Animals in Health & Disease

Veterinary Parasitology

Pasture-borne Nematodes

Nematodes
(aka Roundworms)

Strongylids
(Bursate Nematodes)

Trichostrongyles
- *Haemonchus*
- *Ostertagia*
- *Trichostrongylus*
- *Cooperia*
- *Dictyocaulus*

Strongyles
- *Strongylus*
- Small Strongyles
- *Oesophagostomum*
- *Syngamus*

Metastrongyles
- *Metastrongylus*
- *Aelurostrongylus*

Ancylostomes
(hookworms)
- *Ancylostoma*
- *Uncinaria*

Rhabditids
- *Strongyloides*

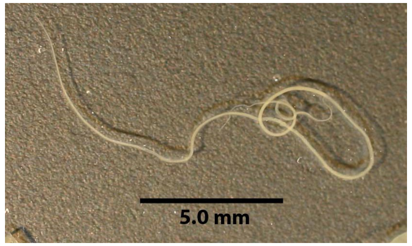
Oxyurids
- *Oxyuris*

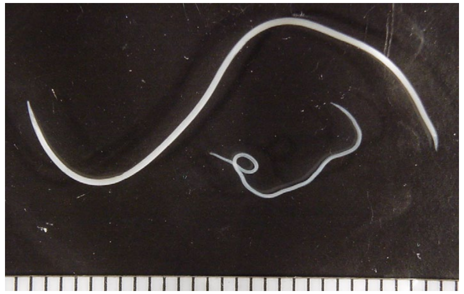
Ascarids
- *Toxocara*
- *Baylisascaris*
- *Parascaris*
- *Ascaris*
- *Ascaridia*
- *Heterakis*

Enoplids
- *Trichinella*
- *Trichuris*
- *Capillaria*
- *Dioctophyme*

Spirurids
- *Physaloptera*
- *Habronema*
- *Draschia*
- *Dracunculus*

Filarids
- *Onchocerca*
- *Acanthocheilonema*
- *Dirofilaria*





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Nematodes by Primary Clinical Sign

Enteritis / Diarrhea
- Strongylids
  - Trichostrongyles
    - *Ostertagia*
    - *Trichostrongylus*
    - *Cooperia*
  - Strongyles
    - *Strongylus*
    - Small Strongyles
    - *Oesophagostomum*
- Rhabditids
  - *Strongyloides*
- Enoplids
  - *Trichuris*
- Ascarids
  - *Toxocara*
  - *Baylisascaris*
  - *Parascaris*
  - *Ascaris*
  - *Ascaridia*
  - *Heterakis*

Gastritis
- Spirurids
  - *Physaloptera*

Anemia
- Strongylids
  - Trichostrongyles
    - *Haemonchus*
  - Ancylostomes
    - *Ancylostoma*
    - *Uncinaria*

Vascular
- Spirurids
  - Filarids
    - *Dirofilaria*
    - *Acanthocheilonema*

Respiratory
- Strongylids
  - Trichostrongyles
    - *Dictyocaulus*
  - Strongyles
    - *Syngamus*
  - Metastrongyles
    - *Metastrongylus*
    - *Aelurostrongylus*
- Enoplids
  - *Eucoleus*

Miscellaneous
- Enoplids
  - *Trichinella*
  - *Dioctophyme*

Dermatitis
- Oxyurids
  - *Oxyuris*
- Spirurids
  - *Dracunculus*
  - *Habronema*
  - *Draschia*
  - Filarids
    - *Onchocerca*

[ ] = Pasture-borne nematodes

VETERINARY PARASITOLOGY GROUP CVM-NCSU HOST PARASITE

PASTURE-BORNE NEMATODES

IMPORTANT CONCEPTS

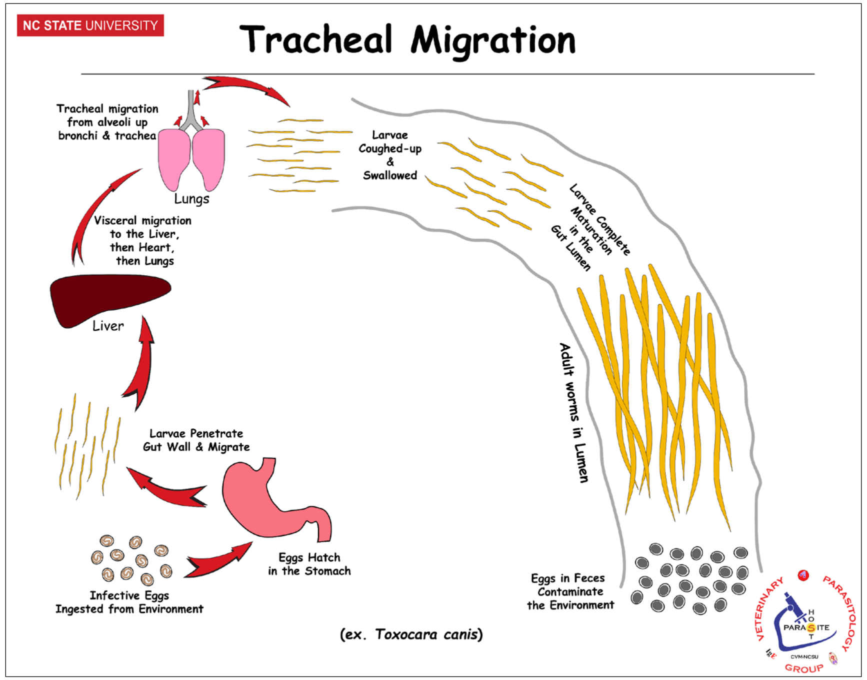
Take Home's

- Understand and be able to utilize important concepts influencing Pasture-borne Nematodes and their biology, treatment, control / management. Specifically:
  - Mucosal Migration of Parasite Larvae
  - Premunition
  - Anthelminthic Resistance
  - Refugia

Important Concepts For Pasture-borne Nematodes

- Larval Migration
  - Tracheal Migration
  - Somatic Migration
  - Mucosal Migration
    - Important for pasture-borne nematodes
- Premunition
- Anthelmintic Resistance
- Refugia

Nematode Larval Migrations



Tracheal Migration

Infection → Liver → Lungs
→ Adult worms in Intestine

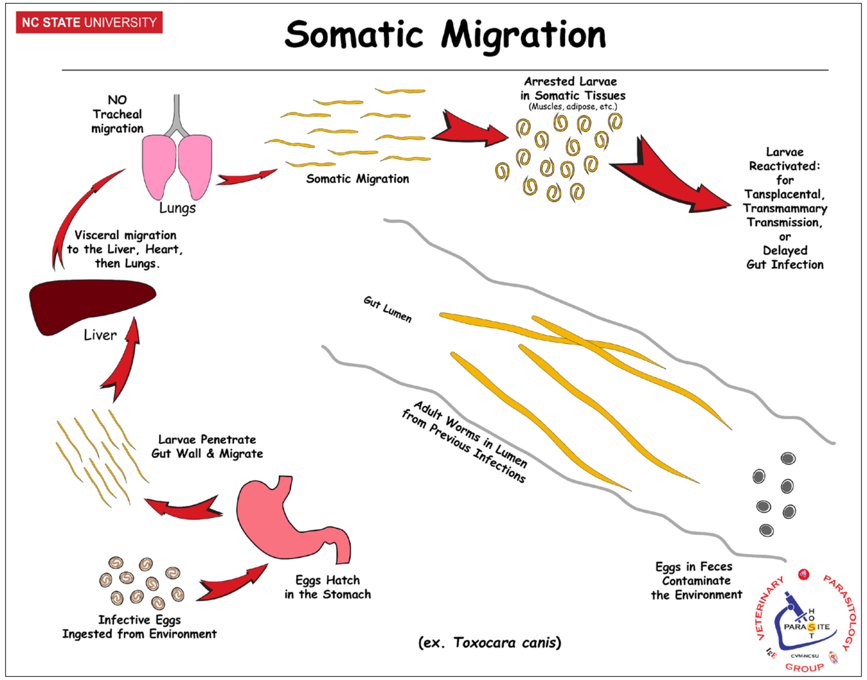
Ex. *Toxocara canis* in puppies
Ex. *Ascaris suum* in pigs

Somatic Migration

Infection → Somatic Tissue →
Arrested Larvae wait for Reactivation

Ex. *Toxocara canis* in adult dog
Ex. *Strongyloides westeri* in mare

Is also important in paratenic hosts for an alternative route to the definitive host



Nematode Larval Migrations

Mucosal Migration

Infection → Intestinal Mucosa → Adult worms in Gut Lumen

Ex. *Ostertagia sp.* in cattle
Ex. Small strongyles in horses
Ex. *Haemonchus sp.* in s. ruminants

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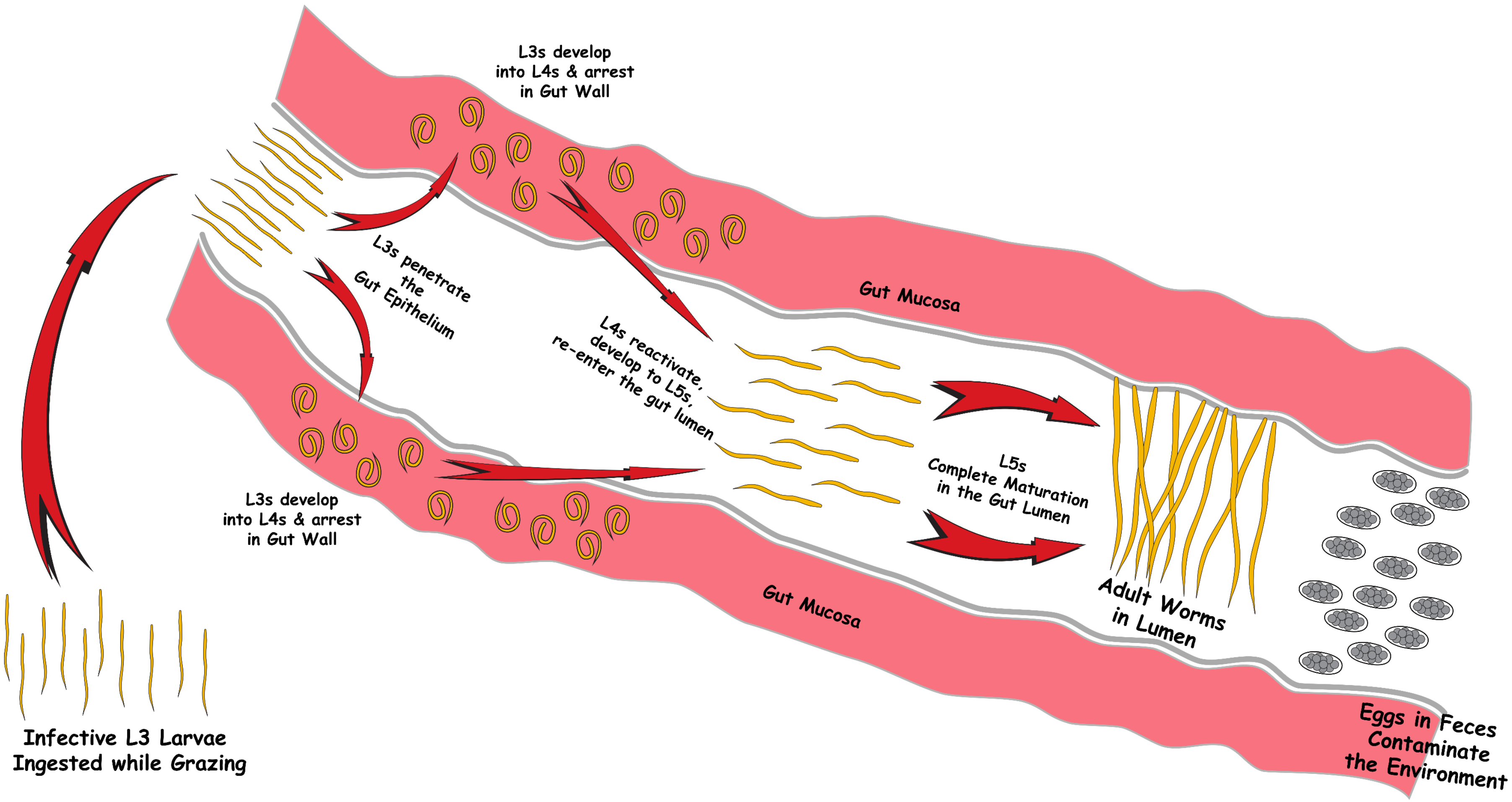
Mucosal Migration



(ex. Small Strongyles)

Nematode
Larval Migrations

Larval Migrations of various nematodes play important roles in transmission, pathology, and treatment.

