The Digestive System for Young Nursing Ruminants…

- Young nursing ruminants do not consume plant forage – only milk;
- Milk is important in terms of early nutrition, health, and immunity;
- “Destruction” of the milk by microbes in the rumen would be detrimental to the health of the young;
- Nature’s solution?? A “bypass”!

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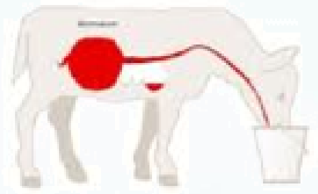
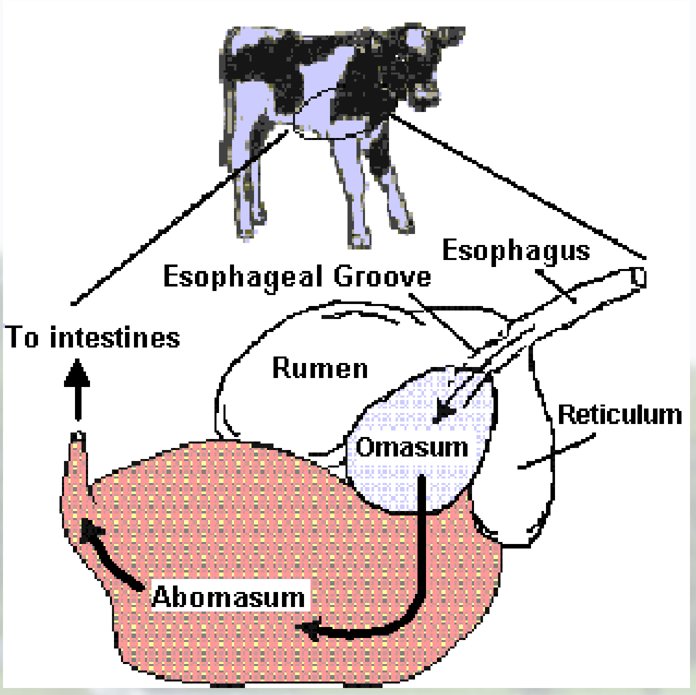
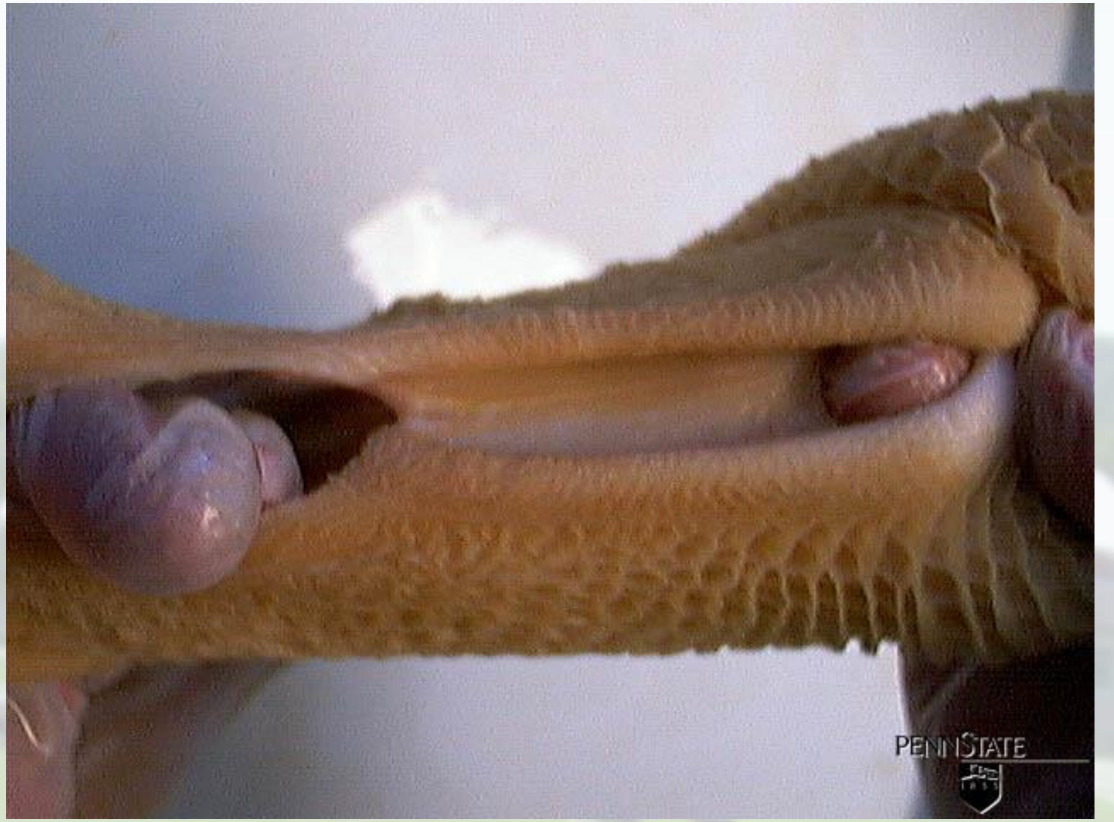
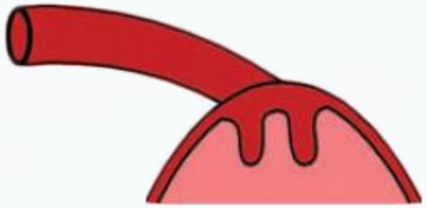
The *Esophageal Groove*





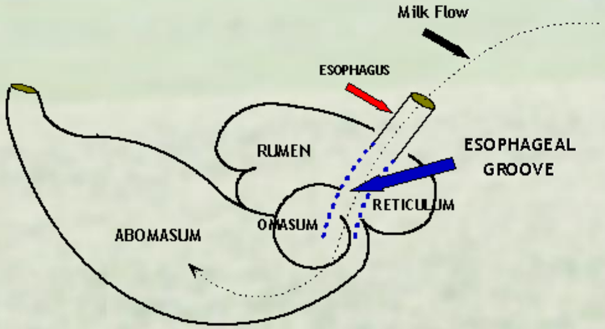




While Milk is still the (sole) diet of the young (before weaning), it is not ideal for the milk to enter the rumen. Rather, it is desirable for it to pass directly to the "stomach".

A combination of factors such as suckling, the presence of milk proteins and "anticipation" result in neural responses that cause muscular folds in the reticulo-rumen to form a groove that extends from the esophagus to the abomasum, and allows milk and milk replacer to bypass the rumen, reticulum and omasum, and to flow directly into the abomasum.

www.merricks.com



http://www.das.psu.edu/research-extension/dairy/nutrition/calves/rumen

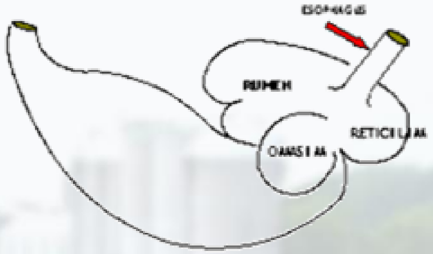
The Esophageal groove

https://www.youtube.com/watch?v=oe9LXVB36T8&index=2&list=PL92593B40D3C053FF

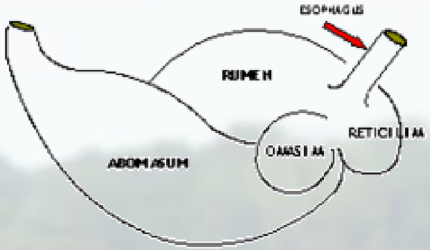
https://www.youtube.com/watch?v=6vrqjqnjMAU

Relative Size of Stomach Compartments in Cattle from Birth To Maturity

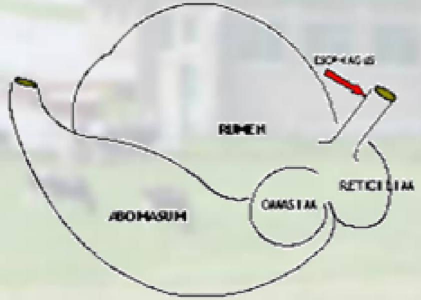
Age	Percentage Of Stomach Capacity	
	Abosmasum (“true” stomach)	Rumen/Reticulum/ Omasum
Birth to 2 weeks	70	30
8 weeks	50	50
3 - 4 months	25	75
Maturity	<10	>90



