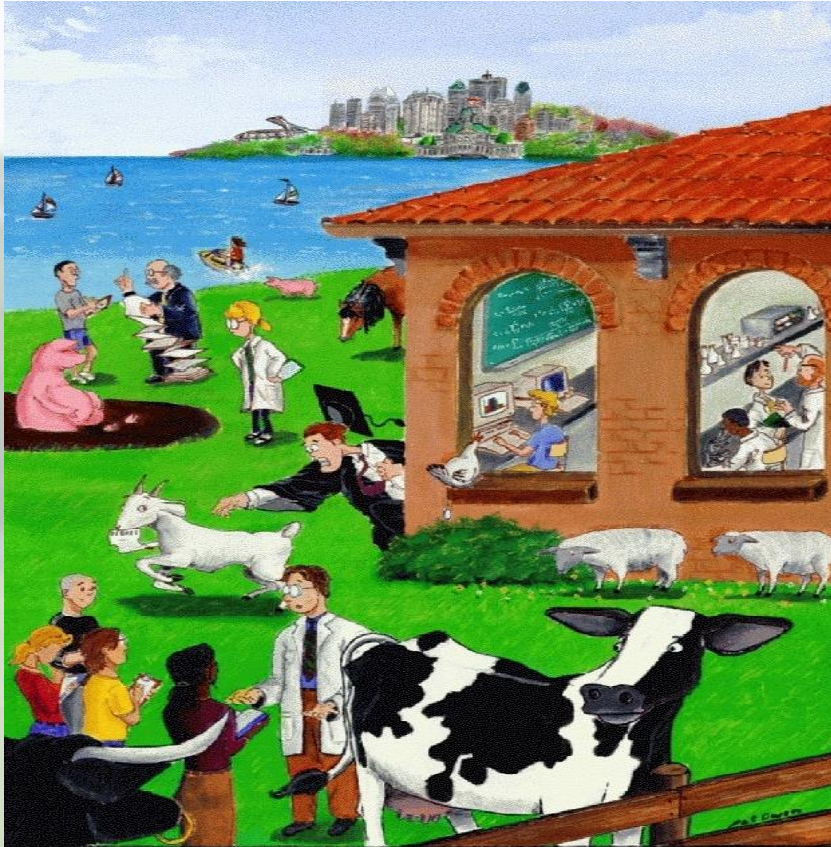
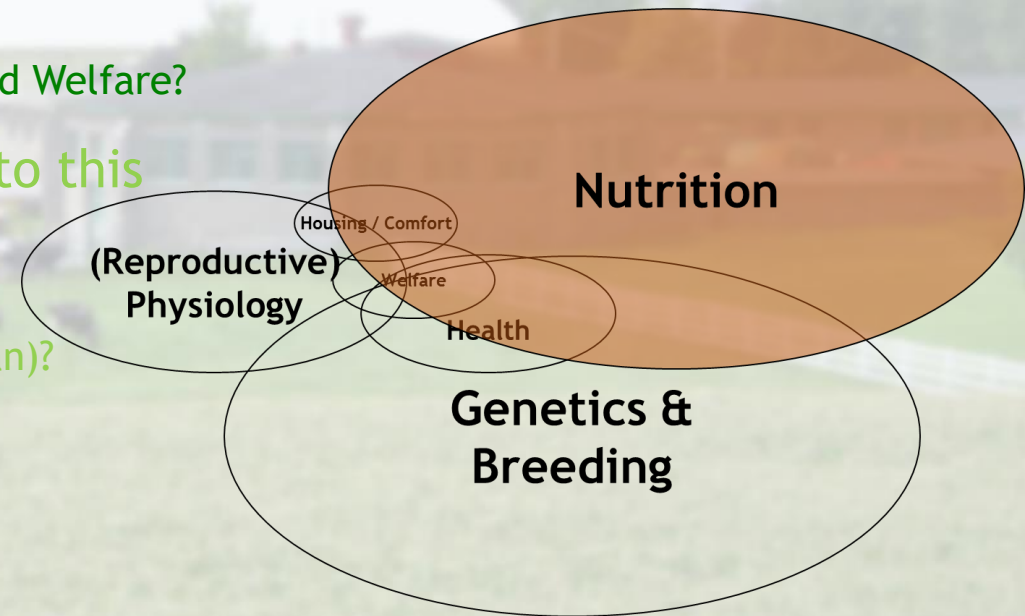


# Outline



- The challenge of sufficient quality food...
- The importance of animal agriculture
- Can livestock production be improved through technology?
  - Reproductive Physiology?
  - Genetic Improvement?
  - Nutritional Needs?
  - Comfort, Management and Welfare?
- Are there constraints to this improvement?
  - Economical?
  - Health (Animal and Human)?
  - Environmental?
  - Ethical?



# What is Nutrition?

- Nutrition consists of interrelated steps by which a living organism assimilates food and uses it for various bodily functions including growth, tissue repair and replacement or elaboration of products.



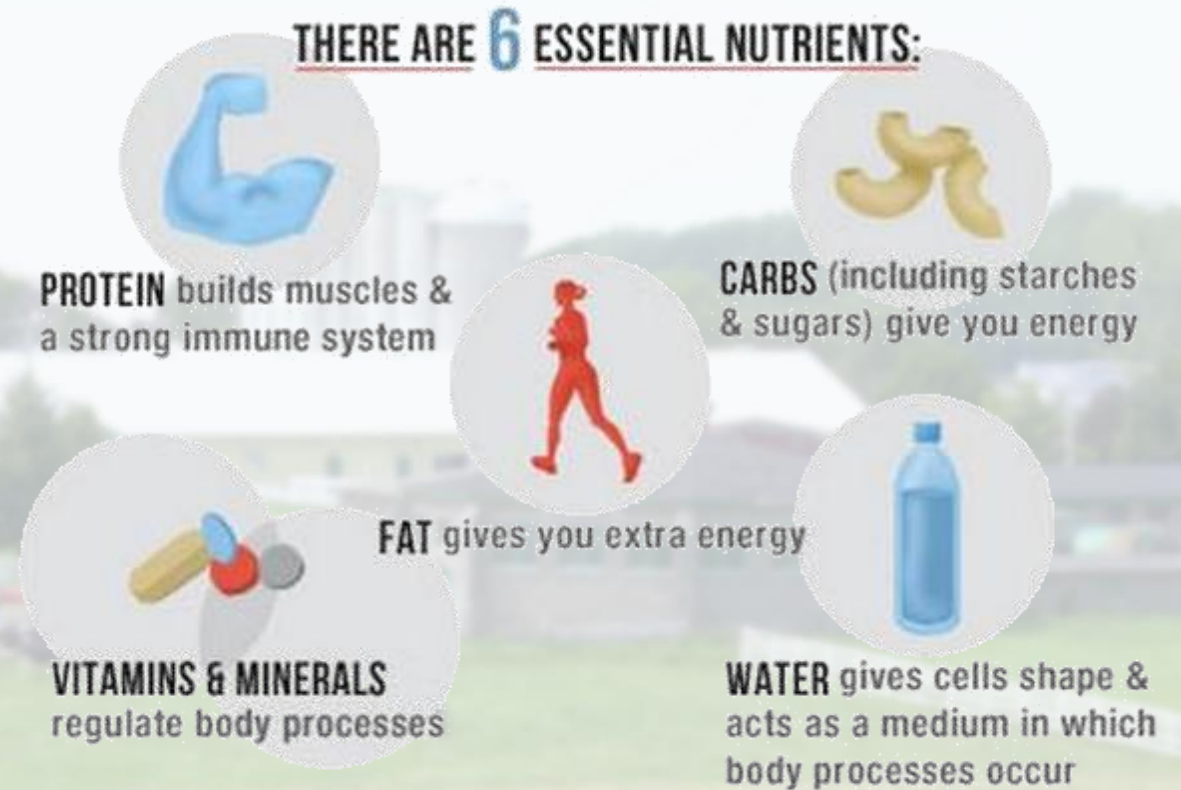
- And a “nutrient” is:

1. A feed constituent that functions in the support of life...
2. A chemical compound in the diet which can be absorbed to ensure the maintenance of normal bodily functions (growth, maintenance, reproduction, lactation, etc.)



# The Six Categories of Nutrients

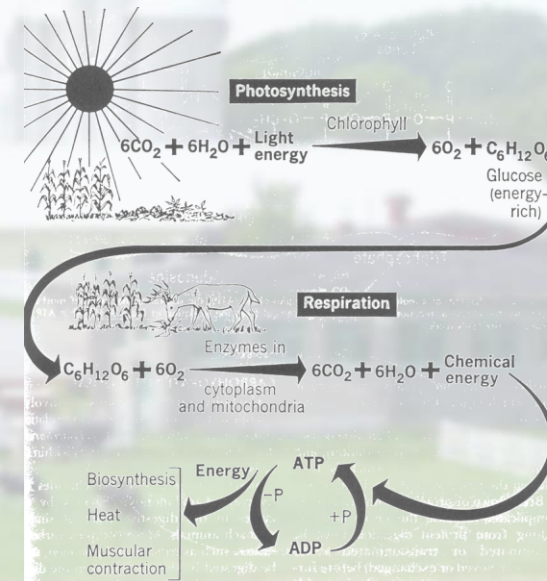
- Carbohydrates (CHO)
- Fats / Oils
- Proteins (Amino Acids)
- Minerals
- Vitamins
- Water



# The Six Categories of Nutrients

- Carbohydrates (CHO)
- Fats / Oils
- Proteins (Amino Acids)
- Minerals
- Vitamins
- Water

- $C_nH_{2n}O_n$
- They include sugars, starch, cellulose, gums, etc.
- Mostly found in plants as a result of photosynthesis;



- 75% of plant dry matter is carbohydrate;
- Animal CHOs (Glucose = simple; Glycogen = complex) are stored in the tissue and available as sources of energy.