- Tracheal Migration: After infection, larvae migrate by the blood stream to the liver, then to the alveoli in the lungs, move up (or coughed up) the trachea to the pharynx, where they are swallowed and mature into adult worms in the small intestine. (aka Hepatotracheal migration)
  - Tracheal Migration occurs in immuno-naïve neonates:
    - Important for *Toxocara sp., Ancylostoma sp., & Strongyloides sp.*
  - Tracheal Migration also occurs in immuno-competent livestock:
    - Important for *Ascaris suum* (swine) & *Parascaris equorum* (equine)
- Somatic Migration: After infection, larvae will be transported by systemic circulation to various organs and somatic tissues where they encyst as arrested larvae.
  - Somatic Migration occurs in immuno-competent pets and livestock:
    - Adult Hosts and Paratenic hosts
    - Important for *Toxocara sp., Ancylostoma sp., Strongyloides*
- Mucosal Migration: After infection, larvae migrate to the intestinal mucosa, where they encyst as arrested larva.
  - Mucosal Migration occurs in immuno-competent adult livestock:
    - Important for *Haemonchus, Ostertagia*, Small Strongyles

Premunition

- **Premunition** (or Concomitant Immunity)
  - A parasitological feed-back mechanism in which the adult population in the lumen inhibits the reactivation and emergence of the arrested larvae from the gut mucosa.
    - Prevents an overwhelming adult population that could kill the host. [Dead Host = Dead Parasite]
  - The danger of deworming is that the sudden death of the adult population in the gut lumen removes the premunition, resulting in massive numbers of arrested larvae emerging and doing pathologic damage to the intestine (tissue trauma, inflammation, diarrhea, hypoproteinemia).
- Important during the treatment of small strongyles in horses.
  - Utilize steroids with dewormer to decrease inflammation

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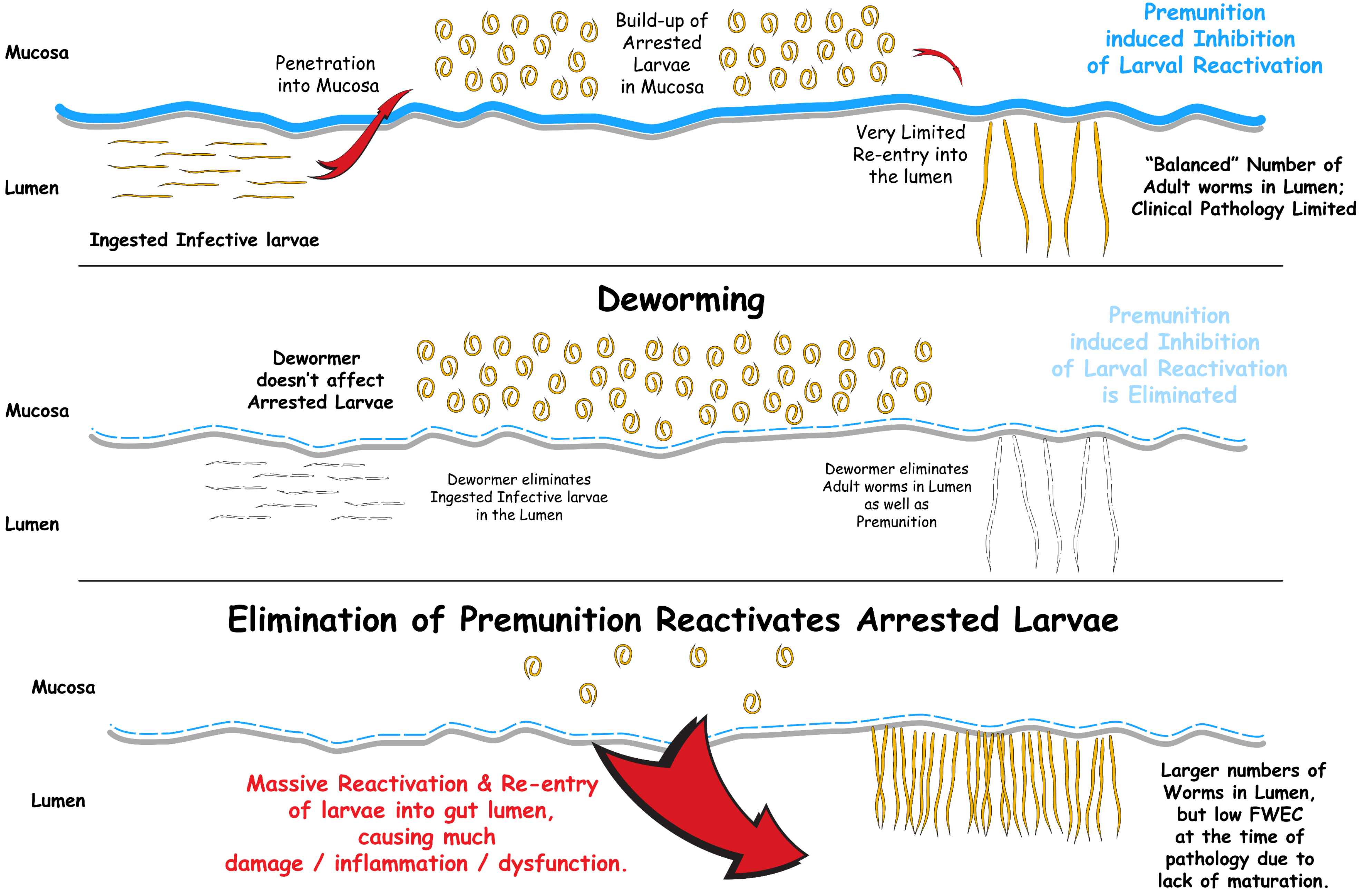
Parasite Population Balance via Premunition



VETERINARY PARASITOLOGY HOST PARASITE IgE CVM-NCSU GROUP

Anthelminthic Resistance

"**Resistance** is the **ability of worms in a population to survive treatments** that are generally effective against the same species and stage of infection. Anthelmintic resistance is **an inherited trait**. The development of resistance first **requires that resistance genes are present**. The **rate of development** of resistance is **determined by selection pressure** and the **extent to which worms surviving treatment pass their genes on to the next generation**. With **continued selection and reproduction of resistant worms, the frequency of resistance genes in the local worm population increases to the point where treatment fails.** Once resistance is present, the population of **resistant parasites do not appear to revert to susceptibility**, so the aims of resistance control are to prevent the first steps in the development of resistance and then to delay the accumulation of resistance genes." (AAEP Parasite Control Guidelines, 2019)

Resistance often develops due to too frequent use of dewormer or underdosing of dewormer.

Many anthelminthic drug classes (Benzimidazoles, Pyrimidines, Imidazothiazoles, Macrocyclic lactones) are generally affective against pasture-borne nematodes. **(Always check for extra-label use and withdrawal times.)**

- Benzimidazoles – Disrupts energy production and cell division.
- Pyrimidines – Causes depolarization paralysis.
- Imidazothiazoles – Causes depolarization paralysis.
- Macrocyclic lactones – Causes hyperpolarization paralysis.

Resistant Parasites avoid the physiological affects of a specific dewormer's mode of action.

Parasite Refugia

"<u>**Refugia**</u> refer to <u>**the portion of a population of parasites**</u> **(or stages of parasites) that** <u>**eludes the drug at the time of a treatment event**</u>. This sub-population includes stages of parasites in the host not affected by the treatment (e.g., encysted larvae when non-larvicidal treatments are used), all free-living parasite stages on the pasture, and all parasites in animals that were not treated. The higher the proportion of worms in refugia, the more slowly resistance develops. The <u>**worms in refugia are not under selection pressure for resistance**</u>, thus <u>**resistant worms remain diluted by susceptible worms**</u>, which continue to make up the majority of the worm population." (AAEP Parasite Control Guidelines, 2019)

Susceptible = worms that can be killed by a specific dewormer
Resistant = worms that cannot be killed by a specific dewormer

Susceptible worms v/s Resistant worms = "Good" worms v/s Bad worms

Refugia is the <u>susceptible</u> worms that are
 In Hosts: L4s & Adults
 On Pasture: Ova, L1, L2, L3

Terms / Concepts

Matching: Match each term with its corresponding concept.

A. Resistance **B.** Refugia **C.** Premunition **D.** Mucosal Migration

___ **1.** The portion of a population of parasites that eludes the dewormer at the time of a treatment event. Also known as the portion of a worm population that is susceptible to a dewormer.

___ **2.** The ability of worms in a population to survive treatments that are generally effective against that species of worm.

___ **3.** The loss of _________, may result in post-treatment pathology caused by the reactivation of arrested L4s after the elimination of adult worms via a deworming treatment.

___ **4.** Important biological event in the life cycle of Pasture-borne Nematodes, in which ingested larvae migrate to and may arrest in the wall of the host gut.

___ **5.** A parasitological feed-back mechanism in which the adult population in the lumen inhibits the reactivation and emergence of the arrested larvae.

___ **6.** Often caused by the over-use or under-dosing of a dewormer.

Pasture-borne Nematodes

A Pastoral Drama

Take Home's

- Understand what is meant by "Pasture-borne Nematodes".
- List and understand the goals for the control of Pasture-borne Nematodes.
- Understand and List what are the biological and environmental "players" of the Pasture-borne Nematode Ecology.

Goals of a Parasite Control Program v/s Pasture-borne Nematodes

The true goal of parasite control in pastured hosts is to keep animals healthy and reduce the risk of clinical illness. **The goal is NOT to eradicate all parasites from a particular individual.** Not only is eradication impossible; the inevitable result is accelerated development of parasite drug resistance. To achieve good parasite control, one must prevent contamination of the pasture with high numbers of parasite eggs and larvae. (AAEP Parasite Control Guidelines, 2024)

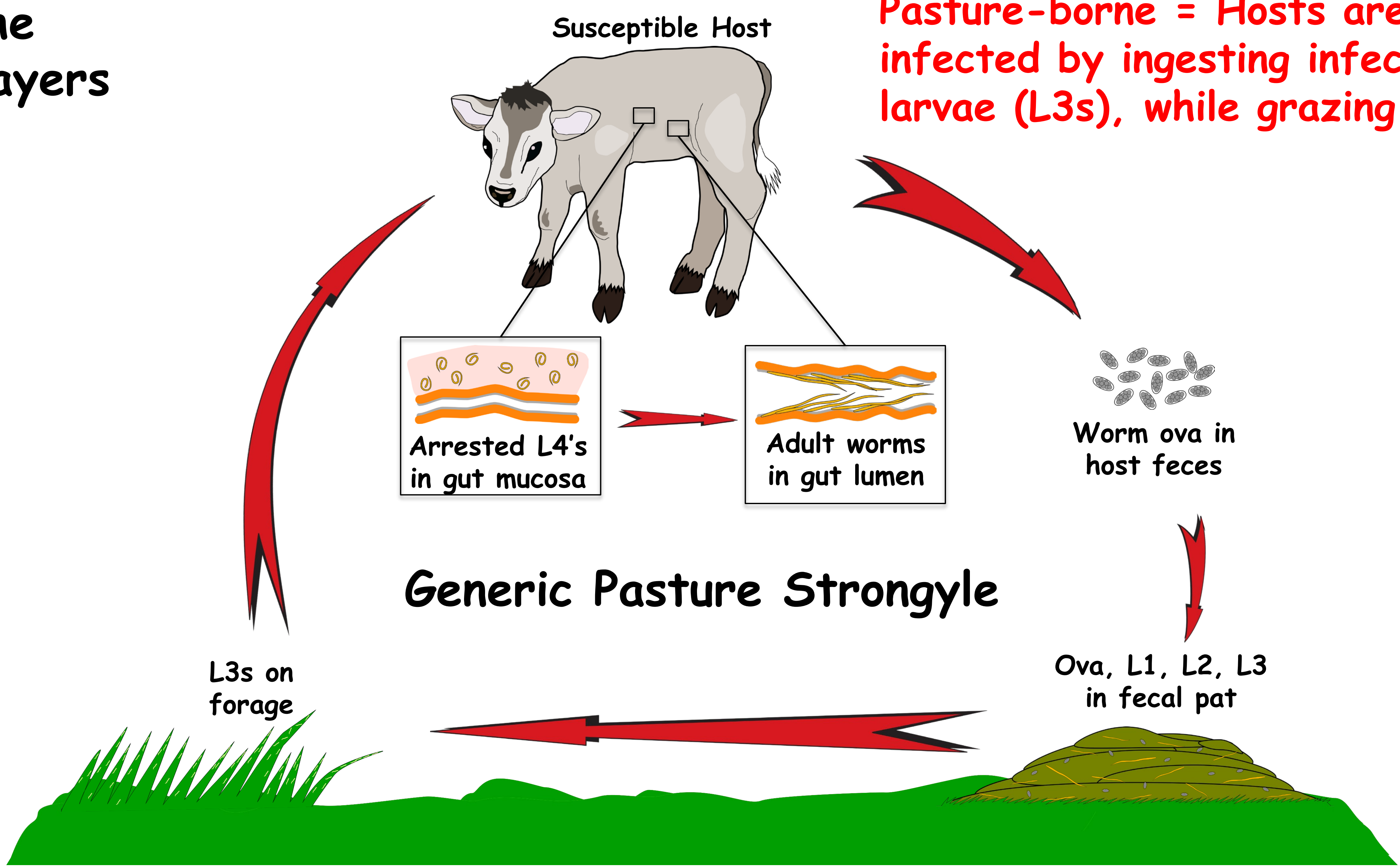
The goal of any parasite control program can therefore be summarized as follows:

- 1. **To minimize the risk of parasitic disease.**
  - Limit Pathology
  - Reduce Pasture Contamination
- 2. **To delay further development of anthelmintic resistance** and maintain efficacious drugs for as long as possible.
  - Reduce Use of Dewormers
  - Promote Refugia
  - Slow Resistance

(AAEP Parasite Control Guidelines, 2024)

The Players

Pasture-borne = Hosts are infected by ingesting infective larvae (L3s), while grazing.



Pasture-Borne Life Cycle

Fill-in-the-Blank

How do grazing hosts become infected with pasture-borne nematodes?

____

Pasture-borne Nematodes

Goals for control

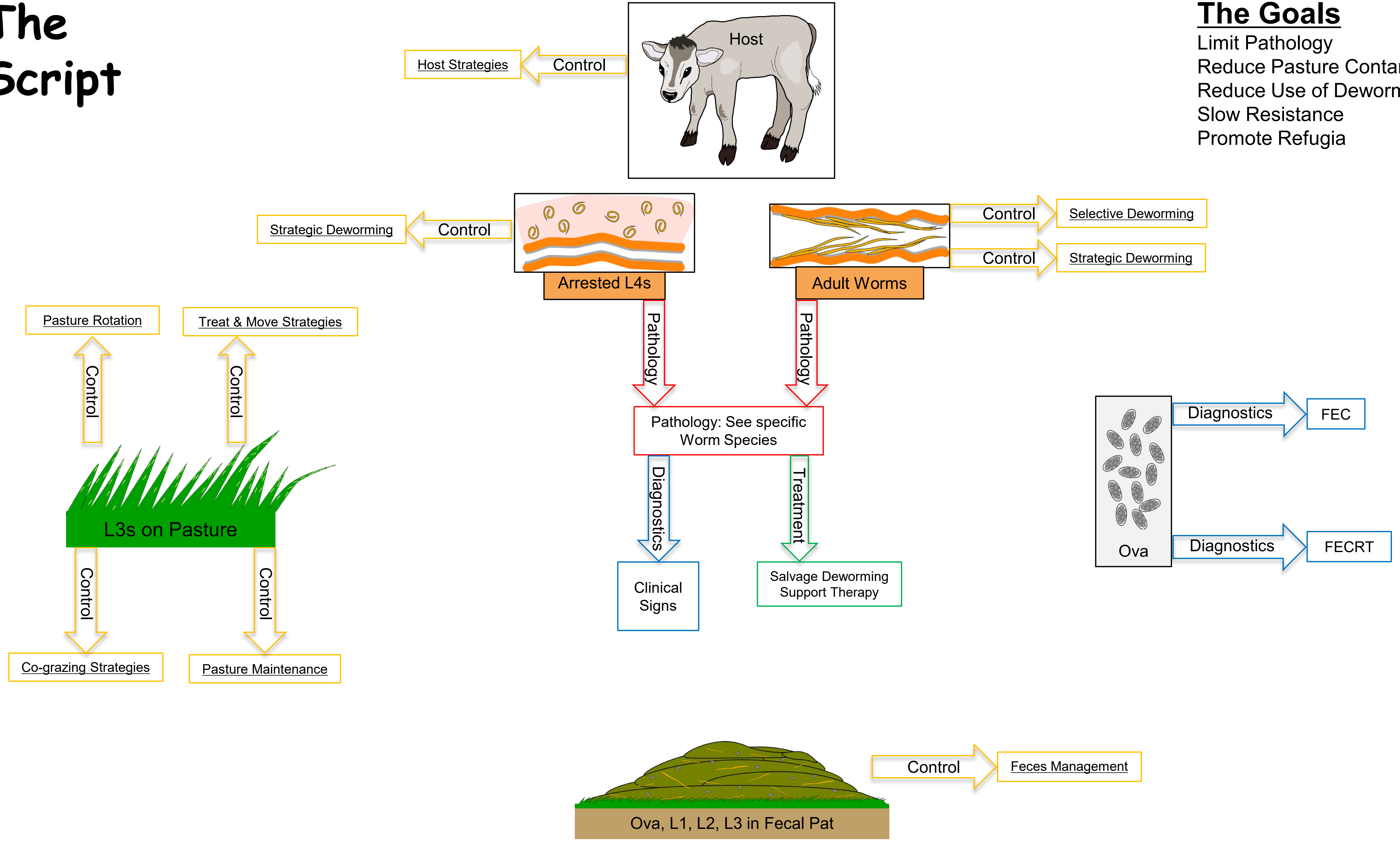
Check box: Check the Boxes that apply to the goals for controlling Pasture-borne nematodes.

- ❑ Promote Refugia
- ❑ Limit Pathology
- ❑ Eliminate all the worms from an individual host.
- ❑ Reduce pasture contamination
- ❑ Promote underdosing of dewormers to save money.
- ❑ Reduce the Use of Dewormers
- ❑ Slow Resistance

The Script

The Goals

Limit Pathology
Reduce Pasture Contamination
Reduce Use of Dewormers
Slow Resistance
Promote Refugia



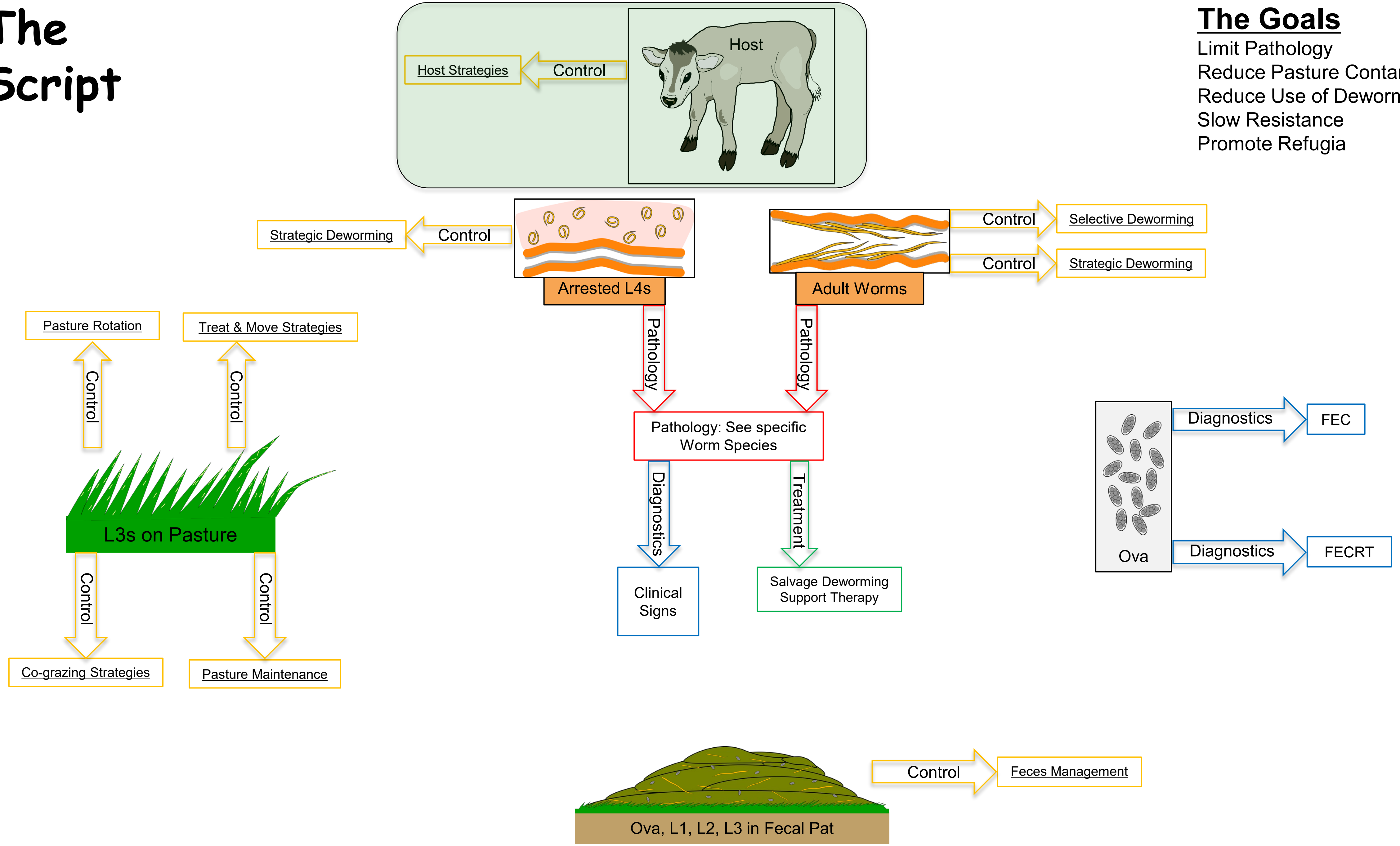
Take Home's

- For the ecology of pasture-borne nematodes understand the role of each of the following "players". Understand the difficulties and/or contributions each "player" can contribute to the pathology, treatment, and control of Pasture-borne Nematodes.
  - Host
  - Adult worms
  - Ova
  - Fecal Pat with free-living stages
  - Pasture with Infective L3s
  - Arrested L4s in the Host Mucosa

The Script

The Goals

Limit Pathology
Reduce Pasture Contamination
Reduce Use of Dewormers
Slow Resistance
Promote Refugia



The Host

Host Strategies

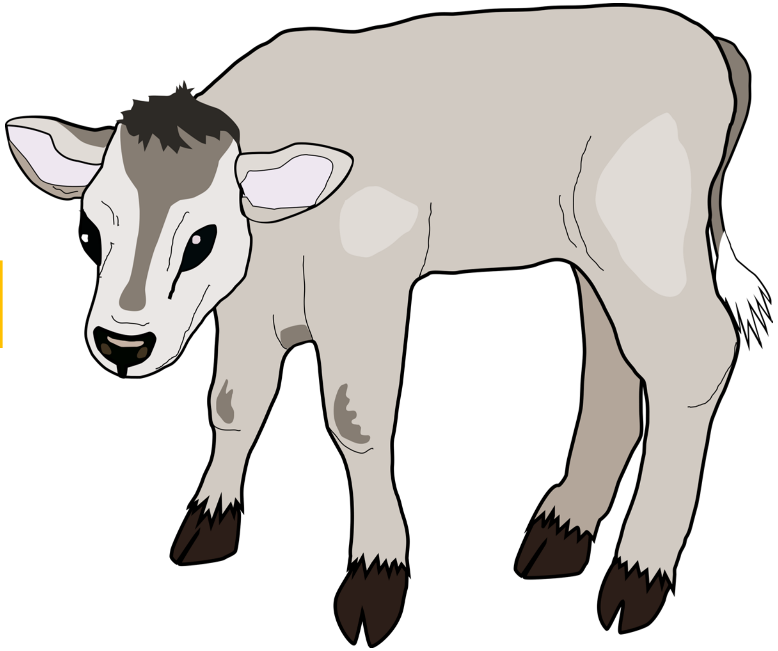
To reduce susceptible hosts

+ Resistant breeds

+ Cull high contamination potential hosts

++ 20% of herd produce 80% of the pasture contamination

Control



Info

In general, young hosts are more susceptible, while older hosts tend to develop acquired immunity.