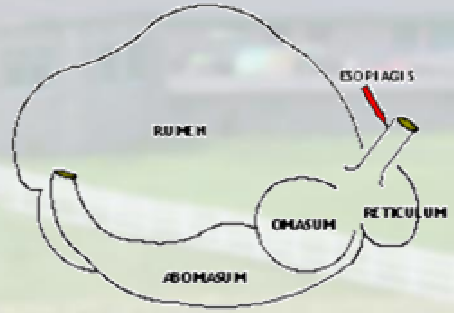
Birth to 2 weeks



8 weeks

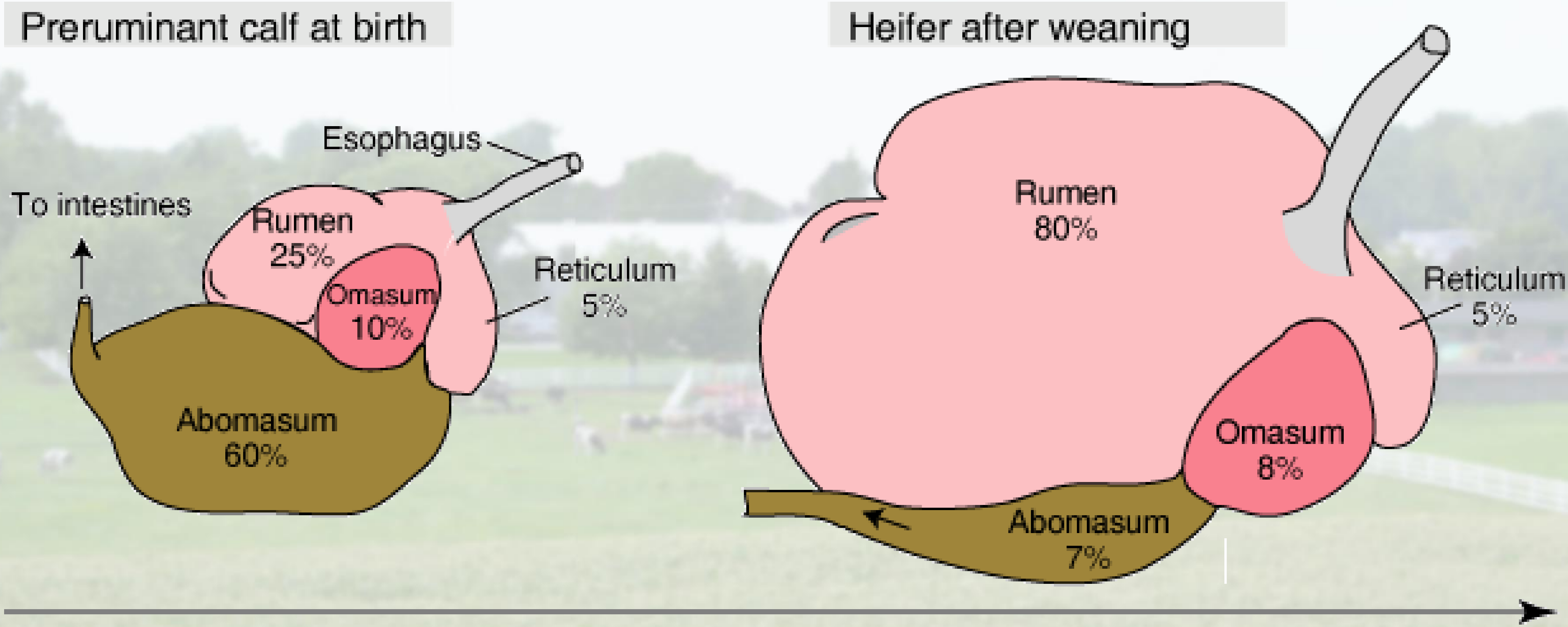


3 – 4 months



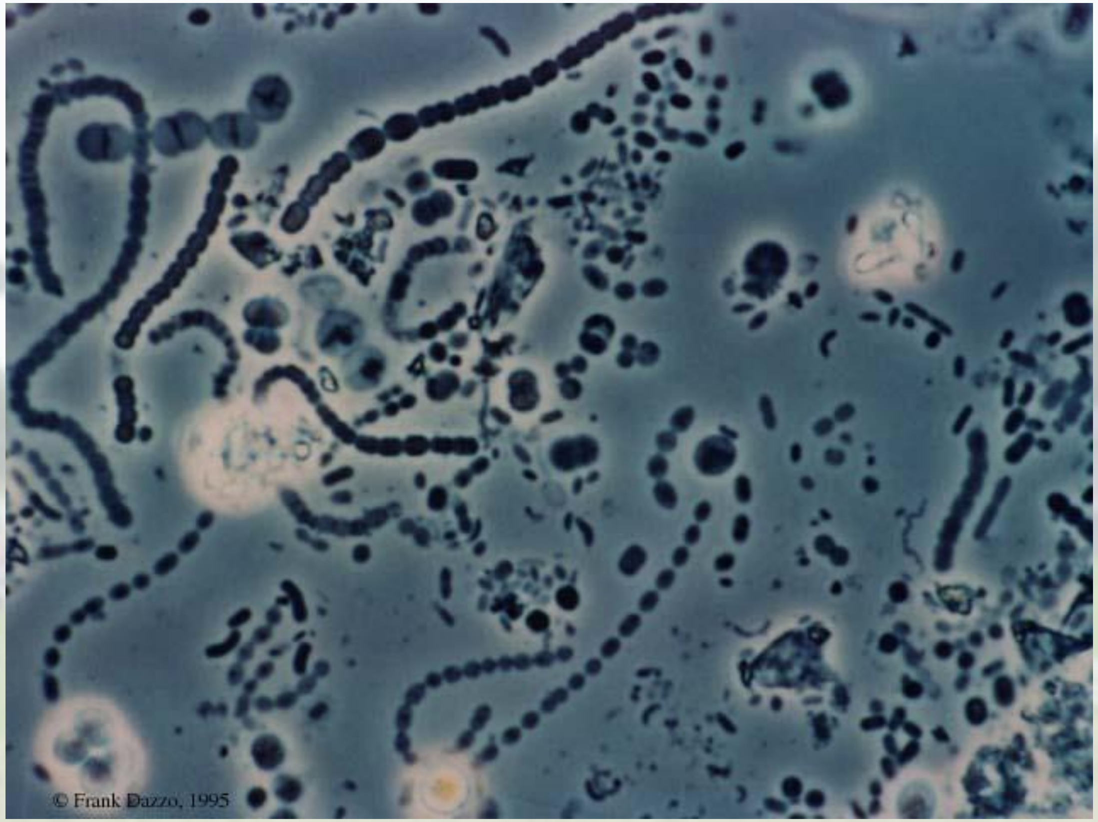
Mature

The Rumen – Birth to Weaning



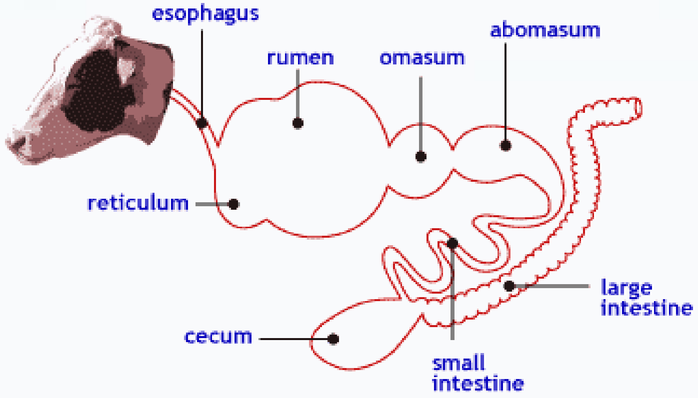
Development of a well-functioning rumen

- Establishment begins as early as 1-3 weeks after birth, and is well developed by 6-9 weeks of age
- Sources:
  - Food & water
  - Contact with other animals
- Anaerobic bacteria are important for carbohydrate fermentation
- The rumen has to be fully functional before the young animal is weaned
- The rumen has to go through anatomical and physiological changes to be functional