# Complex carbohydrates are major components of plant cell walls

- They are not as easily digestible as simple Carbohydrates;
- No animal enzyme is capable of digesting cellulose;
- Ruminants can make use of plant material via microbial action.





# The Six Categories of Nutrients

- Carbohydrates (CHO)
  - Fats / Oils
  - Proteins (Amino Acids)
  - Minerals
  - Vitamins
  - Water
- Organic compounds *insoluble* in water;
  - Simple lipids are composed of C, H, O (Fats/Oils/Waxes) but with a higher ratio of C and H : O versus Carbohydrates;
  - Supply energy (large energy reservoir)
    - 2.25 times more energy than carbohydrates
  - Source of Essential Fatty Acids like Palmitoleic, Oleic, Linoleic, Linolenic, Arachidonic that cannot be synthesized by animal tissues (or at least not in sufficient amount to prevent pathological changes), and must be supplied in the diet.
    - They are important for such processes as healing of wounds, immune system, blood pressure and muscle contraction.
    - Deficiencies can cause significant problems for growth, reproduction and lactation...
  - Carrier of fat-soluble vitamins (A, D, E, K)

# The Six Categories of Nutrients

- Carbohydrates (CHO)
- Fats / Oils
- Proteins (Amino Acids)
- Minerals
- Vitamins
- Water
- Proteins are principal constituents of the cells, membranes, and organelles;
- They are a major component of muscles, and a part of bones and epithelium;
- They are the main component in hair, nails, wool and feathers;
- Animals, therefore, need a considerable and continuous supply in the food throughout their lifetime for growth and repair.

# Protein Content in Feedstuffs...

## Elementary composition of Typical Proteins

	Percent
Carbon	51.0 - 55.0
Hydrogen	6.5 - 7.3
Oxygen	21.5 - 23.5
Nitrogen	15.5 - 18.0 16
Sulfur	0.5 - 2.0
Phosphorus	0.0 - 1.5

Proteins in feeds contain, on average, 16% Nitrogen. This is why feeds are analysed for %N (relatively easy to measure) which is then multiplied by 6.25 to convert to % protein.

Therefore, if a food sample contains 4% N we can assume that it contains how much crude protein??

25% crude protein (i.e.,  $4 \times 6.25$ )



# The Six Categories of Nutrients

- Carbohydrates (CHO)
- Fats / Oils
- Proteins (Amino Acids)
- Minerals
- Vitamins
- Water

- Inorganic elements (no Carbon) and also excluding Hydrogen, Oxygen or Nitrogen;
- They are normally classified as Macro and Micro depending on the amount required (large or trace);

<u>Macro</u>	<u>Micro</u>
Calcium	Chromium
Chlorine	Cobalt
Magnesium	Copper
Phosphorous	Fluorine
Potassium	Iodine
Sodium	Iron
Sulfur	Manganese
	Molybdenum
	Selenium
	Zinc

# The Six Categories of Nutrients

- Carbohydrates (CHO)
  - Fats / Oils
  - Proteins (Amino Acids)
  - Minerals
  - Vitamins
  - Water
- These are *organic* nutrients needed in trace amounts;
  - There are 16 known vitamins that function in animal nutrition;
  - The fat soluble vitamins are A, D, E, and K
  - The water soluble vitamins are members of the B complex and C

# The Six Categories of Nutrients

- Carbohydrates (CHO)
- Fats / Oils
- Proteins (Amino Acids)
- Minerals
- Vitamins
- Water
- Uses...
  - Consistency / Physical Shape
    - Body Water  $\approx$  70% in Human Adults
      - Age, Weight, Health, Sex, Environment, Physical Activity
  - Transport of other Nutrients
    - Blood, Tissue Fluids, Secretions
    - Excreted substances
  - Facilitates Metabolic Reactions
  - Body-temperature Regulation



# Typical water consumption of adult livestock in *temperate* climates

- Water Sources...

- Direct Intake (Drinking!)
- Water present in feed
- Metabolic reactions

≈ 3 litres / day

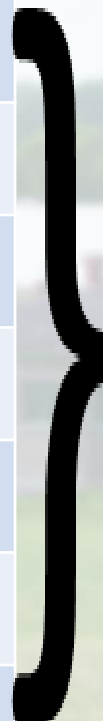
- Water Losses...

- Excretion (urine and faeces)
- Perspiration
- Vaporization from Skin/Lungs



# Typical water consumption of adult livestock in *temperate* climates

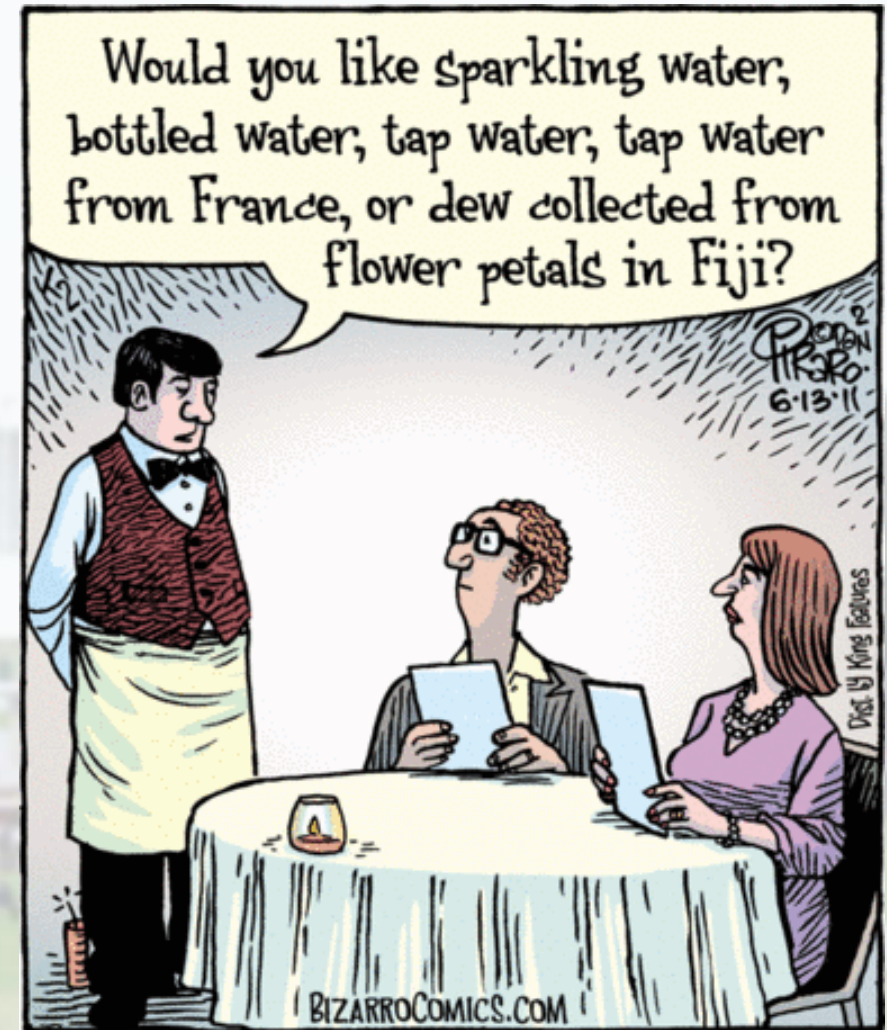
Species	Water (litres / day)
Beef Cattle	26 – 66
Dairy Cattle	38 – 110
Horses	30 – 45
Swine	11 – 19
Sheep and Goats	4 – 15
Chickens	0.2 – 0.4
Turkeys	0.4 – 0.6

- 
- Availability of Water
  - Dry Matter Content of Feed

# Water is essential for life...

“A body can lose practically all of its fat and over half of its protein and still live.