Pasture-born Nematodes
Susceptible Host

Fill-in–the-Blank

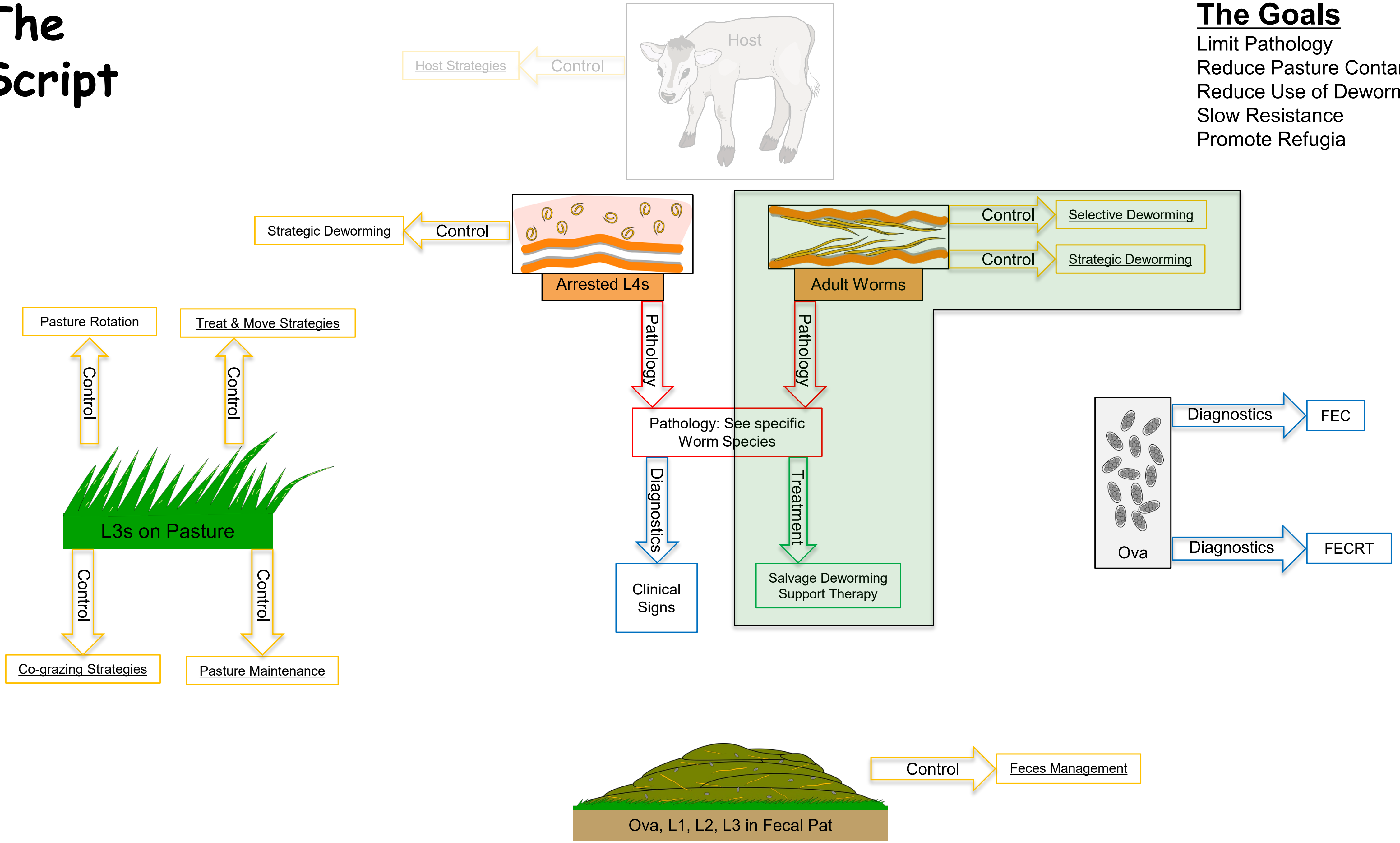
________ In general, 80% of pasture contamination is contributed by 20% of Herd.

- True or False ?

In general, __________________________ are more likely to become heavily infected and seriously affected by parasites.

- Young & Naïve hosts or Older hosts?

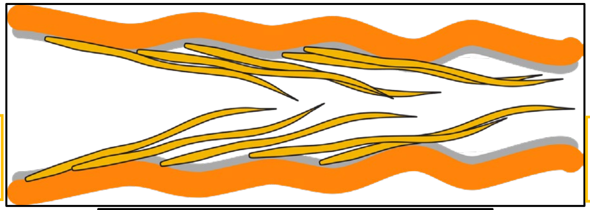
The Script



The Goals

Limit Pathology
Reduce Pasture Contamination
Reduce Use of Dewormers
Slow Resistance
Promote Refugia

The Adult Worms



Adult Worms

Control

Selective Deworming

To retain / promote refugia & limit drug resistance

+ Only symptomatic hosts (ex. FAMACHA)
+ Test & Treat deworming
+ **Combination deworming shows promise**
  ++ https://www.wormx.info/combinations

(Beware of post-treatment pathology due to loss of premunition)

Control

Strategic Deworming

+ (PPP deworming BAD!)
+ Periparturient Rise
+ Spring Rise

Pathology

Pathology: See specific Worm Species

Diagnostics

Clinical Signs

Treatment

Salvage Deworming
Support Therapy

Adult worms: Salvage Deworming

Salvage Deworming
- Treat to stop clinical pathology.

Examples of Deworming Triggers
- Severe anemia due to *Haemonchus* in Small Ruminants
- Diarrhea due to *Ostertagia* in Calves
- Diarrhea due to Small Strongyles in Horses

www.vetsouth.co.nz.webp

https://tofinotack.wordpress.com/2015/01/07/important-horse-diarrhea/

http://www.flockandherd.net.au/cattle/reader/ostertagiasis-type-II.html

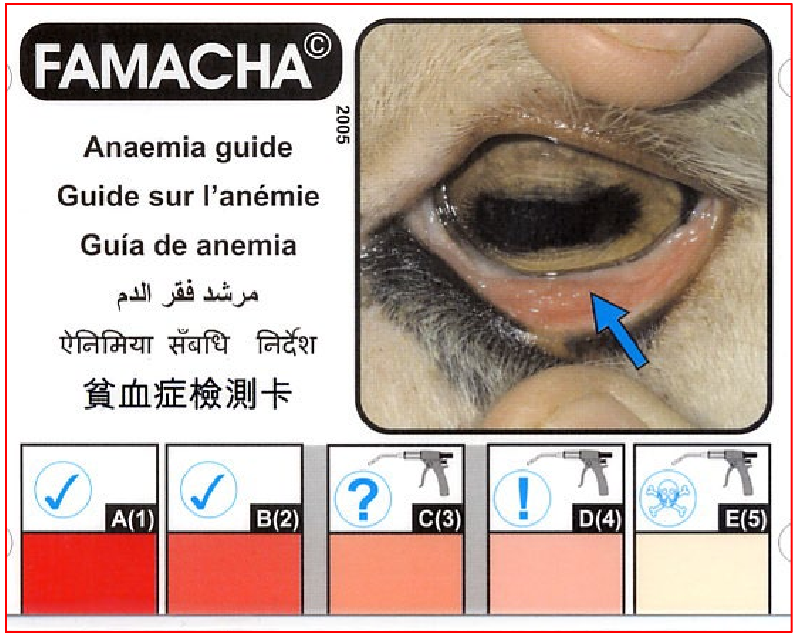
Adult worms: Selective Deworming

<u>Selective (Tactical) Deworming</u>

- Treat hosts with <u>subclinical</u> pathology to prevent clinical pathology.
- Do not treat hosts that are not showing pathology.
  - To Retain Refugia
- Ex. Anemia due to *Haemonchus* in small ruminants
  - FAMACHA -- Dr **FA**ffa **Ma**lan's **CHA**rt

<u>Another Selective Deworming</u>

- Test & Treat Deworming
  - (See Ova section below)



Adult worms: Strategic Deworming

Strategic Deworming

- To prevent future infections by reducing pasture contamination (thus future infections.) (Prophylactic deworming)

Deworming Strategies

- Scheduled Deworming -- Deworm at regular intervals to eliminate maturing adults prior to production of ova and contamination of pastures.
  - Regular deworming v/s Spring rise, Periparturient rise & end of Grazing season. (GOOD)
  - Based on the **PrePatent Period** (PPP) --- Period from ingestion of infective L3 to the production of ova by adult worms. (BAD)
    - Sheep, Goats: *Haemonchus* – 3 weeks
    - Cattle: *Ostertagia* – 3 weeks
    - Horses: Small Strongyles – 2 months
    - Traditional deworming schedules based on PPP (without concern for factors such as worm burden, clinical signs, contamination potential, etc.) has led to an overuse of dewormers and subsequently anthelminthic resistance.

Traditional Equine Deworming Schedule

Traditional Rotational Deworming Schedule

	Large Herds	Small Herds
January	Panacur or Anthelcide	Strongid
March	Ivermectin	----------
April	-----------	Ivermectin
May	Strongid	----------
July	Panacur or Anthelcide	Panacure or Anthelcide
September	Strongid	-----------
October	------------	Ivermectin Gold or Equimax or Quest Plus
November	Ivermectin Gold or Equimax or Quest Plus	---------

http://www.stillwaterequine.com/deworming

"Rote memorization of treatment schedules and antiparasitic drugs without understanding the biology of the worms to be controlled concedes any intellectual advantage to the worms.'" *from Corning. 2009. Equine cyathostomins: a review of biology, clinical significance and Therapy. Parasites & Vectors 2(Suppl 2):S1* http://www.parasitesandvectors.com/content/2/S2/S1

Deworming v/s Adult worms

Matching: Match each type of deworming with its associated scenario.