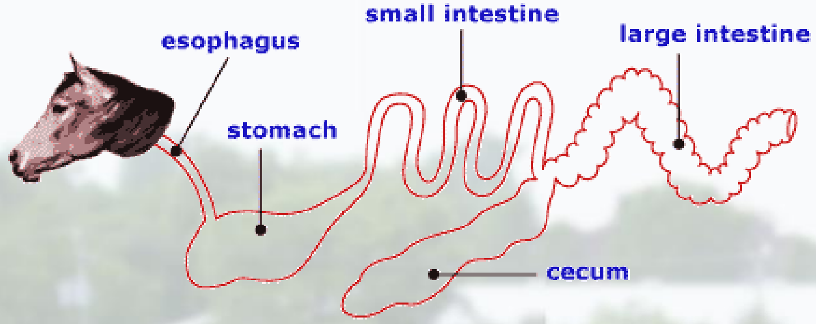


Rumen symbiants
(protozoa, fungi, eubacteria, Methanosarcina)

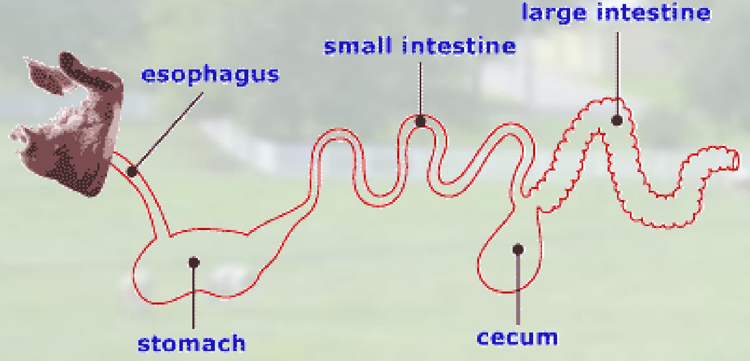
Which is the more desirable rumen?

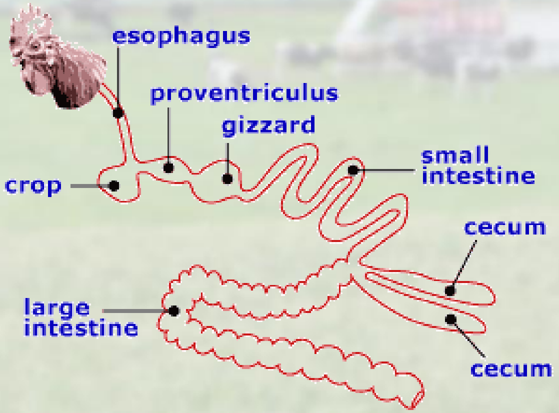


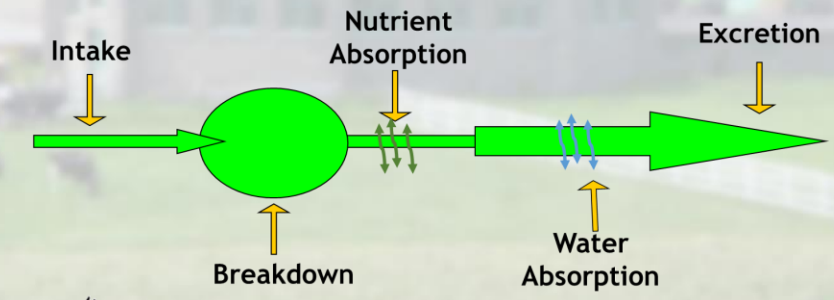
Comparative capacity of the gastro-intestinal tract of different species



Species	Relative Capacity (%)			
	Stomach	Small Intestine	Cecum	Colon & Rectum
Cattle	71	18	3	8
Sheep	67	21	2	10
Horse	9	30	16	45
Pig	29	33	6	32
Dog	63	23	1	13
Human	17	67		17







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Courtesy of Fench, Oregon State University

Animal Nutrition

1. Digestive tract and digestion in monogastrics, birds, and ruminants
2. **Digestible Energy of Nutrients**
3. Feedstuffs
4. Feeds analyses and Ration Formulation

The Need for Energy

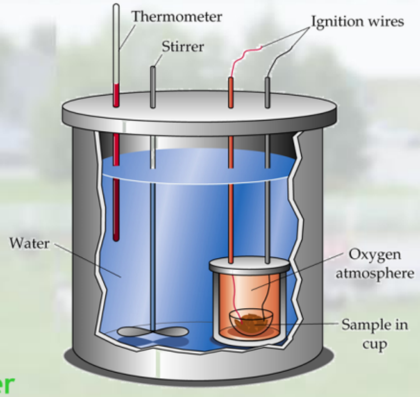
- All animals need energy for the basic body functions:
    1. for the mechanical work of essential muscular activity;
    2. for chemical work such as the movement of dissolved substances across concentration gradients; and
    3. for the synthesis of replacement body constituents, enzymes, and hormones
- An animal that is deprived of food continues to require energy for the basic functions: in this ("starving") condition the energy will need to come from the animal's own body reserves:
    1. Glycogen; followed by
    2. Fat; followed by
    3. Protein
- The minimum goal of the energy fed is one of meeting the requirement for body maintenance and so preventing the catabolism of the animal's tissues.

Feed Intake

Gross Energy

- We can measure Energy in terms of <u>heat</u> (1 calorie is defined as the amount of energy needed to raise 1 gram of water from 16.5ºC to 17.5ºC) ***or*** in terms of <u>work</u> (1 joule is defined as the work done when a force of 1 newton acts through a distance of 1 metre, or when 1 amp passes through a resistance of 1 ohm for 1 second)
- 1 calorie is equivalent to 4.184 joules
- The rupture of each high-energy bond (ATP → ADP → AMP) yields approximately 50KJ (i.e., 50,000 joules) but up to 60% of this can be lost in heat.

- Gross Energy is measured as the heat resulting from the complete oxidation of a known weight by burning it - normally determined by using a bomb calorimeter.



Typical Gross Energy values...

- CHOs range from 16 to 18MJ/kg (dry matter)
- Fats range from 36 to 42MJ/kg (dry matter)
- Proteins range from 23 to 25MJ/kg (dry matter)