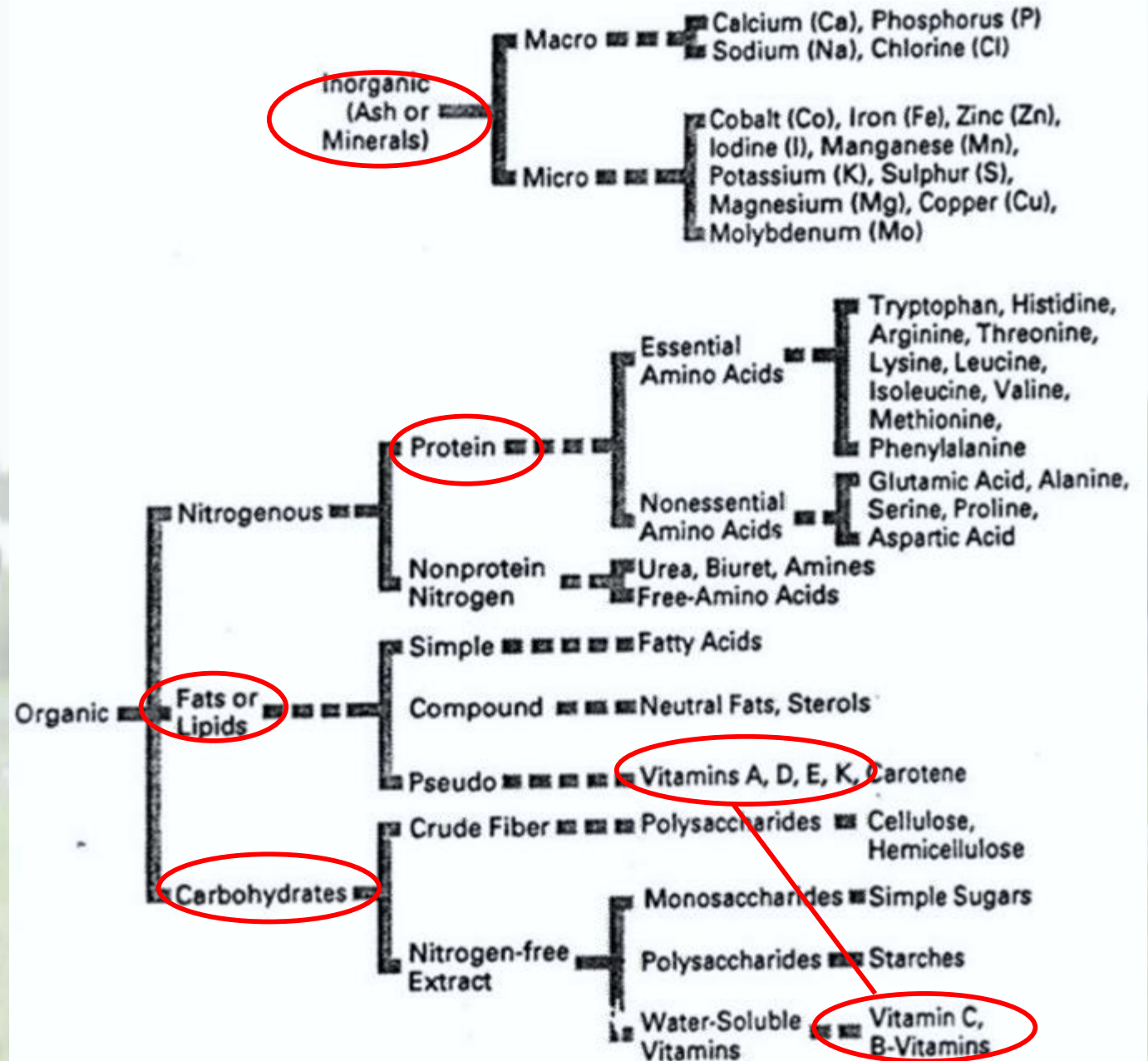
However, a loss of only 12% of its water can result in a life-threatening situation.”



But maybe we've gone too far!!



# Chemical Analysis Scheme of Nutrients



# Animal Nutrition

1. Digestive tract and digestion in monogastrics, birds, and ruminants
2. Digestibility, Energy and Protein utilization
3. Nutrient requirements for body functions
4. Feedstuffs
5. Feeds analyses and Ration Formulation

# Digestion of Feed and Absorption of Nutrients

- Feed and drink provide substances for all body functions: in order for the nutrients to be *absorbed*, the feed must undergo *digestion*.

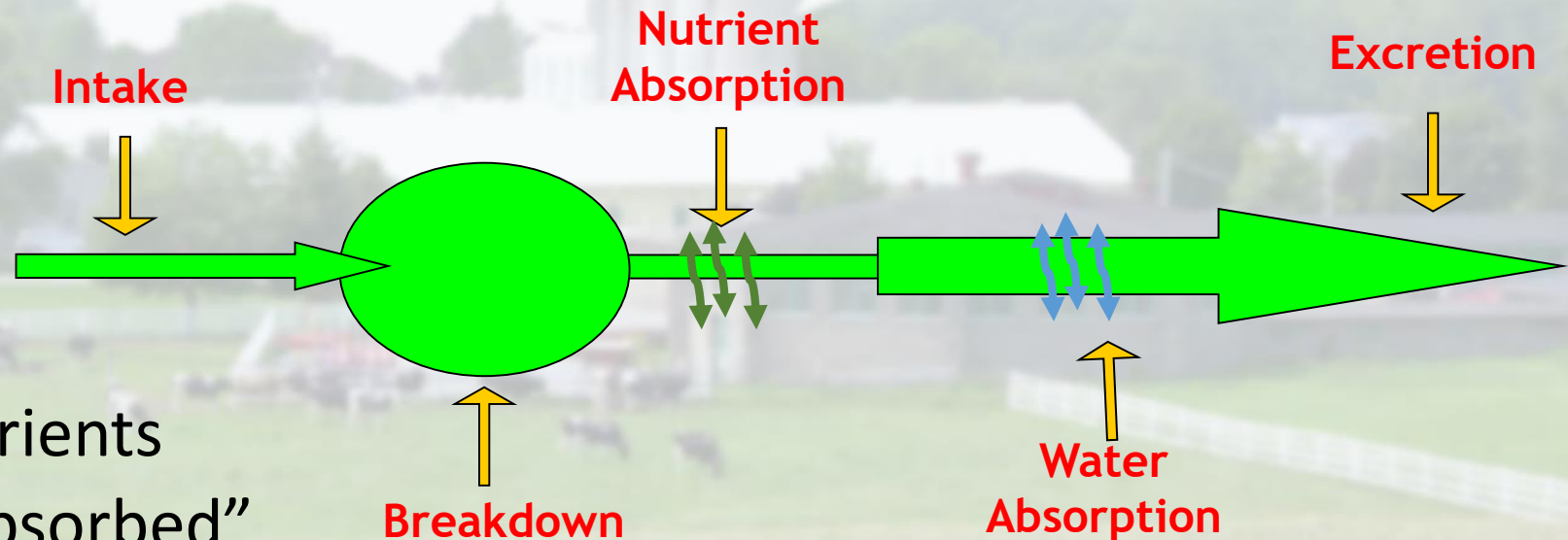


- The objective is to reduce feed particles to molecules so that they can be absorbed into the blood where they will subsequently be used to support body functions.