___ 1. A subclinical horse with a FEC* above specified threshold

___ 2. Planned Deworming v/s the Periparturient Rise

___ 3. Host showing severe clinical pathology

___ 4. A subclinical goat with a FAMACHA score of D(4)

___ 5. Calf with intense diarrhea and anorexia

___ 6. Has led to overuse of dewormers and resistance.

___ 7. Used to promote refugia and delay resistance

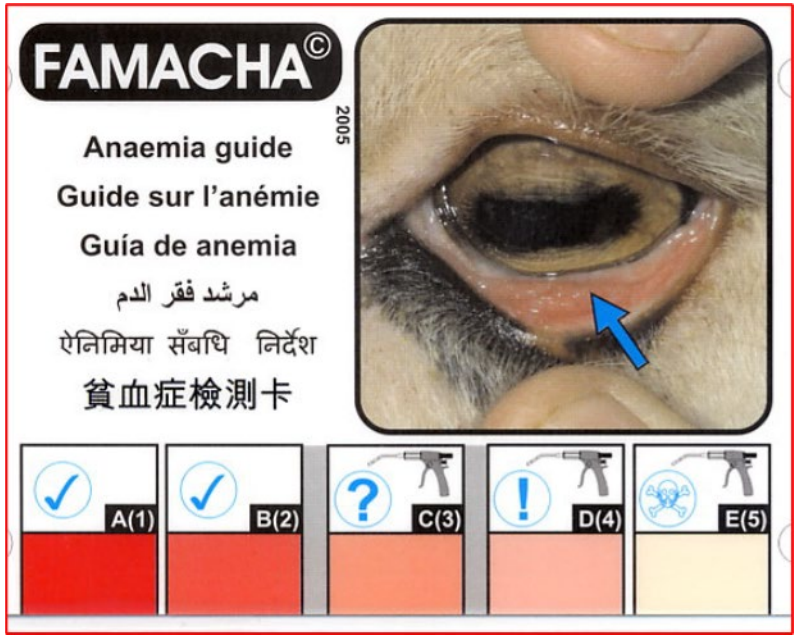
___ 8. Deworming Based on PPP**

*FEC = Fecal Egg Count; **PPP – PrePatent Period

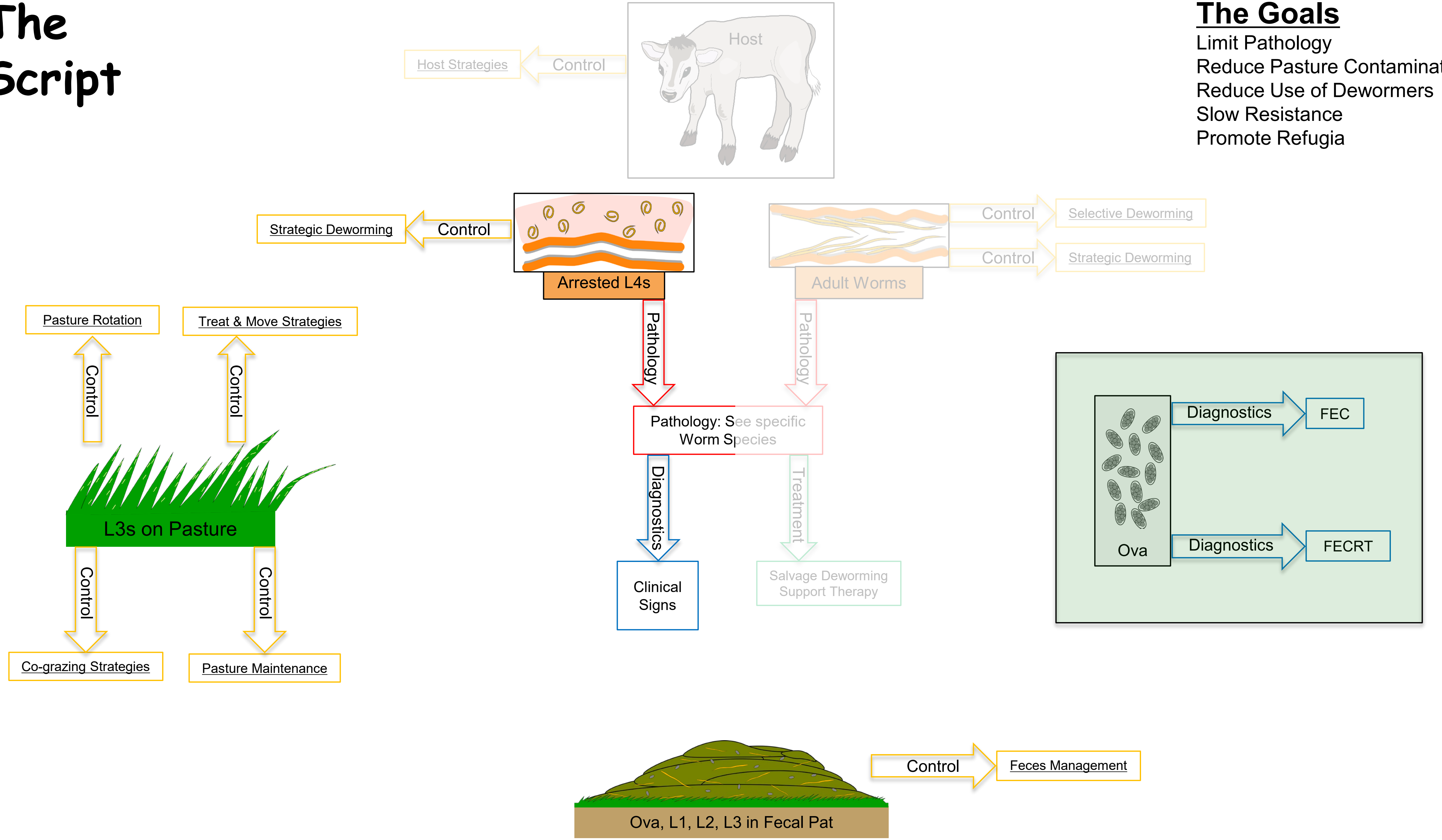
A. Salvage deworming

B. Selective (Tactical) deworming

C. Strategic deworming



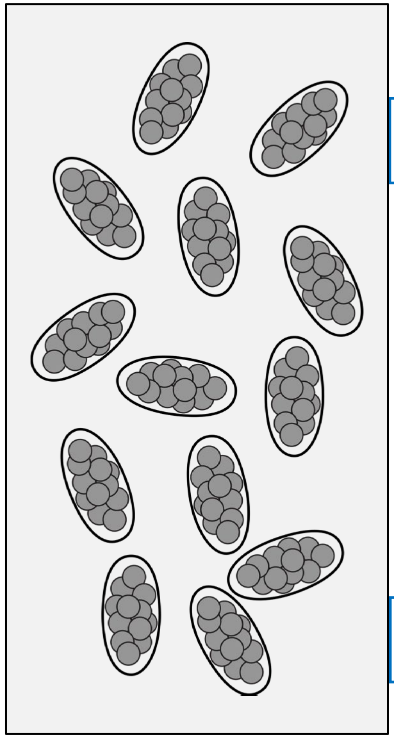
The Script



The Goals

Limit Pathology
Reduce Pasture Contamination
Reduce Use of Dewormers
Slow Resistance
Promote Refugia

The Ova



Diagnostics → Fecal Egg Count

- Info → Identifies hosts with high contamination potential
- Info → End of grazing season to check efficacy of control program.
- Treatment → Test & Treat
  Treat above specific FEC threshold

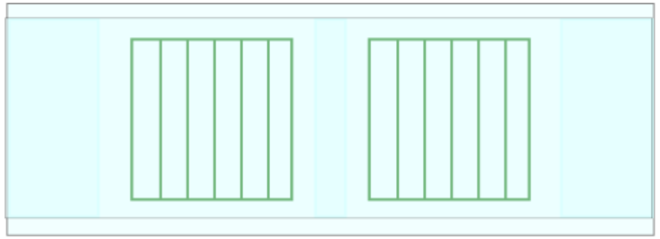
Diagnostics → Fecal Egg Count Reduction Test

- Info → Informs about Anthelminthic Resistance / Efficacy

Ova: Diagnostics

Diagnostics

- Fecal Egg Counts (FEC)
  - Reveals deworming needs
  - Reveals contamination potential
  - Compliments clinical signs to assist with deworming decisions.
  - Techniques
    - McMasters
      - Small Ruminants, Camelids -- Assume *Haemonchus*
      - Horses -- Assume small strongyles
    - Double Centrifugation (Wisconsin Technique)
      - Cattle -- Assume *Ostertagia*
    - reported as worm eggs per gram (epg) of feces)
  - Why different techniques for different parasites?



McMasters Counting Chamber

Ova: Diagnostics

Diagnostics

- Fecal Egg Count Reduction Test (FERT)
  - Reveals Efficacy of Dewormer
  - Reveals Prescence of a Resistant Worm Population
  - Technique
    - Collect Pre-treatment Fecal
    - Deworm immediately after collecting Pre-treatment Fecal
    - Do Pre-treatment Fecal Egg Count (pre-FEC)
    - Wait 10-14 days
      - Need time to clear out dead worms & their eggs
      - But before new adult worms repopulate the gut (reinfection)
    - Collect Post-treatment Fecal
    - Do Post-treatment Fecal Egg Count (post-FEC)
  - Formula:

Fecal Egg Count Reduction Test (FECRT)

$$\frac{\text{EPG (pre-treatment)} - \text{EPG (14 day post-treatment)}}{\text{EPG (pre-treatment)}} \times 100 = \_\_\_\_\_ \text{ \% Efficacy}$$

Interpreting Results of Strongyle FECRT*

Anthelmintic	Expected efficacy if no resistance	Observed Results of the FECRT: Susceptible (no evidence of resistance)	Suspected resistant	Resistant
Fenbendazole/Oxibendazole	99%	>95%	90-95%	<90%
Pyrantel	94-99%	>90%	85-90%	<85%
Ivermectin/Moxidectin	99.9%	>98%	95-98%	<95%

* from 2019 AAEP Parasite Control Guidelines

Ova: Diagnostics

- Test & Treat
  - A Selective Deworming Strategy
  - Treat only when the Fecal Egg Count (FEC) has reached a specified threshold.
    - Use quantification technique (McMasters or Double Centrifugation)
    - **Note: The use of test & treat thresholds is controversial, with no consensus.**
      - Horses -- 500 epg (Currently suggested by some equine practitioners)
      - Cattle -- Clinical Signs are primary, FEC provides support for deworming decisions.
      - Sheep, goats, camelids -- FAMACHA results are primary, FEC provides support for deworming decisions.
        - An Arkansas Extension brochure states: *"you should deworm your dry does, dry ewes, bucks and rams when the fecal egg count goes above 2,000 eggs per gram. Lactating females and young stock (yearlings or younger) are more susceptible to the Barber Pole worm and should be dewormed if the count exceeds 1,000 eggs per gram. Lactating dairy does should be dewormed if there are more than 750 eggs per gram"* (https://www.uapb.edu/sites/www/Uploads/SAFHS/FSA-9608.pdf)

  - Specific decision-making concerns to be considered.
    - Limit Pathology
      - Ex. *Strongylus vulgaris* (In the past, 100 epg from a *S. vulgaris* infection corresponded to serious pathology.)
    - Limit Pasture contamination
      - Avoid excessive future infections and pathology
    - Provide for refugia to slow the development of resistance.
      - Pre-threshold ova expelled on pasture contribute to the susceptible worm population (aka refugia).

Informative Ova

Matching: Match each type of Fecal Diagnostics with its associated use.

___ 1. Utilizes the McMasters technique

___ 2. Used to identify Hosts with High Contamination Potential

___ 3. Informs about the presence of Dewormer Resistance

___ 4. Used to check efficacy of one's deworming program

A. Fecal Egg Count

B. Fecal Egg Count Reduction Test

C. Both

Multiple Choice: Choose the best answer.