Remember Fats have approx 2¼ energy of CHO

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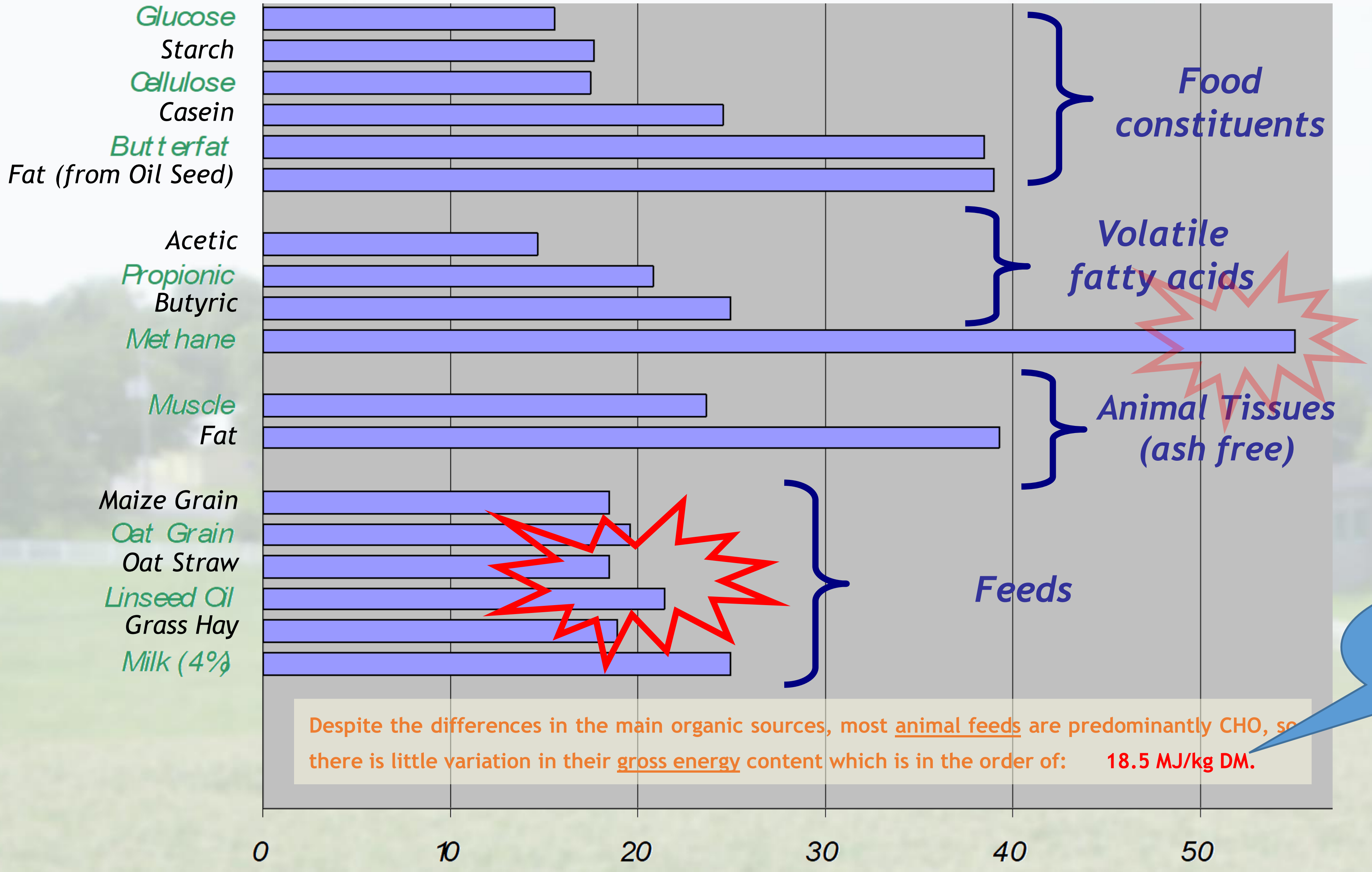
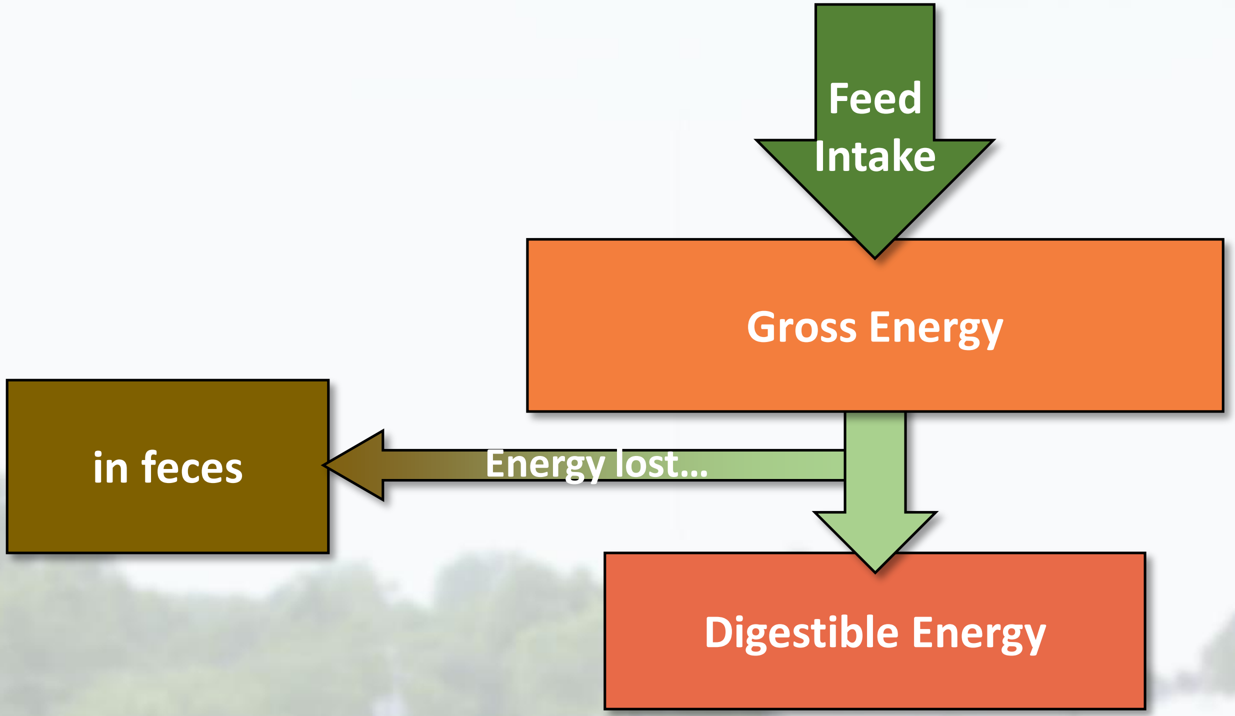
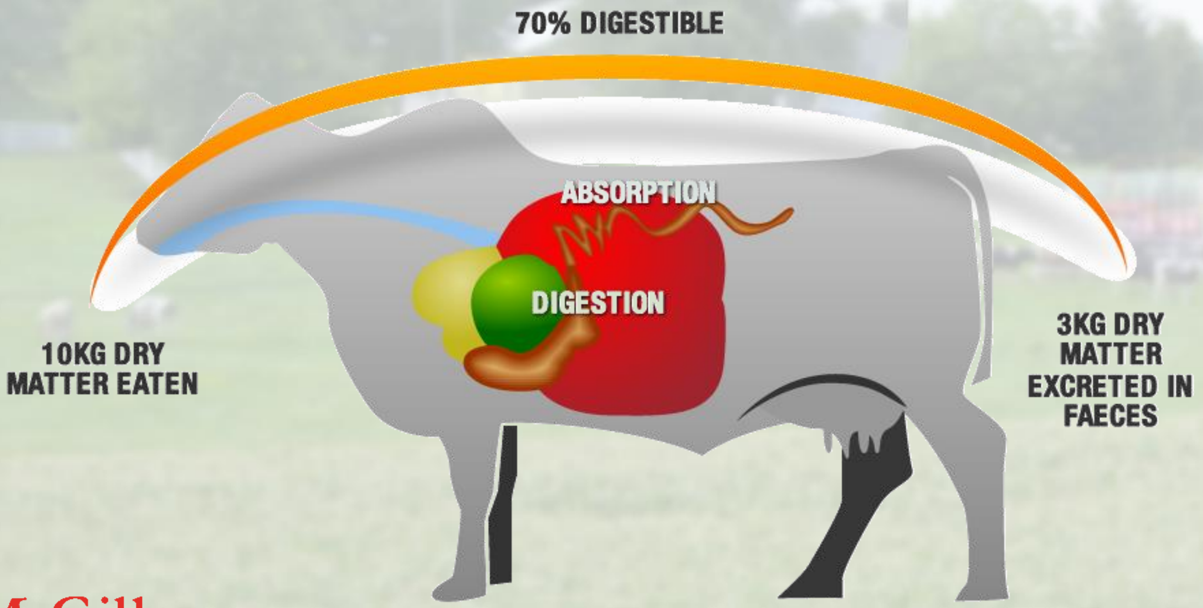
Some typical gross energy values (MJ/kg DM)



Despite the differences in the main organic sources, most animal feeds are predominantly CHO, so there is little variation in their gross energy content which is in the order of: **18.5 MJ/kg DM.**

Rule of Thumb



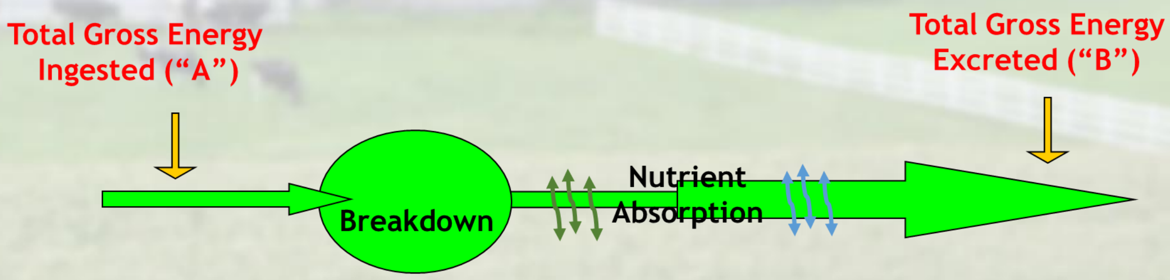


- Digestibility refers to the amount of the various nutrients in a feed that can be absorbed from the digestive tract.

- It is normally expressed on a dry matter (DM) basis.

- Different feeds and nutrients *vary* in their digestibility.

- The difference between ***total*** nutrients fed and ***total*** nutrients excreted in the feces is the *apparent digestible energy*.



Apparent **DE = Total Energy Intake – Total Energy Excreted**

"A" – "B"

Energy in Feeds…

- **<u>Gross Energy</u>** is a good indicator of the energy of food substances but is not an accurate measure of the energy actually available to the animal.