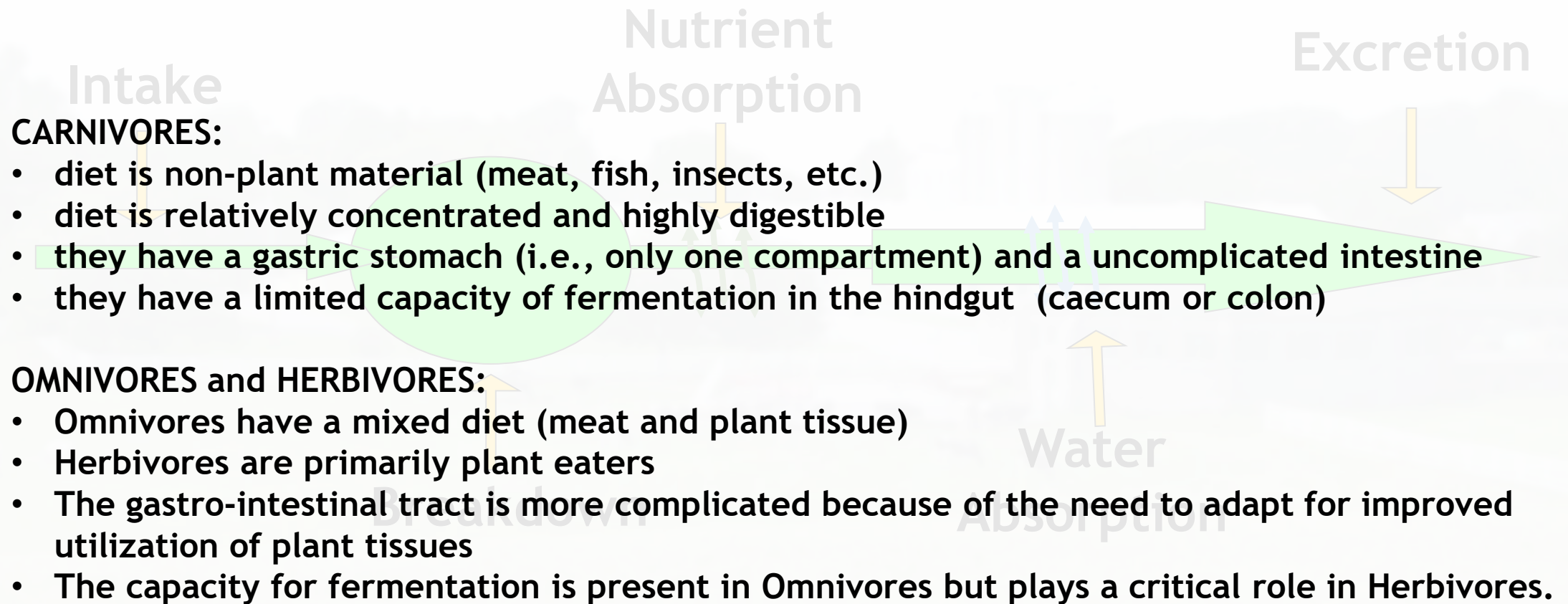


# The Digestion Process...

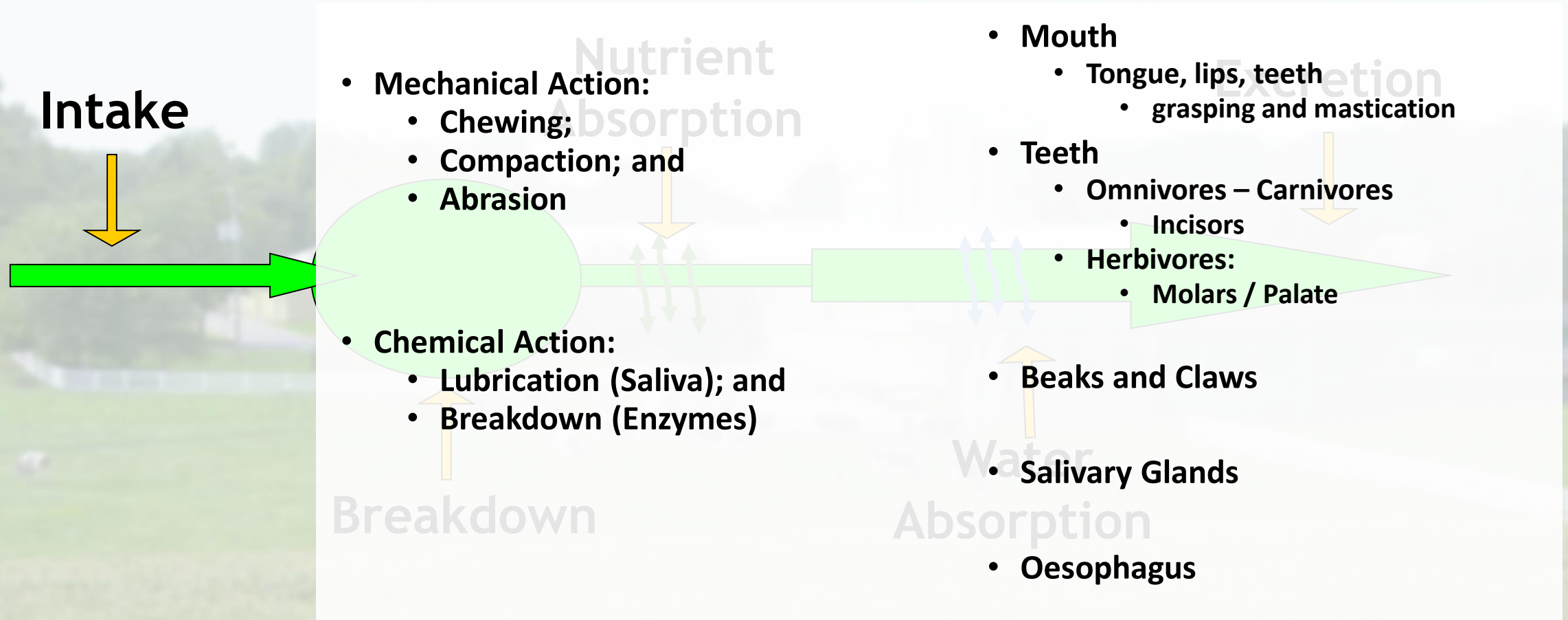
- System of organs, glands and specialised structures concerned with the normal process of:
  - Procurement
  - Initial Breakdown
  - Swallowing
  - Digestion
  - Absorption of Nutrients
  - Excretion of “Unabsorbed” Material



# The Digestive Process: Diet

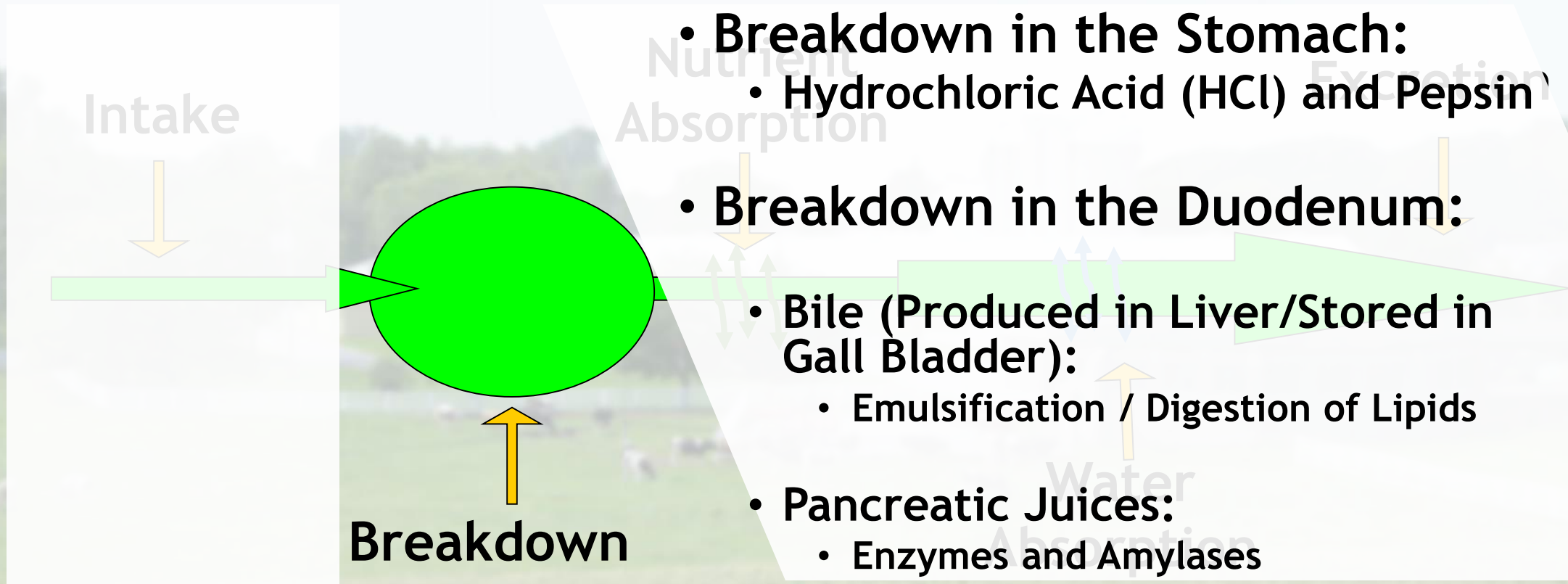


# The Digestive Process: Intake of Nutrients





# The Digestive Process: Breakdown of Nutrients

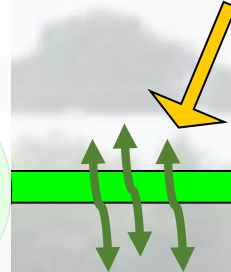


# The Digestive Process: **Absorption of Nutrients**

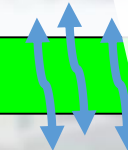
The passage of small molecules from the lumen of the gastrointestinal (GI) tract through the mucosal cells lining the surface of the lumen and into the blood or lymph systems

Breakdown

**Nutrient  
Absorption**

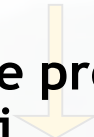


**Water  
Absorption**

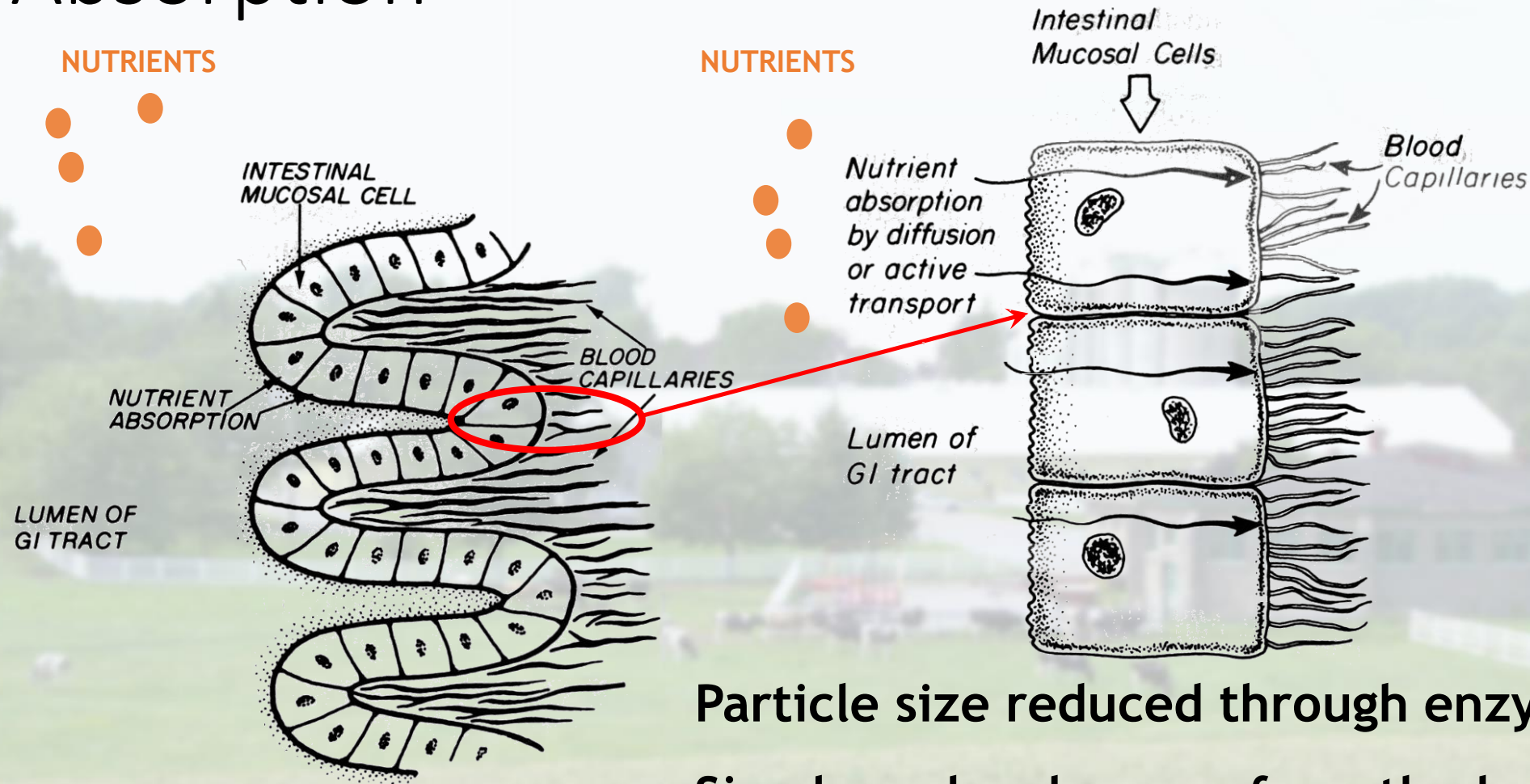


• **Small Intestine:**

- Long!!
- Finger-like projections called villi



# Absorption



Particle size reduced through enzymatic action  
Simple molecules pass from the lumen of the gastro-intestinal (GI) tract to the blood system

