</td>
</tr>
<tr>
<td>Vit C (mg/gm)</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>1.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Gross Energy (Kcal/g)</td>
<td>4.2</td>
<td>4.3</td>
<td>4.0</td>
<td>4.2</td>
<td>4.0</td>
<td>4.0</td>
<td>3.9</td>
</tr>
</tbody>
</table>
Energy Requirements

- Curvilinear relationship
- Energy = body weight$^{3/4}$

<table>
<thead>
<tr>
<th>Condition</th>
<th>Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maintenance</td>
<td></td>
</tr>
<tr>
<td>Pregnancy</td>
<td>30%</td>
</tr>
<tr>
<td>Lactation</td>
<td>3 fold</td>
</tr>
</tbody>
</table>
## Food Consumption

<table>
<thead>
<tr>
<th>Rodents</th>
<th>Mouse</th>
<th>Rat</th>
<th>Hamster</th>
<th>GP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food Consumption (g/100g/day)</td>
<td>15.0</td>
<td>10.0</td>
<td>15.0</td>
<td>6.0</td>
</tr>
<tr>
<td>Water Consumption (ml/100g/day)</td>
<td>15.0</td>
<td>10.0</td>
<td>20.0</td>
<td>10.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Rabbits</th>
<th>Stock</th>
<th>Grw/prg</th>
<th>Lact.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food Consumption (g/kg/day)</td>
<td>35.0</td>
<td>50.0</td>
<td>100.0</td>
</tr>
<tr>
<td>Water Consumption (ml/kg/day)</td>
<td>120.0</td>
<td>120.0</td>
<td>1200.0</td>
</tr>
</tbody>
</table>
# Feed Presentation

<table>
<thead>
<tr>
<th>Presentation</th>
<th>Uses</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pelleted</td>
<td>NPD, Purified</td>
<td>Easy to handle, &lt;5% waste, Homogenous, Pasteurized, Hard</td>
<td>Can't modify</td>
</tr>
<tr>
<td>Meal (Powdered)</td>
<td>NPD, Purified</td>
<td>Can modify</td>
<td>More labor intensive, &gt;25% waste, Settling, Dusty, Soft</td>
</tr>
<tr>
<td>Semi-moist (Critical care diet)</td>
<td>NPD, Purified, Chemical</td>
<td>Can modify, Homogeneous, Stable, Palatable, Rehydration</td>
<td>Short shelf life, Soft</td>
</tr>
<tr>
<td>Liquid</td>
<td>Chemical</td>
<td>Can modify</td>
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Feeders and Feed
Management and Storage

- Reject damaged bags
- Store in cool, dry, dark areas to prevent oxidation
- Stack according to Milling Date and use oldest bags first
- Discard old feed
  - 180 days for rodents and rabbits
  - 90 days for guinea pigs (unless stabilized)
- Prevent contamination
  - Off the floor (on pallets)
  - Not touching walls
Feed Handling in Animal Rooms

- Feed bags are not clean
- Don’t take bags into animal rooms
  - Unless you disinfect outside of bag
- Store in sealed containers once bags are opened
- Containers should be labeled
  - Type of feed
  - Mill Date
  - Date container disinfected
- Containers must be disinfected minimum every 6 months
Sterilization of Diets

• Gamma Irradiated Diets
  – Available commercially

• Autoclavable Diets
  – Fortified
  – Coated pellets

• Filtration
  – Liquid diets
Food as Enrichment

• Rats and mice
  – Seeds: Sunflower safflower, or pumpkin
  – Cheerios
• Limit quantities
  – Rats: 3 – 4/week
  – Mice: 1 - 2/week
Food as Enrichment

• Rabbits
  – Hay: Oat or wheat
    • May be provided *ad lib*
    • Helps with satiation
  – Fresh veggies
    • Clean thoroughly
    • Not suitable for rabbits younger than 4 months of age