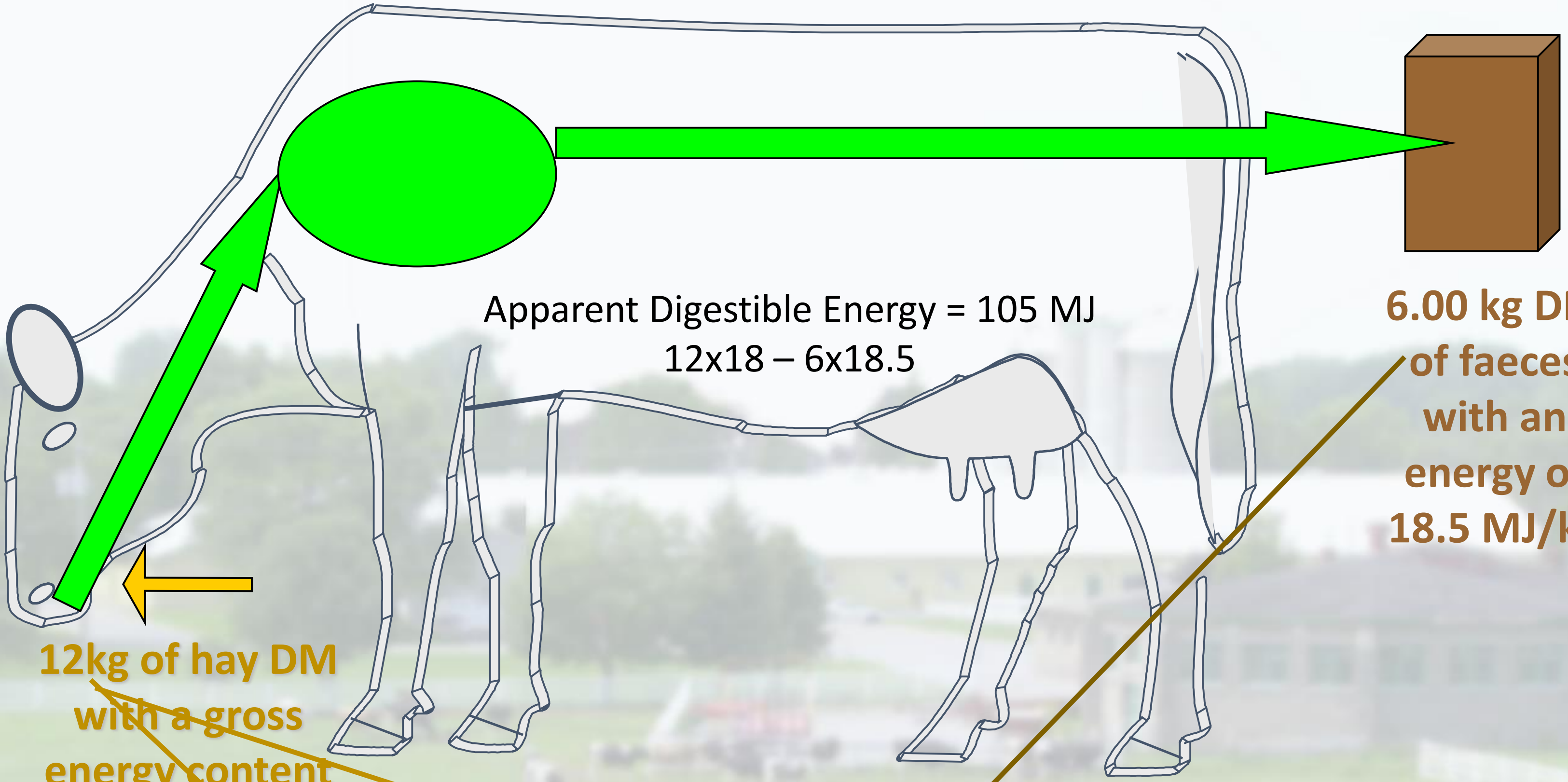
- Apparent Digestible Energy is simply the total Gross Energy fed minus the total energy in the faeces (due to the input of that food).

- **<u>Digestible Energy</u>** takes account of the first major source of energy losses - the faeces

- Digestible Energy is the Gross Energy X the efficiency of digestion (a multiplicative factor).

An Example from a Digestibility Trial:

Calculating Digestible Energy

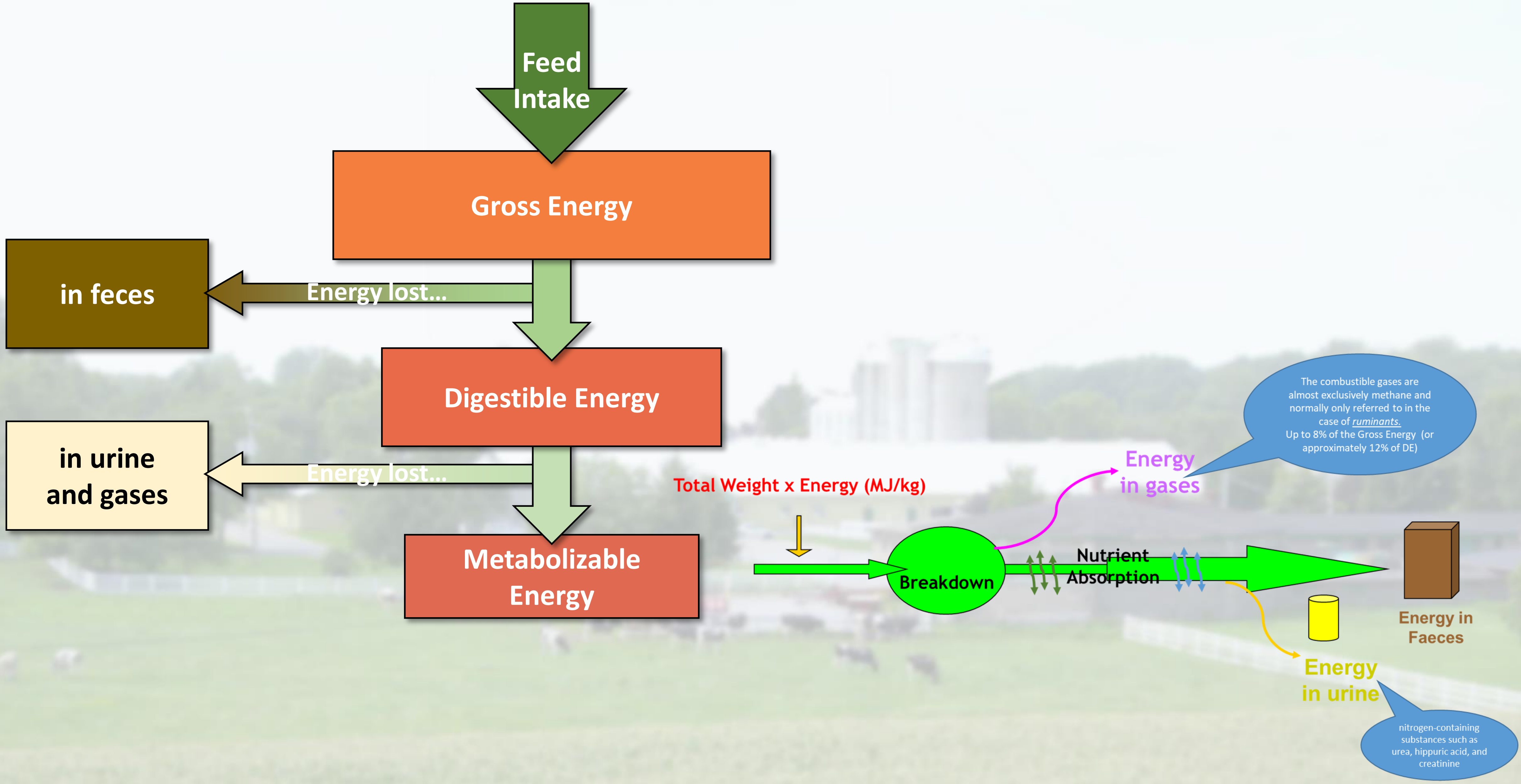


12kg of hay DM with a gross energy content of 18.0 MJ/kg

6.00 kg DM of faeces with an energy of 18.5 MJ/kg

Efficiency of digestion = [(12.00 x 18.0) - (6.00 x 18.5)] / (12.00 x 18.0) = 0.486