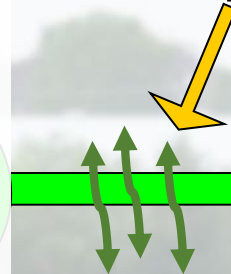


# The Digestive Process: **Absorption of Nutrients**

The passage of small molecules from the lumen of the gastrointestinal (GI) tract through the mucosal cells lining the surface of the lumen and into the blood or lymph systems

Breakdown

**Nutrient Absorption**



**Water Absorption**



• **Small Intestine:**

- Long!!
- Finger-like projections called villi

• **Large Intestine**

- Cecum (bacteria present, some breakdown of cellulose)
- Colon (water absorption)

# The Digestive Process: Excretion

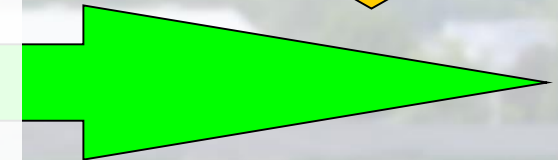
- **Rectum**

- **Fecal material excreted:**

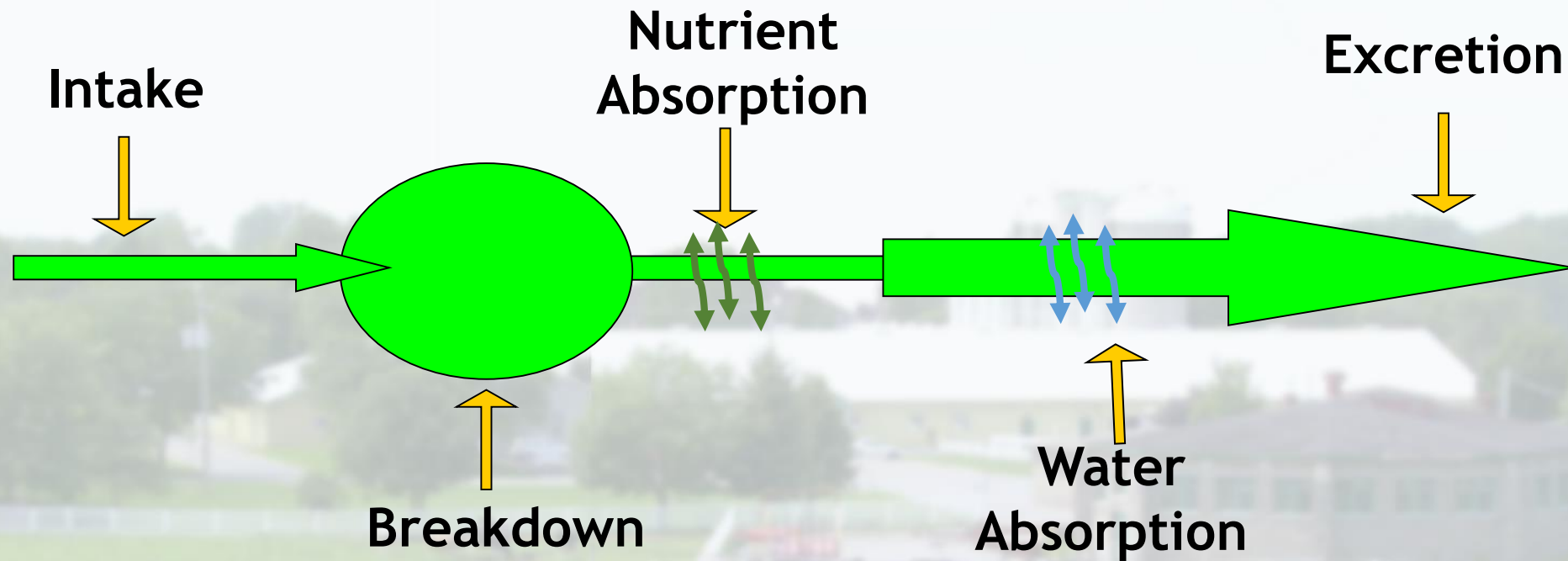
- Undigested material;
    - Residues of gastric secretions (bile, pancreatic juices, GI walls);
    - Microbia (mainly in ruminants).

- **Urinary Tract**

**Excretion**

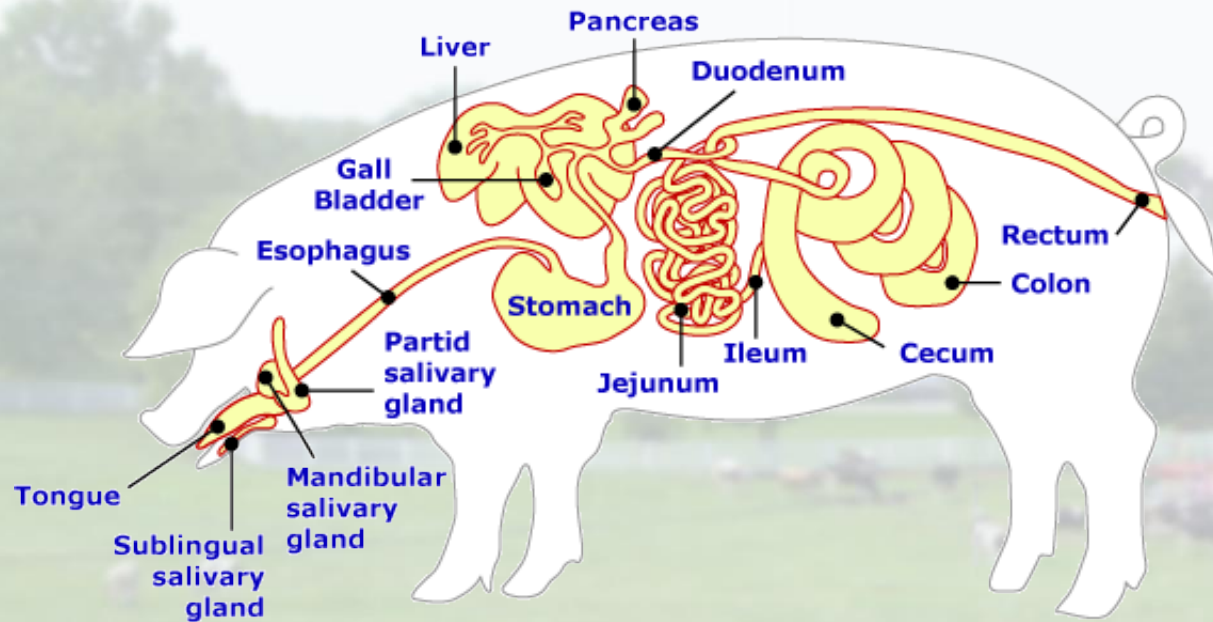


# The Monogastric Digestive Process





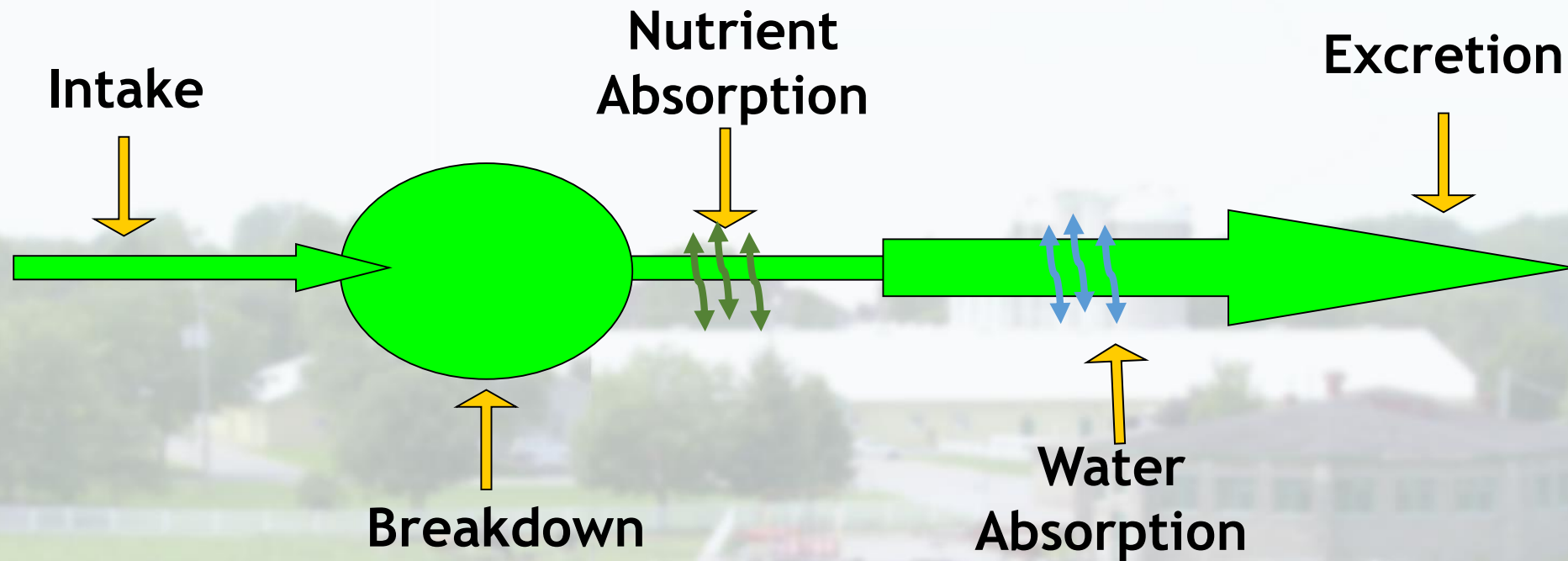
# The (Simple) Monogastric Digestive Tract...