___ 1. When is the best time to check the efficacy of one's pasture-borne nematode control program?

A. Beginning of Grazing Season

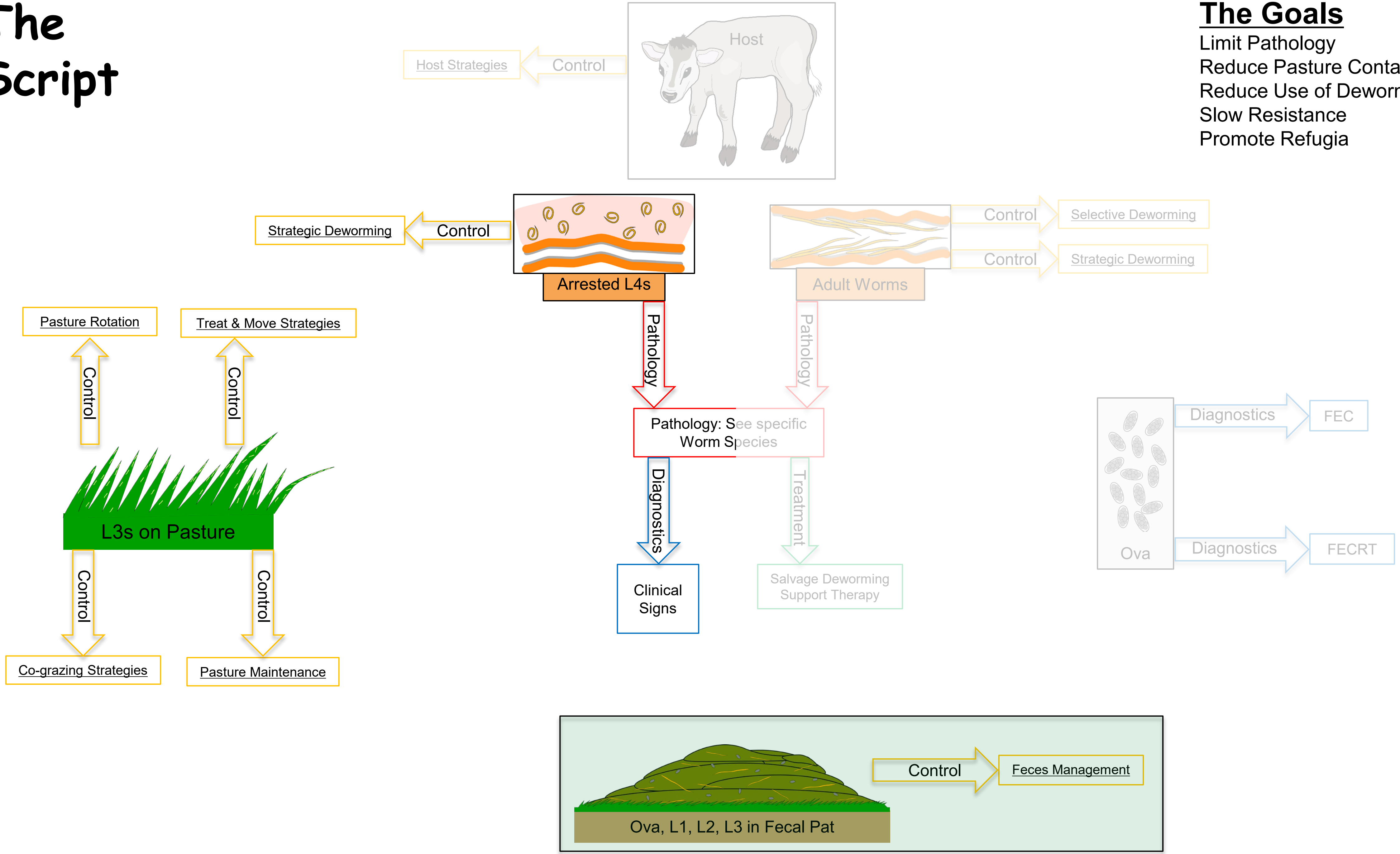
B. Middle of Grazing Season

C. End of Grazing Season

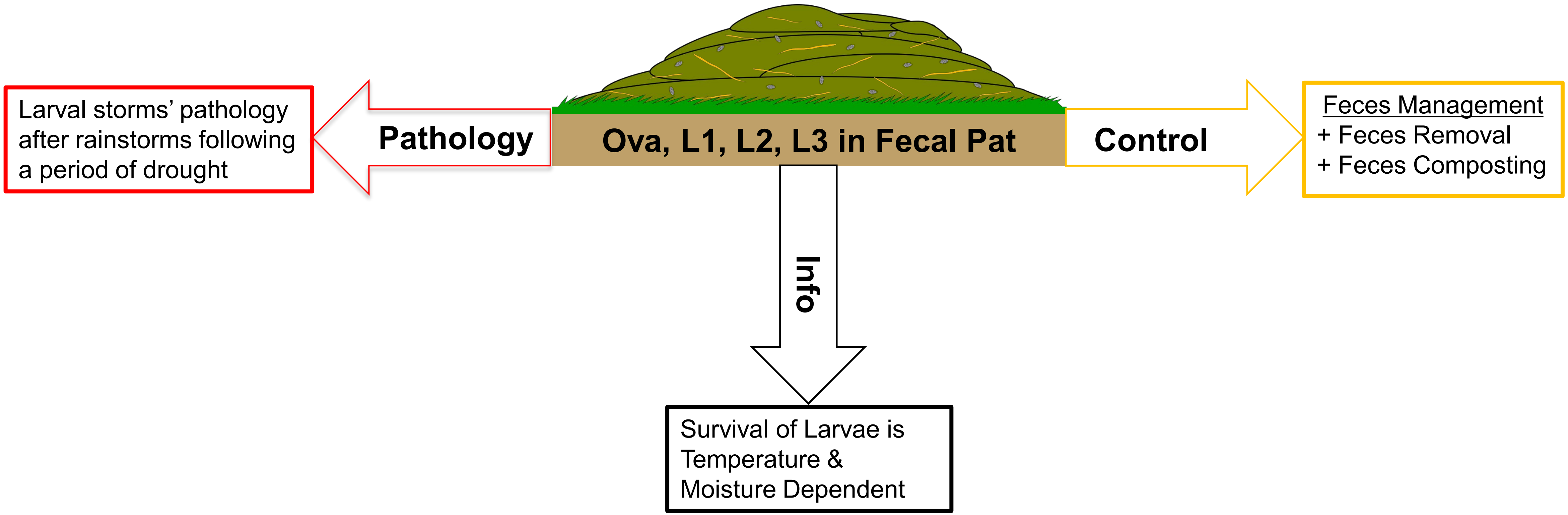
The Script

The Goals

Limit Pathology
Reduce Pasture Contamination
Reduce Use of Dewormers
Slow Resistance
Promote Refugia



The Fecal Pat



Fecal Pat: L1s & L2s

Temperature and moisture are the dominant influences on the free-living stages.

<u>L1 & L2</u>

- No protective sheath, feeds on microbes in feces
- Stages most Susceptible to Harsh Conditions
  - Temperature
    - Extreme cold => Decreased Survival
    - Cold => Slow rate of Development, Increased Survival Period
    - Mild => Moderate rate of Development, Basic Survival
    - Hot => Rapid Rate of Development, Decreased Survival
    - Extreme Heat => Lethal [104 °F (40 °C)]
  - Moisture Improves Development and Survival

Some references:

- AAEP Guidelines
- Goldberg. 1968. Development and survival on pasture of gastrointestinal Nematode Parasites of Cattle. Journal of Parasitology. 54: 856-862.
- Williams & Bilkovich. 1971. Development and Survival of Infective Larvae on the Cattle Nematode, *Ostertagia ostertagi*. Journal of Parasitology 57: 327-338
- O'Connor, Walkden-Brown,& Kahn. 2006. Ecology of the free-living stages of major trichostrongylid parasites of sheep. Veterinary Parasitology. 142: 1-15

Fecal Pat: Egg, L1, L2, L3

FYI

Effects of temperature on the survival, development, and persistence of free-living stages (eggs, L1, L2, L3) of equine strongyles.*

Development	Temperature Range	Survival
No development above this level	>40°C (>104°F)	Free-living stages die rapidly
Optimal Temperature Range Egg to L3 in as little as 4 days	25-33°C (77-91°F)	Larvae survive short-term, but too warm for long-term survival
Eggs to L3 in 2-3 weeks	10-25°C (50-77°F)	L3 survive for weeks to a few months
Eggs to L3 in many weeks to months	6-10°C (43-50°F)	L3 survive many weeks to many months
No hatching and No development	0-6°C (32-43°F)	Eggs and L3 can survive for several months
No development	<0°C (<32°F)	L1 & L2 are killed, but eggs and L3 can survive for months
No development with alternate freeze & thaw	<0>°C (<32>°F)	Repeat freeze-thaw cycles detrimental to egg and larval survival

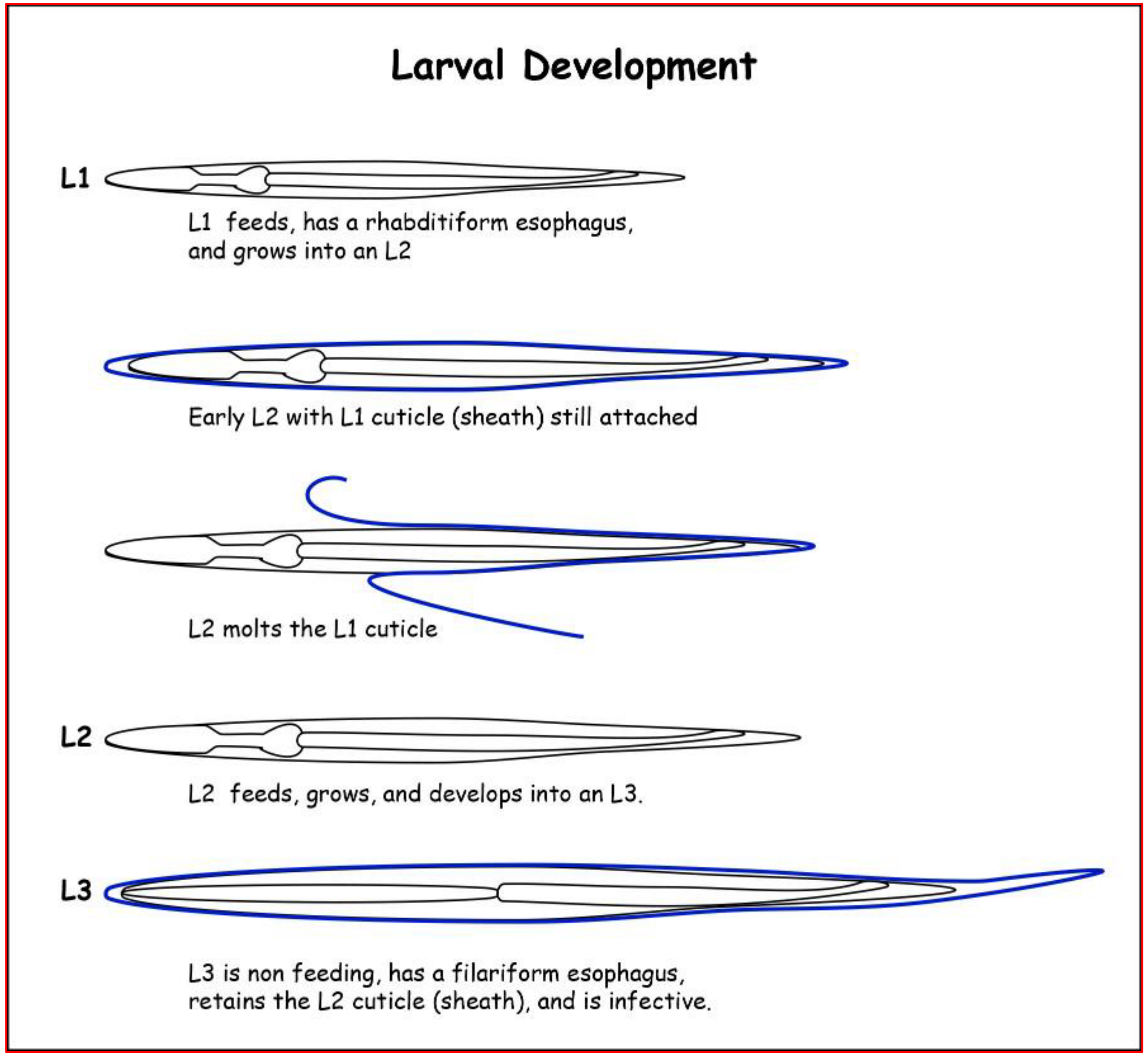
* from 2019 AAEP Parasite Control Guidelines

Fecal Pat: L3s

<u>L3s</u>

- Retains protective sheath
  - Less susceptible to harsh conditions
    - Survives desiccation better

- But cannot feed (due to sheath)
  - Cannot replenish energy stores
    - Increased Temp => Increases rate of energy expenditure => Increases death rate

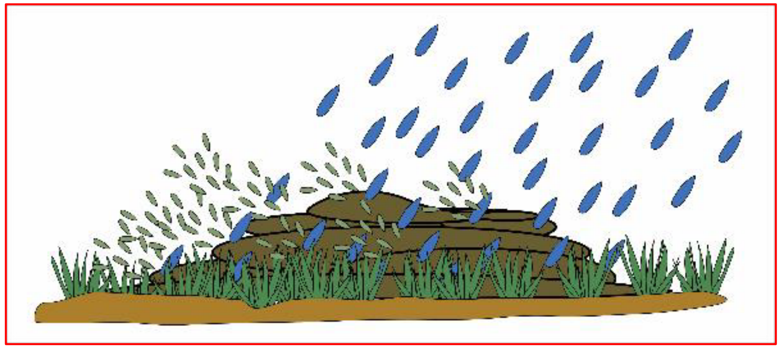


Fecal Pat: L3s

<u>Fecal Pat</u>

- Provides a protected habitat, especially from desiccation, for better development & survival of larvae.

- Larval Storms
  - Fecal Pat provides protection for development of a large population of infective L3, that is retained within the fecal pat.
  - Fecal Pat provides protection during extended dry periods
  - When dry period is ended, the sudden rainstorm will disperse the fecal pat and release the large numbers of L3
  - Pathology is often seen in hosts soon after such rainstorm events due to the high numbers of L3 made available within a short period of time.