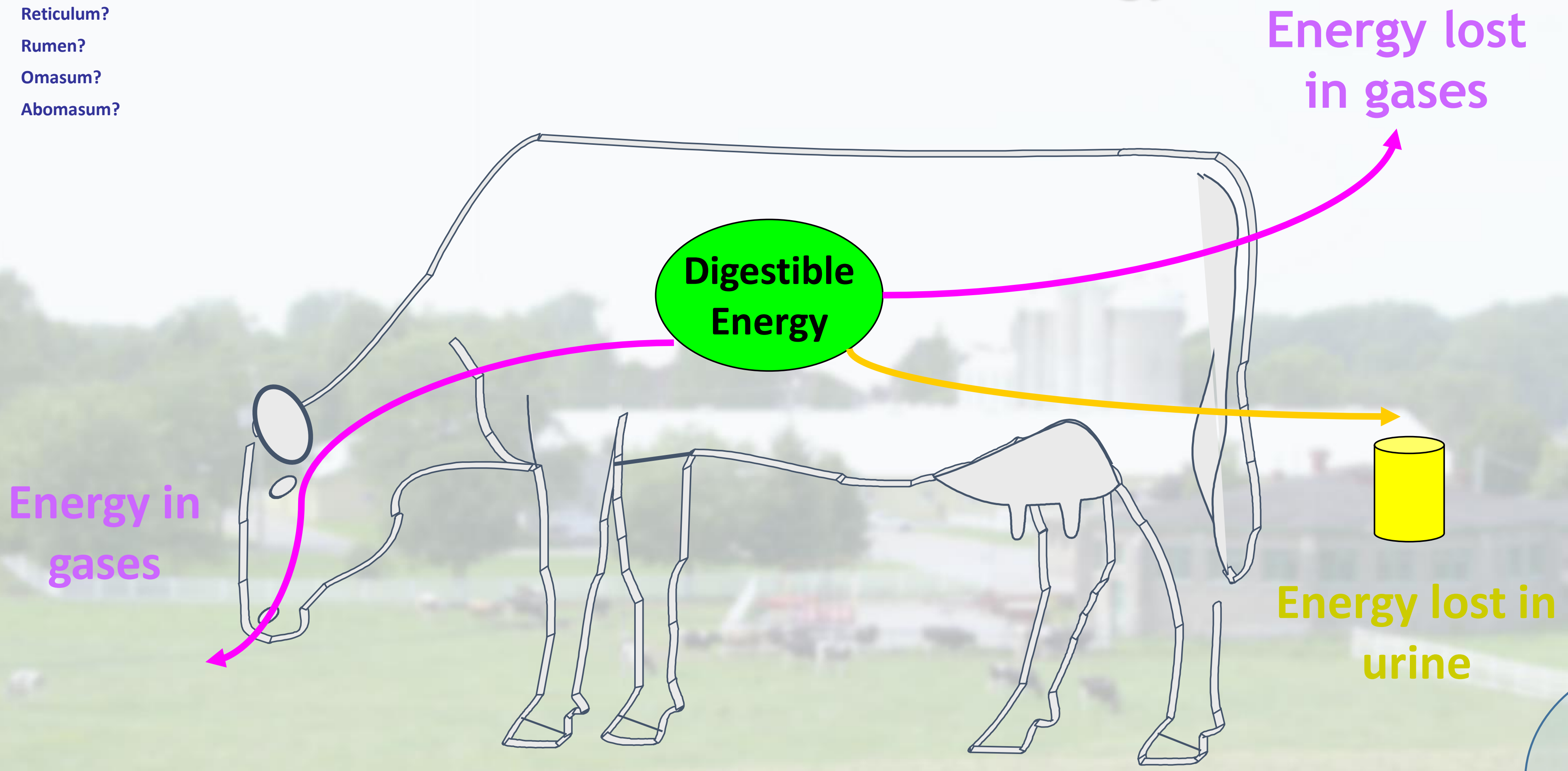
Digestible Energy = 18 x 0.486 = 8.75 MJ/kg


Feed Intake
Gross Energy
Energy lost...
in feces
Digestible Energy
Energy lost...
in urine and gases
Metabolizable Energy
Total Weight x Energy (MJ/kg)
Breakdown
Nutrient Absorption
Energy in gases
The combustible gases are almost exclusively methane and normally only referred to in the case of ruminants. Up to 8% of the Gross Energy (or approximately 12% of DE)
Energy in Faeces
Energy in urine
nitrogen-containing substances such as urea, hippuric acid, and creatinine

Metabolisable Energy

Gas "expelled" by?

a) Reticulum?
b) Rumen?
c) Omasum?
d) Abomasum?



Rule of Thumb for *Ruminants*

Metabolisable Energy (ME) = Digestible Energy - Urine/Gas Energy

ME ≈ DE x 0.82 (rule of thumb)

Metabolisable energy values of some typical feeds

MJ / kg of Feed Dry Matter (DM)

			Energy lost in:			
Animal	Food	Gross Energy	Faeces	Urine	Methane	ME
Fowl	Maize	18.4	2.2		-	16.2
	Wheat	18.1	2.8		-	15.3
	Barley	18.2	4.9		-	13.3
Pig	Maize	18.9	1.6	0.4	-	16.9
	Oats	19.4	5.5	0.6	-	13.3
	Barley	17.5	2.8	0.5	-	14.2
Sheep	Barley	18.5	3.0	0.6	2.0	12.9
	Dried rye grass (young)	19.5	3.4	1.5	1.6	13.0
	Dried rye grass (mature)	19.0	7.1	0.6	1.4	9.9
	Grass Hay (young)	18.0	5.4	0.9	1.5	10.2
	Grass Hay (mature)	17.9	7.6	0.5	1.4	8.4
	Grass silage	19.0	5.0	0.9	1.5	11.6
Cattle	Maize	18.9	2.8	0.8	1.3	14.0
	Barley	18.3	4.1	0.8	1.1	12.3
	Wheat bran	19.0	6.0	1.0	1.4	10.6
	Lucerne hay	18.3	8.2	1.0	1.3	7.8

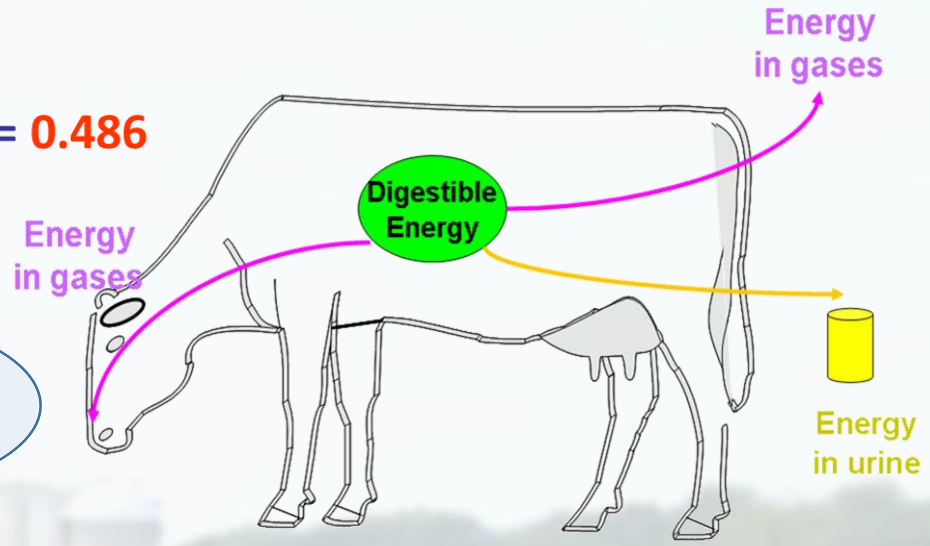
Gross Energy = 18.0MJ/kg

Efficiency of digestion = [(12.00 x 18.0) - (6.00 x 18.5)] / (12.00 x 18.0) = 0.486

Digestible Energy = 18 x 0.486 = 8.75 MJ/kg

Metabolisable Energy = DE x 0.82 = 7.175MJ/kg

Rule of Thumb for Ruminants



Sample Problem:

Input: 4kg of Maize with 18.9 MJ/kg DM

Output: 1.8 kg of faeces with 18.6MJ/kg DM

What is the Metabolisable Energy of this Maize (MJ/kg)?