Courtesy of Fench, Oregon State University

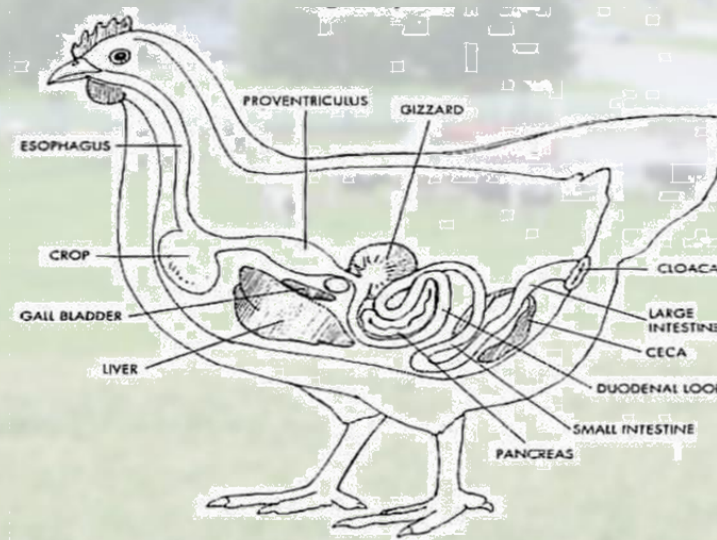
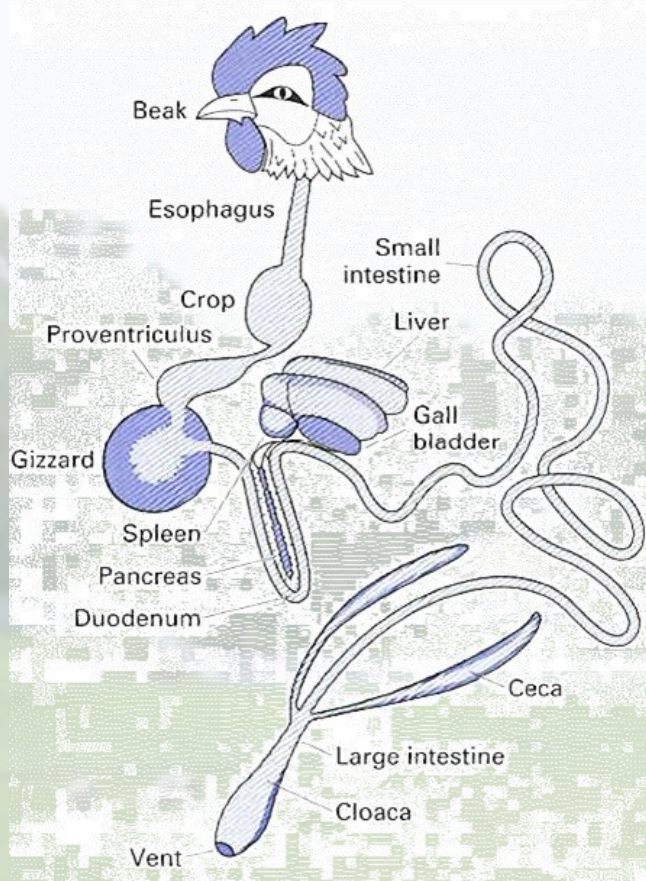
- Mouth, Tongue, Lips, and Teeth for grasping and mastication;
- Simple Stomach system;
- Duodenum (first section after stomach):
  - Digestive secretions (enzymes);
  - Pancreatic secretions (enzymes); and
  - Bile (stored in the Gall Bladder, produced by the Liver).
- Small Intestine where absorption of nutrients occurs
- Large Intestine
  - Cecum (bacteria present, some breakdown of cellulose)
  - Colon (water absorption)
  - Rectum (storage of faeces)

# The Avian Digestive Process





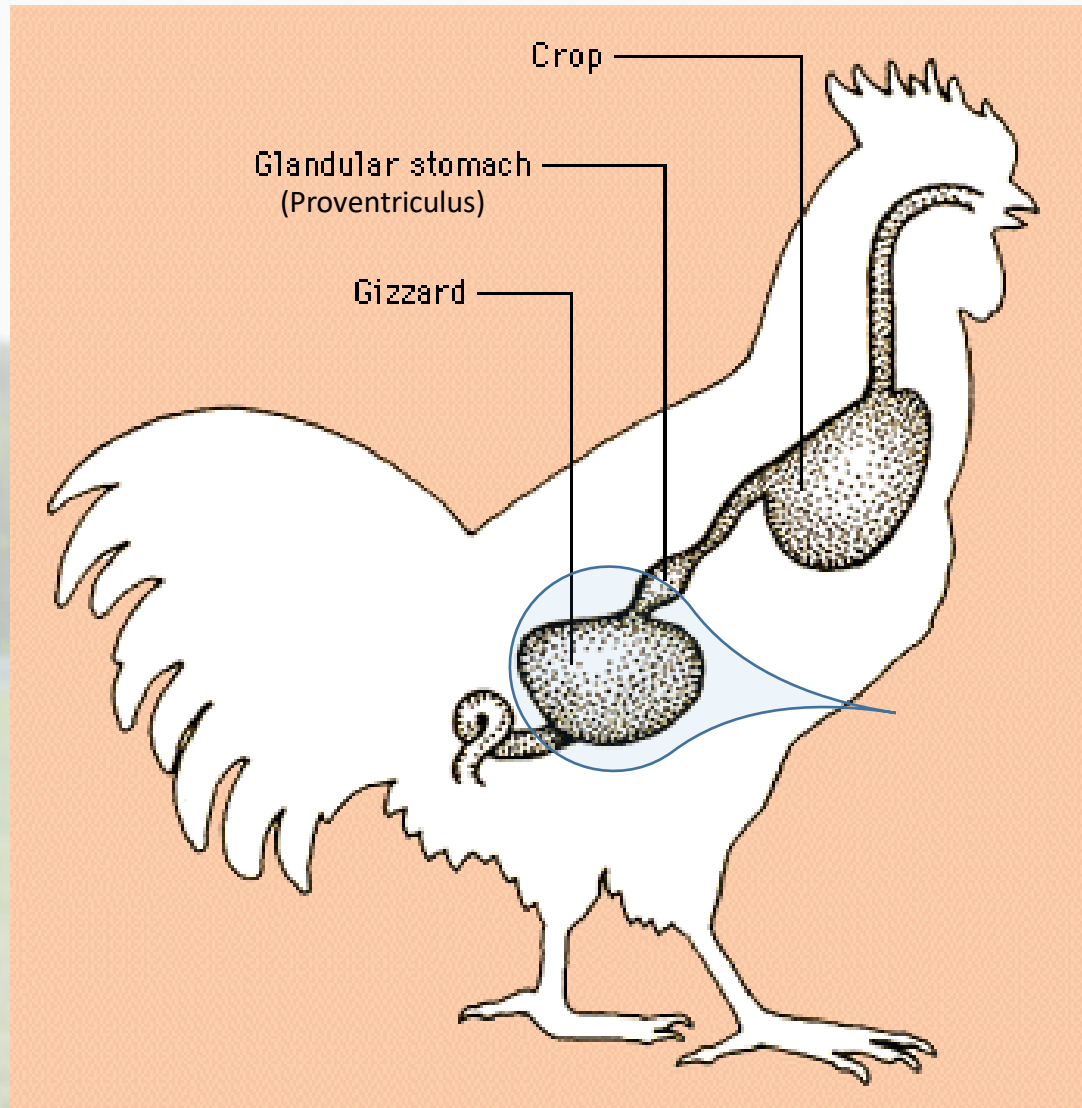
# The *Avian* Digestive Tract...