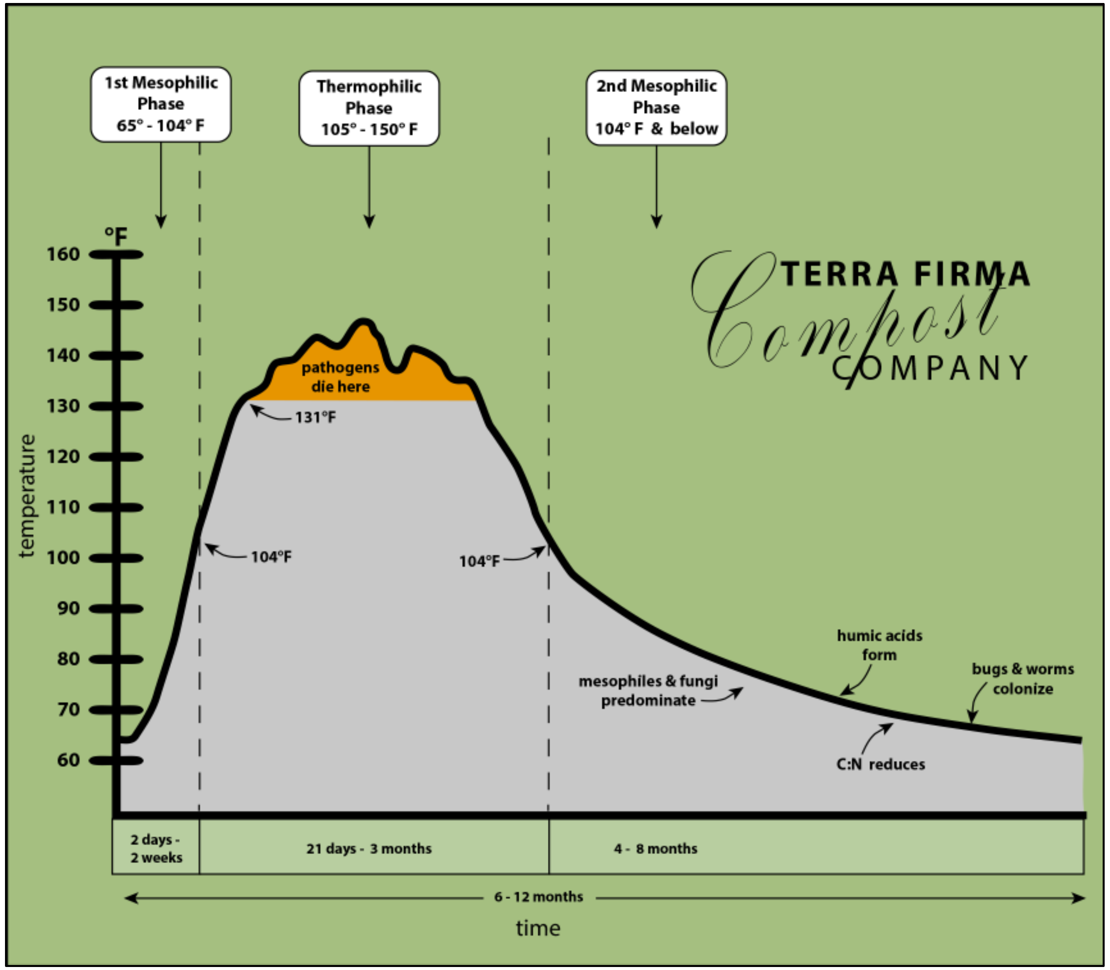


Fecal Pat: Feces management

<u>Targeting the Fecal Pat</u>

- Fecal Pat (Ova, L1, L2, L3)
- Removal
  - Fork, Shovel
  - Vacuum

- Compost
  - Fermentation temps above 104 °F (40 °C) kill nematode larvae.
    - other pathogens may require higher temps.
- To Drag or not to Drag Pastures ??
  - Break up feces for L3 desiccation v/s spreading L3 all over ?
    - AAEP – No! Do NOT drag pastures.
      - Don't spread L3's & *Parascaris* eggs
      - In general, horses avoid the "roughs" around fecal piles



https://www.rvarecycling.com/post/how-to-hot-compost

Fecal Pat

Multiple Choice: Choose the best answer.

___ **1.** Which environmental conditions are most detrimental to the free-living stages (ova, L1s, L2s, L3s) of pasture-borne nematodes?

A. High Humidity & Low Temperature
B. Low Humidity & High Temperature
C. Mild Humidity & Mild Temperature

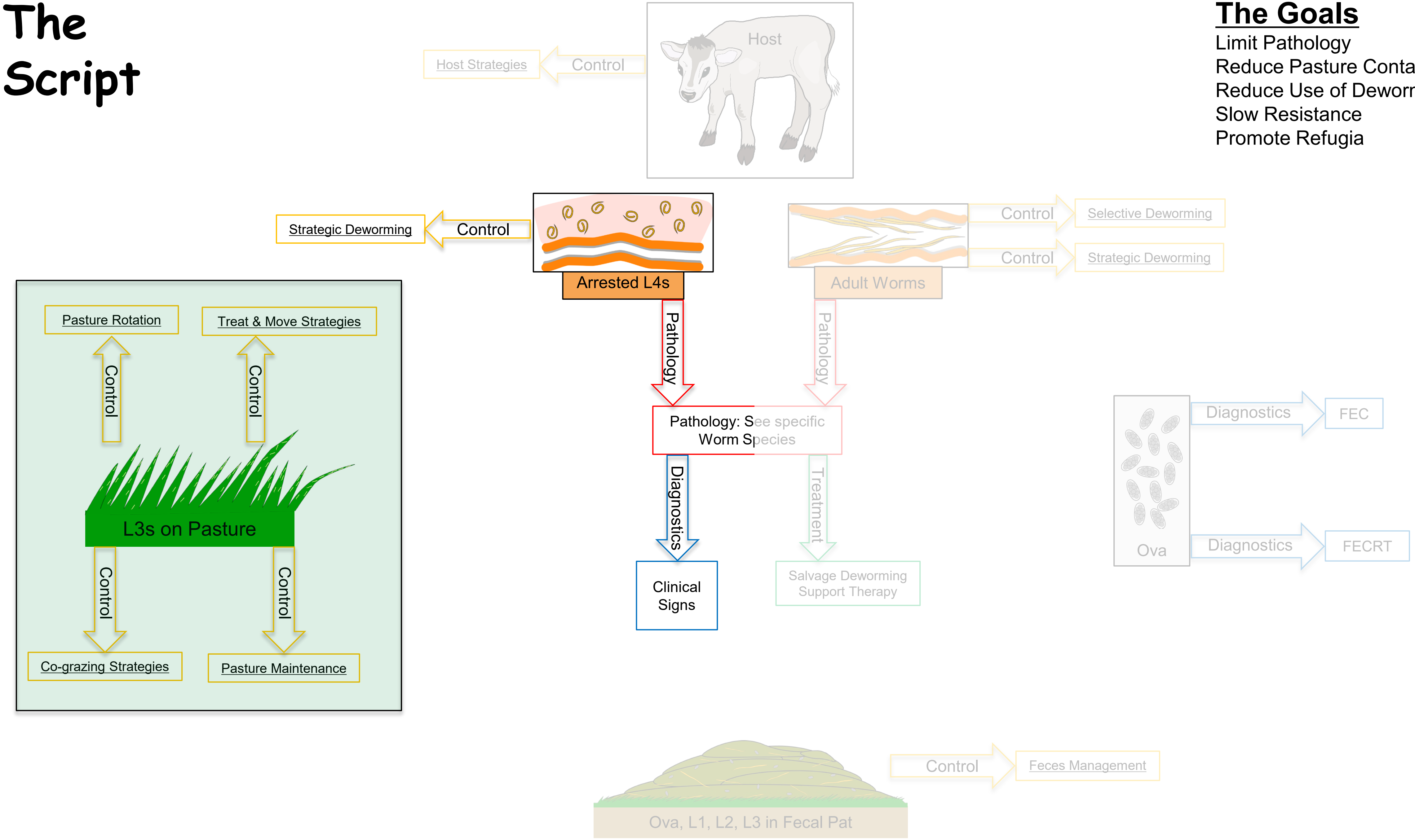
___ **2.** The release of large numbers of L3s from fecal pats, which cause pathology in hosts soon after a rainstorm event following a dry period.

A. Resistance **B.** Refugia **C.** Premunition **D.** Larval Storms

The Script

The Goals

Limit Pathology
Reduce Pasture Contamination
Reduce Use of Dewormers
Slow Resistance
Promote Refugia



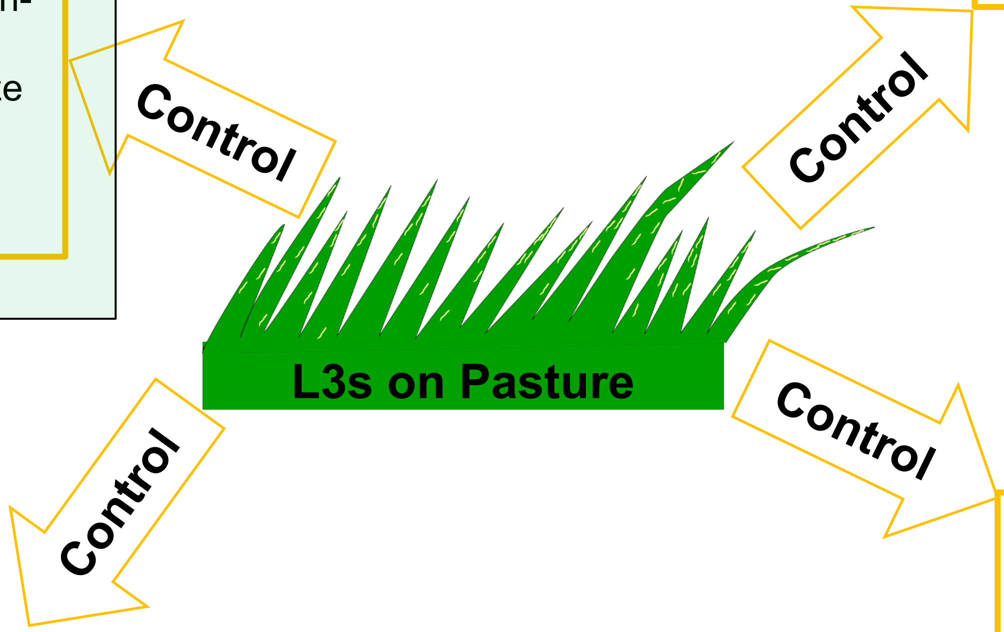
The
L3s on Pasture

<u>Pasture Management / Rotation</u>
<u>Avoid L3s</u>

To maintain healthy pastures & "run-away" from L3s
+ Don't Overstock, Don't Overgraze
+ various grazing strategies (Planned intensive grazing, mob grazing, strip grazing, etc.)

<u>Treat & Move Rotation</u>

To retain refugia & limit exposure to pasture contamination
+ Treat & Move (Bad!)
+ Treat, Wait, Move
+ Move, Wait, Treat



<u>Co-grazing Strategies</u>

To target L3s with non-susceptible hosts
+ Interspecific Co-grazing
    (Host specificity)
+ Intraspecific Co-grazing
    (Age acquired immunity)

<u>Pasture Maintenance</u>
<u>Target L3s</u>

To eliminate L3s from pasture
+ Pasture rest until L3's die off
+ Take hay off pasture
+ Use Browse with anthelminthic properties

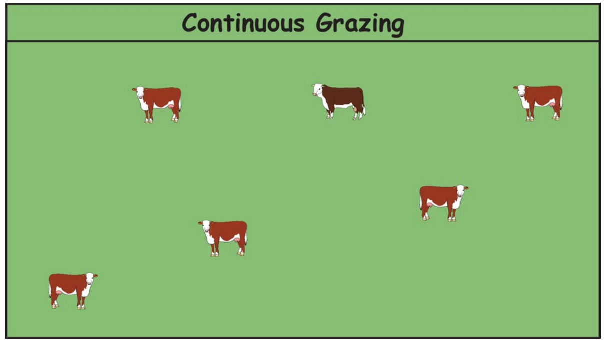
L3s: Pasture Management/Rotation

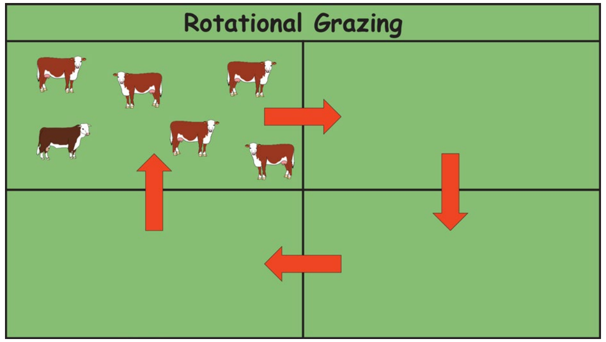
<u>Healthy Pastures</u>

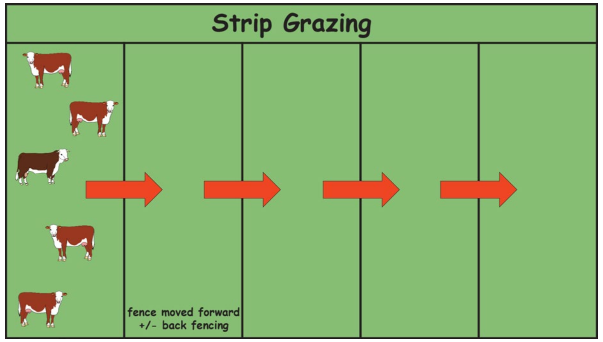
- Avoid Overgrazing or Overstocking
  - Allows Recovery of Forage
  - Deters Weed Growth
  - <u>Limits Excessive Pasture Contamination of Parasites</u>
  - etc.