Answer:

8.63MJ/kg or a total of 34.52MJ

= {[(4 x 18.9) – (1.8 x 18.6)] / (4 x 18.9)} x 18.9 x 0.82

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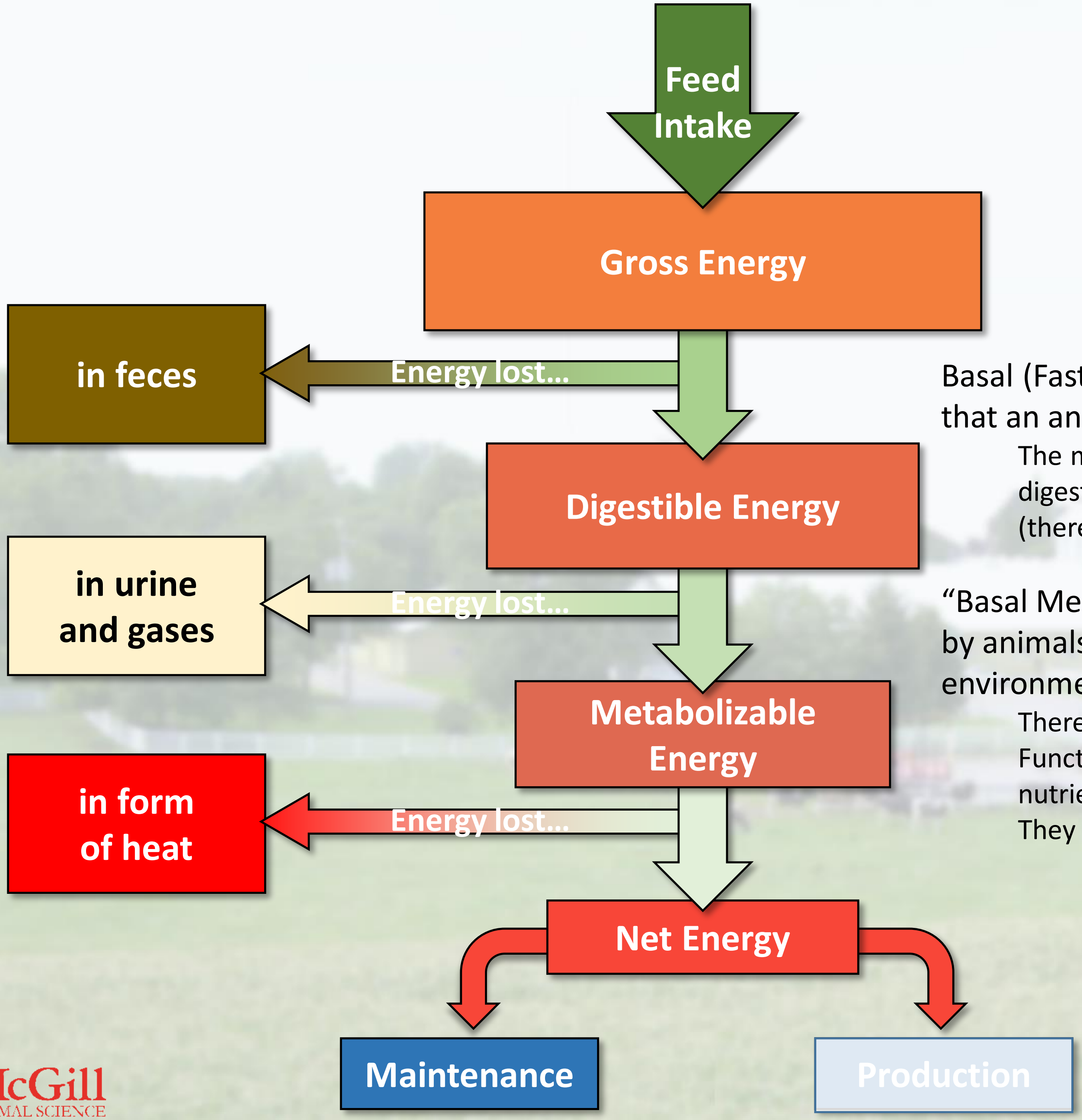


Basal (Fasting) Metabolism is an estimate of the quantity of net energy that an animal needs in order to meet its demands for maintenance.

The measurement is complicated by heat that is produced from the digestion and metabolism of food and also voluntary muscular activity (therefore, normally estimated after a period of fasting).

"Basal Metabolic Rate (BMR) is the amount of daily energy expended by animals at rest. Rest is defined as existing in a neutrally temperate environment while in the post-absorptive state."

There is no gain or loss in the weight or production of an animal.

Functions with a high nutrient need receive that receive priority in terms of nutrient utilization, and can range from 40% to 90%.

They include:

- Body tissue repair
- Control of body temperature
- Energy to keep vital organs functioning
- Water balance maintenance

Kleiber's law…

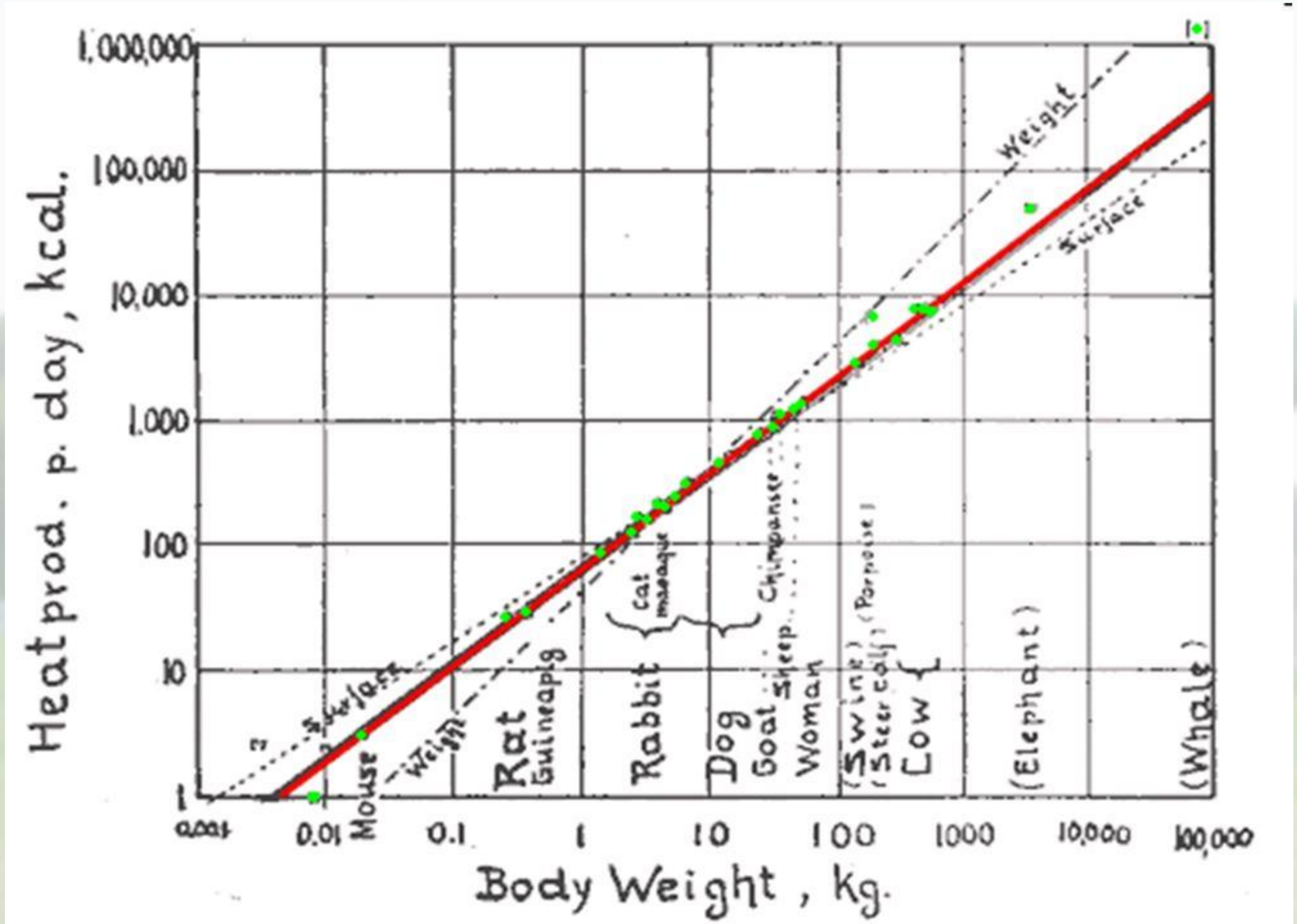


Fig. 1. Log. metabol. rate/log body weight

Wikipedia

Think of Metabolic Weight **[i.e., (Weight)$^{0.75}$]** as "active" weight.