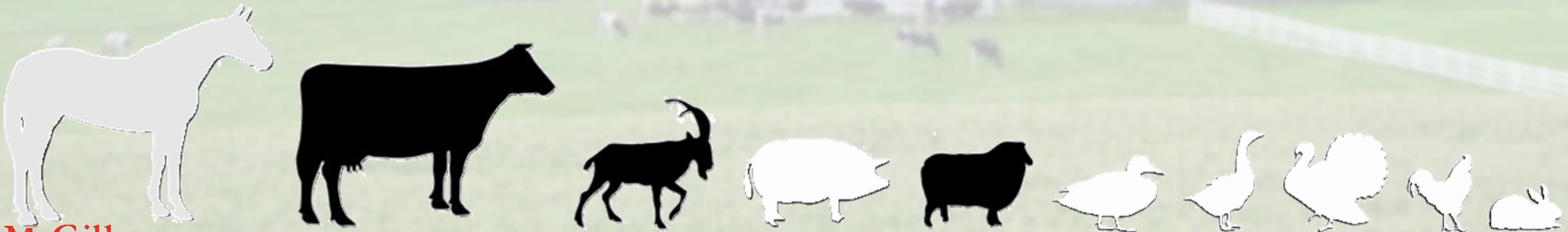
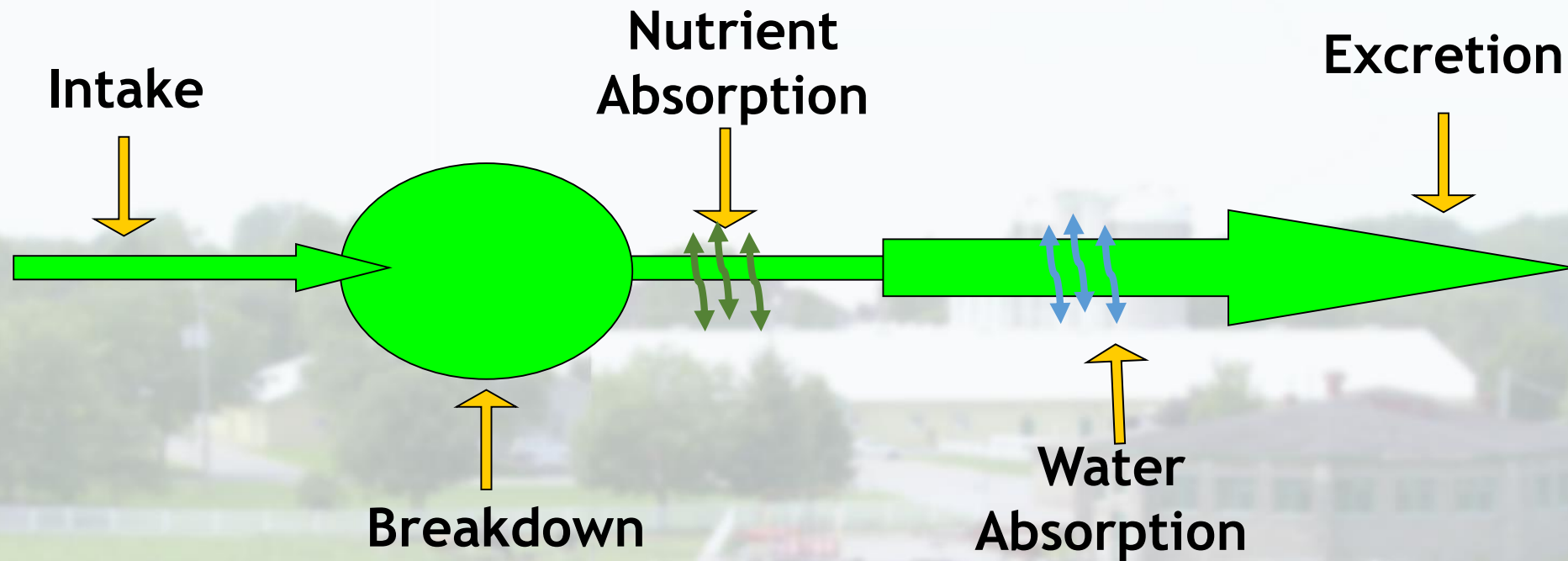
- Teeth?
  - None! They use their beak and claws
- Crop
  - Enlargement of the esophagus
  - Storage of food (limited fermentation)
  - Can be bypassed if “stomach” is empty
- Proventriculus
  - mix with digestive (gastric) enzymes and HCl, leading to fermentation (glandular stomach)
- Gizzard
  - muscular grinding (often contains grit and small stones)
- Small intestine
  - Enzyme action and absorption of nutrients
- Large intestine
  - water re-absorption
- Paired Ceca
  - Unclear – fibre digestion and Vit B production but little absorption
- Cloaca
  - Digestive and urinary tracts empty here and exit through Vent



# The Gizzard



# The Ruminant Digestive Process



# The *Ruminant* Digestive System...

- Examples of Ruminants:
  - Cattle, Goats, Sheep, Deer, Bison, Buffalo, Yaks, Camels, Llamas, Giraffes, Wildebeest, Antelopes...
- Why are they call ruminants?
  - Because they have a rumen !
  - and because they “ruminate” !
    - 9 - 10 hours per day spent ruminating!
- Grazing:
  - 4 – 9 hours in cattle
  - 9 – 11 hours in goats and sheep





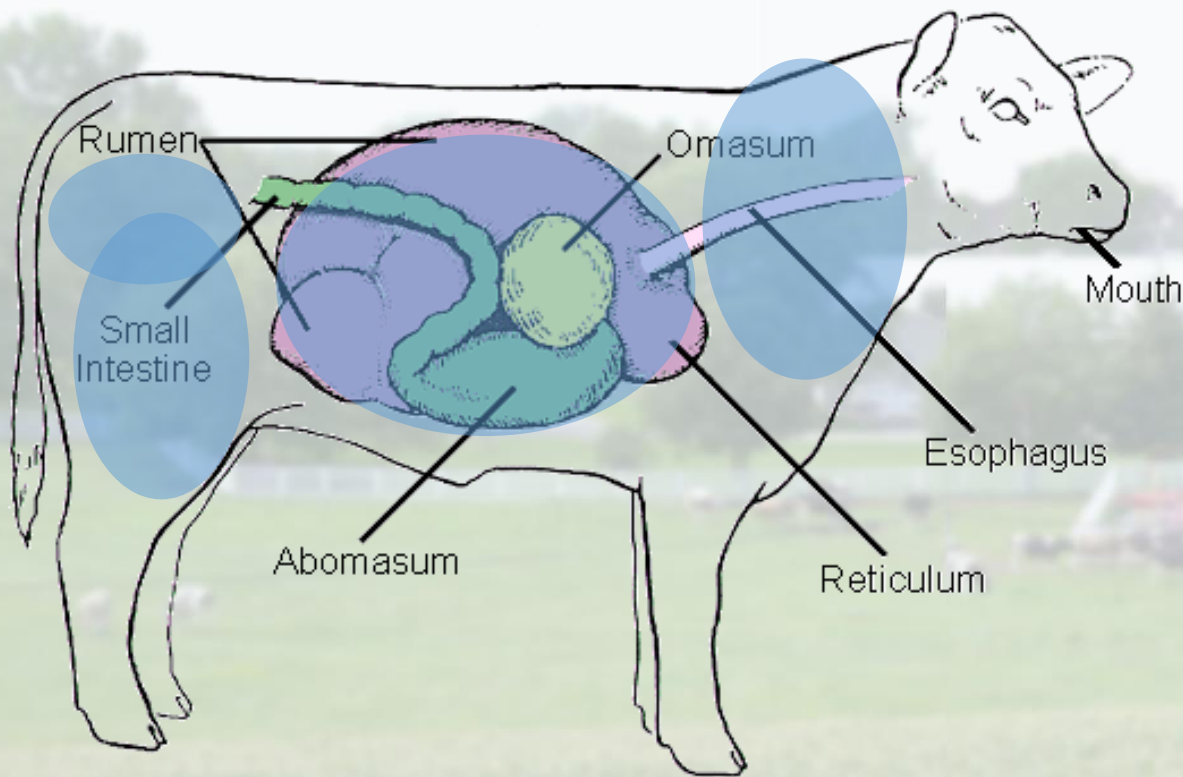
# The *Ruminant* Digestive Tract...



- The Mouth:
  - No upper incisor teeth
  - Flat palate on upper side
  - chew one side at a time (tongue helps!)
- Saliva:
  - Large and continuous production
  - Daily production of:
    - up to 150 litres in the cow; and
    - up to 10 litres in sheep
  - Helps in buffering (pH control)
  - Greater need with acid-producing feeds like cereals
  - Suppresses foaming
  - Reduces the risk of bloat
  - Acts as a lubricant
  - Contains small quantities of amylase (hydrolysis of starch and sugars)



# The *Ruminant* Digestive Tract...



- The esophagus plays the same role as other digestion systems except there is a lot of regurgitation:
  - 300 - 400 bolus (cuds)/day in cattle
  - 400 – 600 bolus (cuds)/day in sheep
- The absorption of nutrients in the small intestine is similar to other digestion systems;
- The absorption of water in the large intestine is also similar to other digestion systems.
- The difference is in the stomach area.

# The *Ruminant* System



1. Reticulum (also called the honeycomb) determines if the size of the ingested feed is small enough to pass on for rumination, or if it's not small enough and needs to be regurgitated.

The Reticulum is not completely separate from the

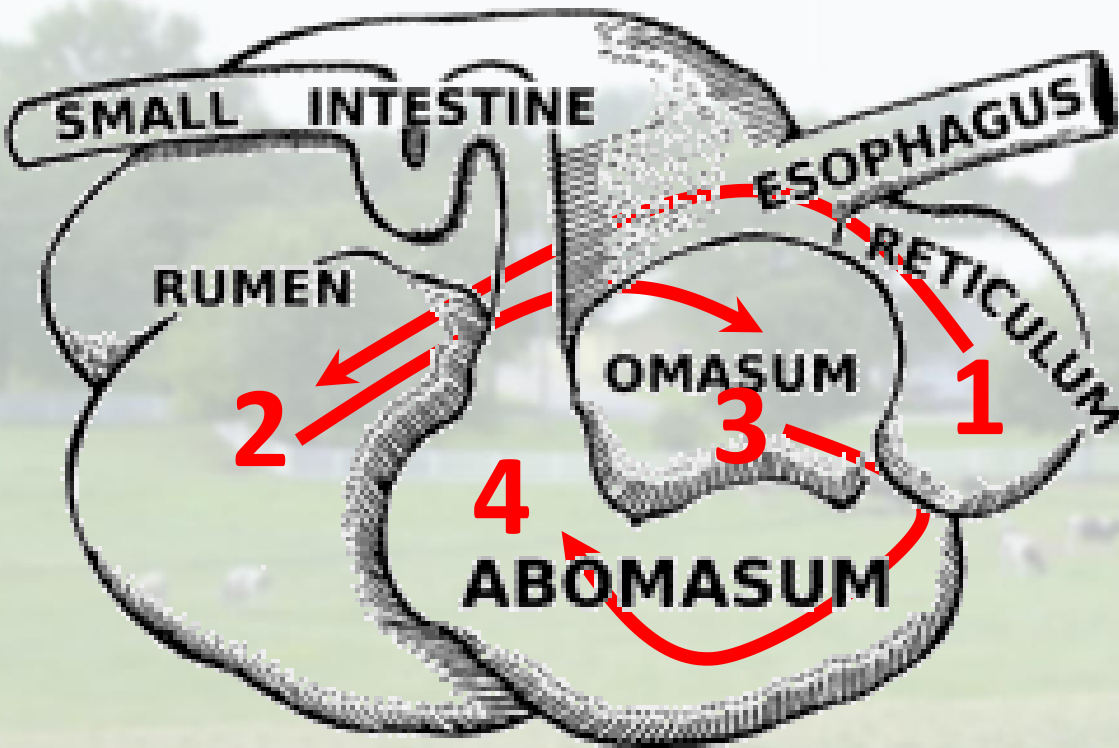
2. Rumen: fermentation vat, filled with micro-organisms (bacteria/protozoa) →
3. Omasum (“folds for grinding”): control of passage/some absorption (leads to the eruption of gas)
4. Abomasum: (comparable to the simple monogastric stomach)



# The *Ruminant* System



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# Inside the rumen!!