As an example, a bull could be 10 times heavier than a pig, but its metabolism would only be roughly 6 times greater.

Body size versus metabolic rate for a variety of species. Originally published in Kleiber (1947).

Some typical values for fasting (basal) metabolism in adult animals of various species

In other words, how much energy does an animal need when "at rest"?

These values will vary due to age and sex of the animal even *within* a species.

Animal	Average Weight (kg)	Basal / Fasting Metabolism (MJ/day): Per animal (MJ/day)	Per kg liveweight	Per sq. metre surface area	Per kg $W^{0.75}$
Cow	500	34.10	0.068	7.0	0.32
Pig	70	7.50	0.107	5.1	0.31
Human	70	7.10	0.101	3.9	0.29
Sheep	50	4.30	0.086	3.6	0.23
Fowl	2	0.60	0.300	4.6	0.36
Rat	0.3	0.12	0.400	3.6	0.30

0.3

How did we get this number?

$34.1 \ / \ 500^{0.75} = 0.32$MJ/day

which leads to the Rules of Thumb!

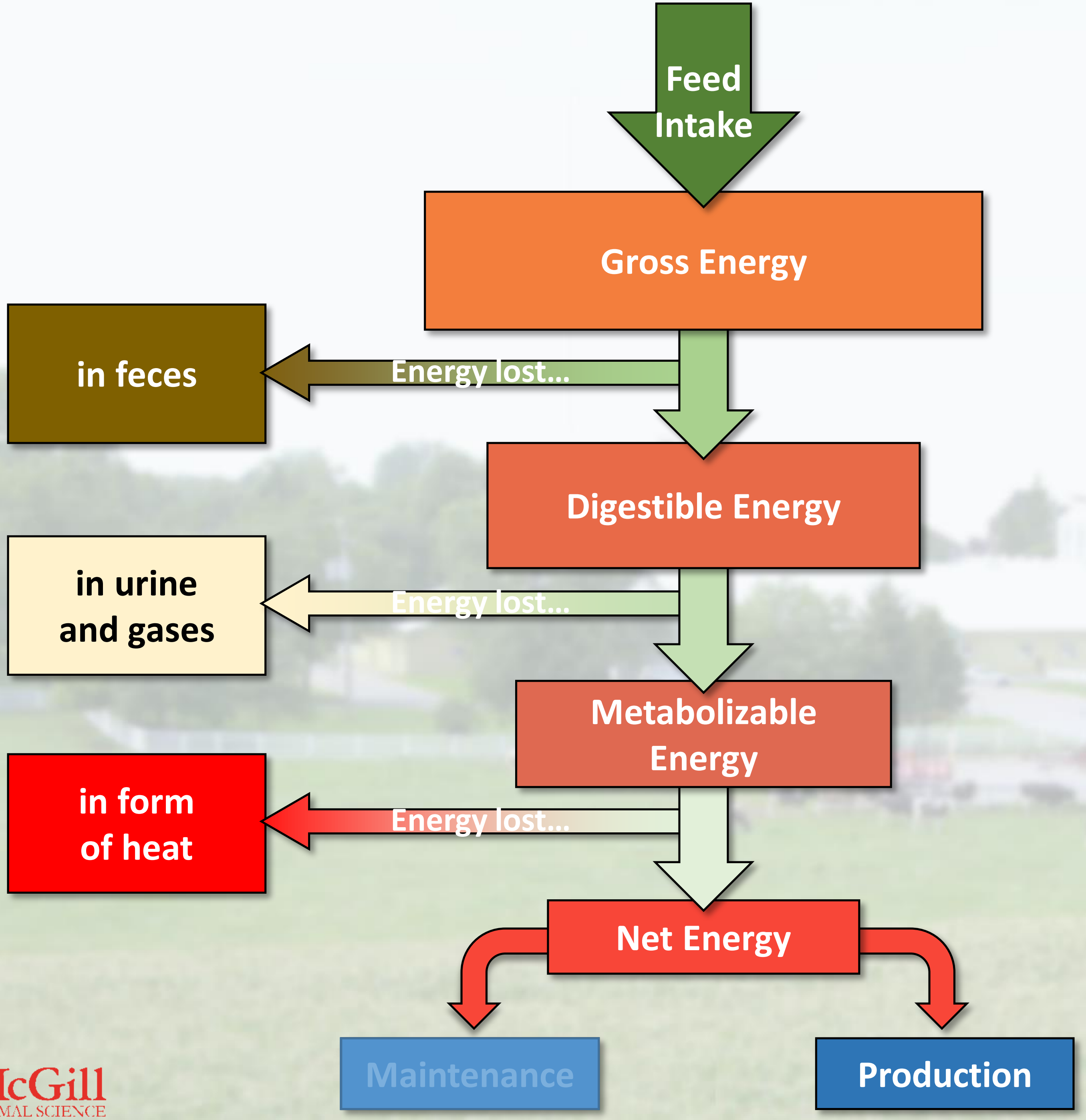
Basal Metabolism Requirements can be estimated as 0.3 x (Weight in Kg)$^{0.75}$ Mj/day

or 300 x (Weight in Kg)$^{0.75}$ kJ/day

or 70 x (Weight in Kg)$^{0.75}$ kcal/day

Remember: The rupture of each high-energy bond yields approximately 50kj (0.05MJ)

So this cow would require 682 (i.e., 34.1/0.05) high-energy bond ruptures for maintenance alone

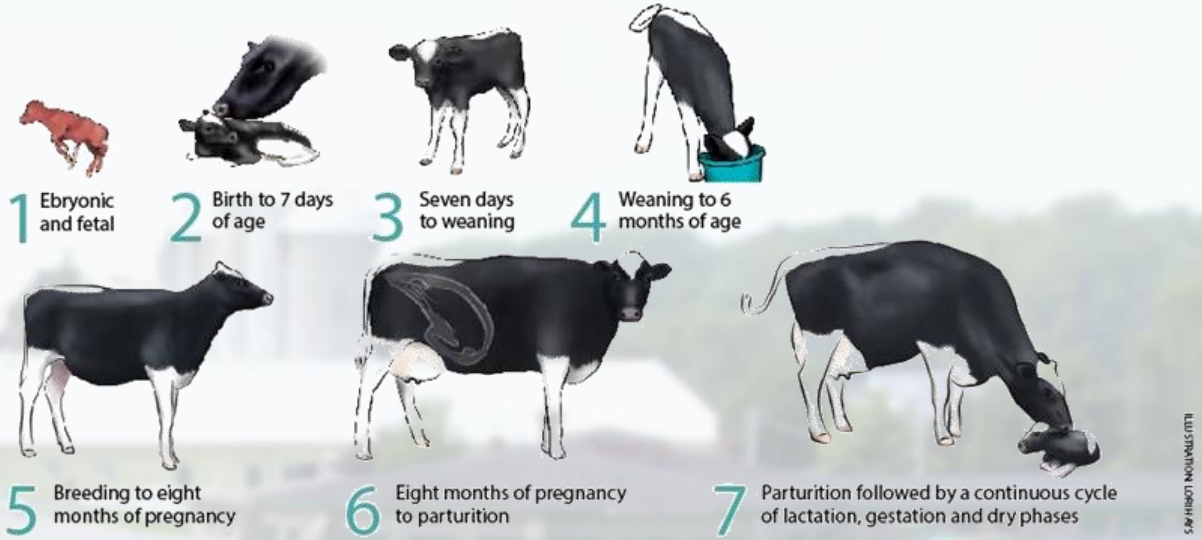


- In addition to Basal Metabolism, the various production systems require energy:
  - Growth
  - Fattening/Finishing
  - Reproduction
  - Lactation
  - Egg laying
  - Wool production
  - Work/Exercise
- Each of these functions can have a unique set of nutrient requirements, and are *additive* in cases of more than one function.

Body Functions that Require Energy

- In addition to Basal Metabolism

- **Growth**
- **Fattening/Finishing**
- **Reproduction**
- **Lactation**
- **Egg laying**
- **Wool production**
- **Work/Exercise**



Each of these functions can have a unique set of nutrient requirements, and are <u>*additive*</u> in cases of more than one function.