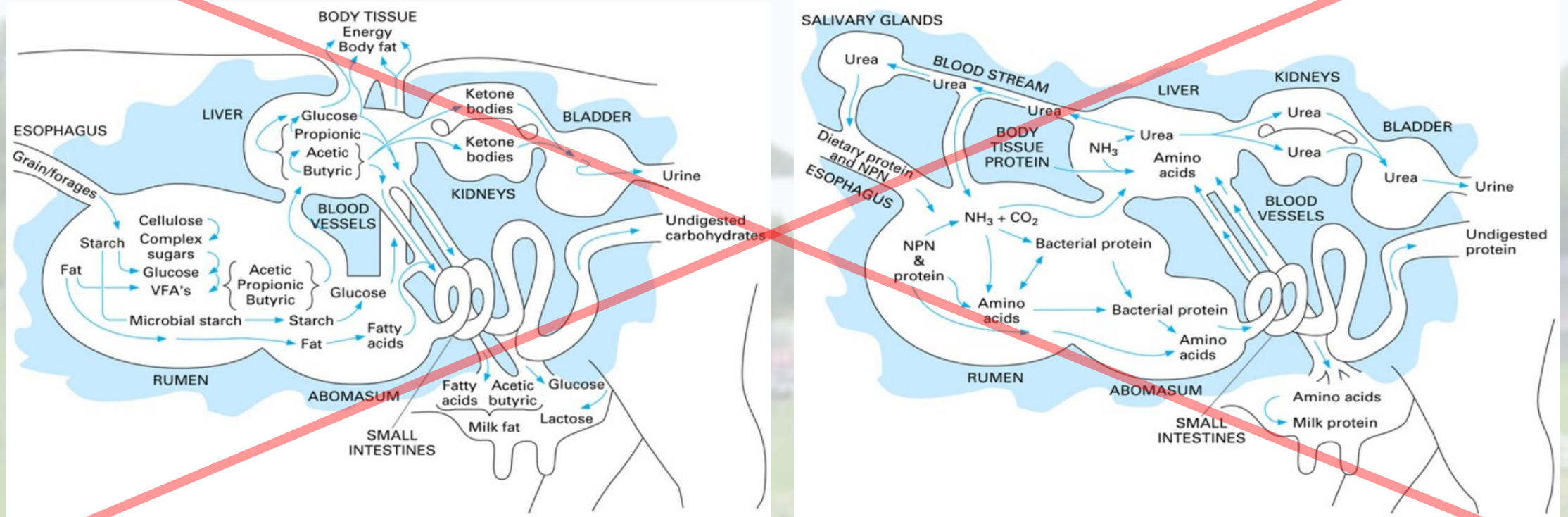


Courtesy of Washington State University

- Site of pre-digestive fermentation;
- Billions of bacteria and protozoa consume the roughage (plant) feed;
- The result of microbial fermentation of CHO's leads to volatile fatty acids - a major energy source for the animal;
- Excess microbes are continuously removed from the rumen into the “true stomach” of the abomasum where they are destroyed by the strong acids, and then digested in the small intestine as microbial protein.



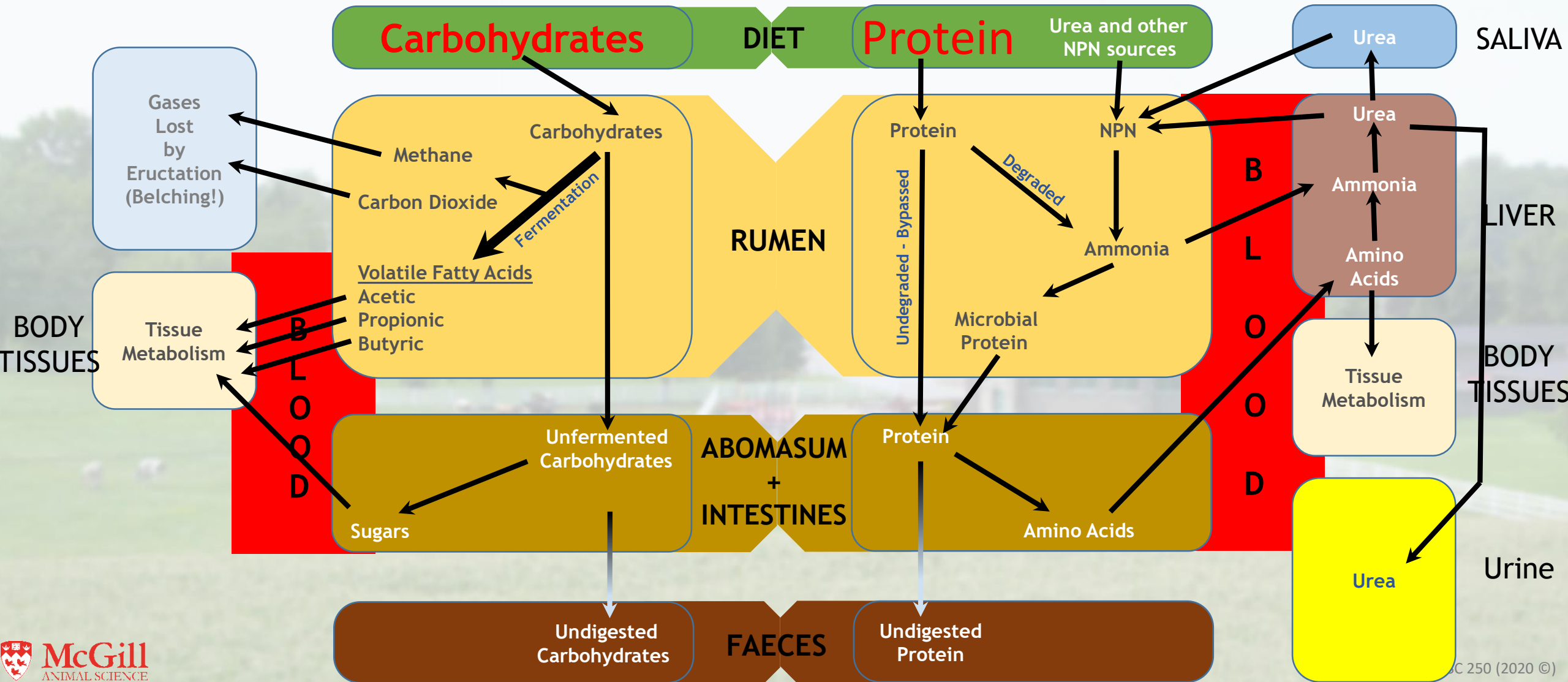
# Digestion and Utilization of Nutrients by Ruminants



This slide is *more* detail than needed... See next slide for simplified version

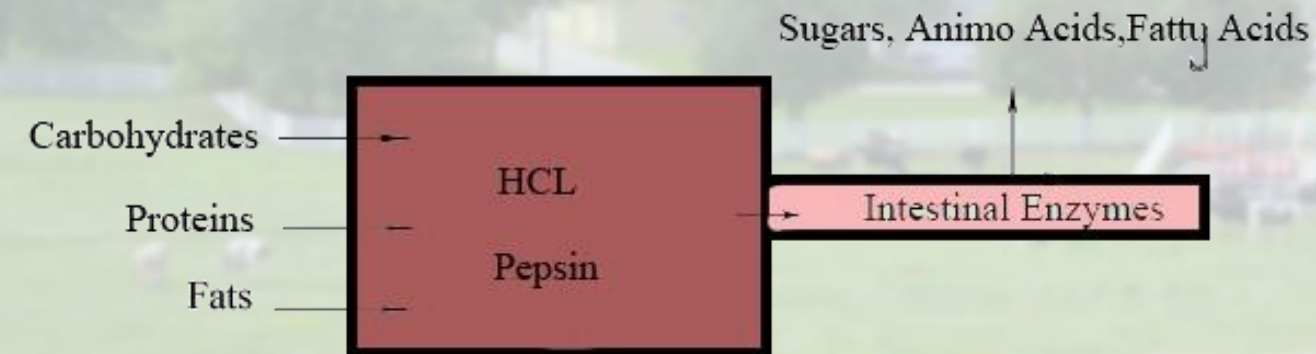
# Digestion and Utilization of Nutrients by Ruminants

Adapted from [www.RCVets.com](http://www.RCVets.com)



# Monogastric versus Ruminant Digestion

## Monogastric (e.g., pig)



## Ruminant (e.g., sheep)