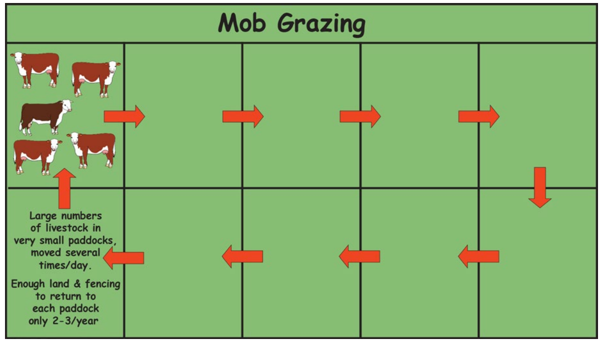
<u>Types of Pasture Grazing</u>

- Continuous Grazing
  - Not good for Pasture Health or Parasite Control
- Rotational Grazing
  - Better for Pasture Health & Parasite Control
- Planned Intensive Grazing
  - Best for Pasture Health & Parasite Control
    - Strip grazing
    - Mob grazing
    - etc.
  - <u>**But requires much land, fencing, water sources, planning, rotation coordination, etc.**</u>









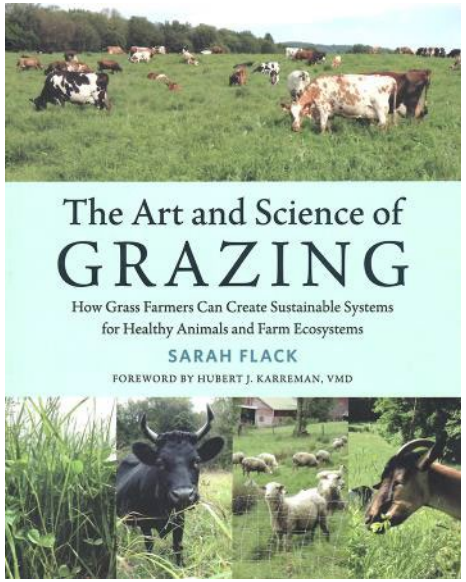
Information:
https://grazer.ca.uky.edu/content/grazing-methods-which-one-you
http://www2.ca.uky.edu/agc/pubs/id/id143/id143.pdf

L3s: Pasture Management/Rotation

FYI only

Table 2.1. Comparing Grazing Systems

System Characteristic	Continuous Grazing Systems	Rotational Grazing Systems	Management Intensive Grazing and Holistic Planned Grazing
Period of occupation and frequency of moves to new pasture	Livestock remain in the same paddock for the whole grazing season.	Livestock rotate around several pastures, often on a set rotation. Recovery periods are kept the same length, even when plant growth slows.	Livestock are moved to a new paddock only when it has fully regrown. Recovery periods are variable based on plant regrowth time requirements.
Forage supply	Livestock graze selectively, making it difficult to balance the ration. Pastures will generally provide enough feed in spring, but later in the summer pasture will be too short or too mature to provide enough dairy-quality feed.	Livestock may have adequate dry matter intake (DMI) and pasture quality in the spring, but as plant growth rates slow the pastures will be too short or plants will overmature and provide lower-quality feed.	Livestock will have adequate DMI and pasture quality throughout the grazing season.
Forage quantity	Pasture quantity usually declines as the season progresses. Productivity of the pasture also declines from season to season as plants become more damaged by overgrazing.	As livestock rotate back into pastures that are not fully regrown, the quantity and quality of feed will decline. Each year the productivity will be lower.	Livestock only rotate back into pastures that are fully recovered, so pasture quality and quantity remain good. More acres are added into the grazing rotation as growth rates slow. Over the years, this management system will increase pasture productivity.
Forage quality	Pasture quality will decrease each year due to overgrazing damage, increased weeds, and rejected forage. Clipping and eventually renovation and reseeding may be needed.	Pasture quality will gradually decrease due to overgrazing damage, weeds, and rejected forage. Clipping can help prevent weeds from spreading, but eventually renovation and reseeding may be needed.	Pasture quality will improve over time. The more intensive the management, the faster the pasture will improve.

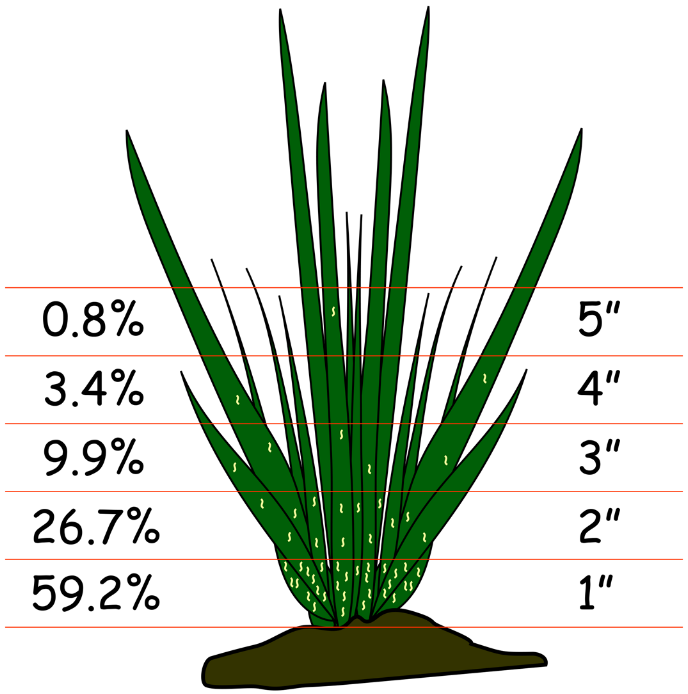


L3s: Avoid Infective Larvae

<u>Larval Migration</u>

- Horizontal migration from fecal pat
  - *Ostertagia*[1]: Most larvae only 2.5", Max 5"
  - Small Strongyles[2]: Most larvae <12", Max 40"
  - <u>Except rain events distribute L3's away from Fecal Pats</u>.
- Vertical migration up the grass blades
  - *Haemonchus*[3]: Most larvae only climb 1-3" high.
    - Graze grass down to 3-4 inches then move to a clean pasture.
- Host Feeding Preference
  - "Roughs" = areas of tall grass around fecal piles
  - Most hosts avoid roughs. Last resort grazing.[2]
    - To avoid feces
    - And because tall grasses have become tougher and less nutritious.

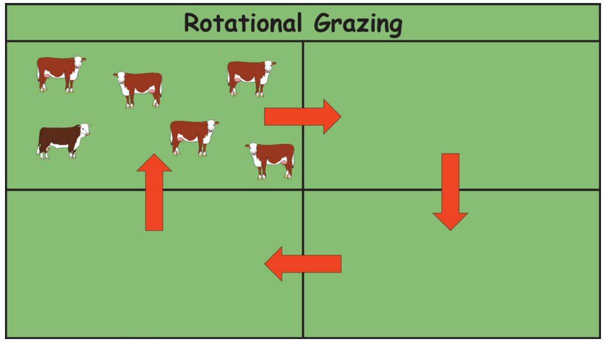
Vertical Migration of Larvae



Silangwa & Todd. 1964. Vertical Migration of Trichostrongylid larvae on Grasses. Journal of Parasitology. 50: 278-285.

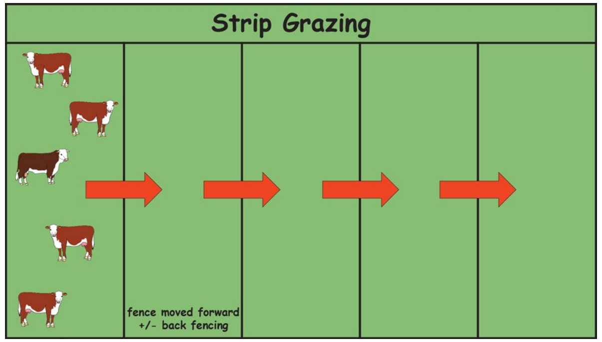
1 - V. S. Pandey. 1974. Ecological observations on the free-living stages of *Ostertagia ostertagi*. Annales de Recherches Vétérinaires, 1974, 5 (3), pp.261-279. hal-00900805
2 - Fleurance et al. 2007. Selection of Feeding Sites by horses at pasture: Testing the anti-parasite theory. Applied Animal Behaviour Science. 108:288-301
3 - Silwanga & Todd. 1964. Vertical Migration of Trichostrongylid larvae on Grasses. Journal of parasitology. 50: 278-285.

L3s: Avoid Infective Larvae



Pasture Rotation (run away)

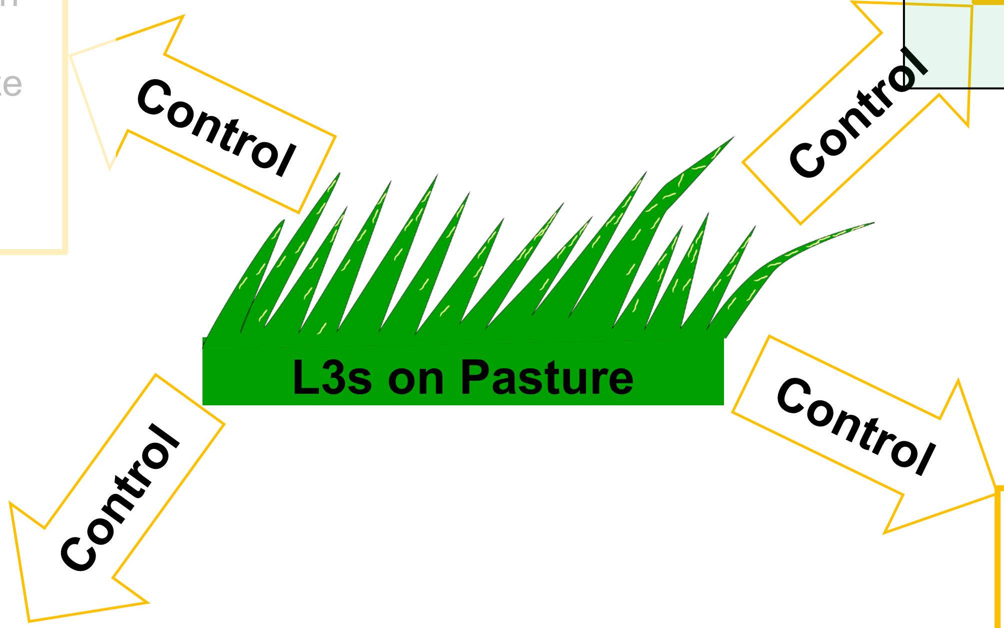
- Planned Intensive Grazing
  - Move hosts to "clean" forage frequently
    - Rotational Grazing, Strip Grazing, Mob Grazing, etc.
    - Much land, much fencing, much labor.
- Life Cycle: Egg to L3 in 3+ days depending on environmental conditions.
  - Move hosts to new pasture every 3 days
- Life Cycle: L3 can survive on pasture for a few days to 14 months depending on environmental conditions.
  - Don't return hosts to used pasture for "few days to 14 months"
    - Unreliable due to variability in regional conditions.
    - Check with Extension agents in your region.
- L3 Behavior: L3 rarely migrates higher than 3" from ground.
  - Move herd when average forage is 3-4" high -- Don't graze too Low!
    - More reliable indicator of when to move herd.



The
L3s on Pasture

Pasture Management / Rotation
Avoid L3s
To maintain healthy pastures & "run-away" from L3s
+ Don't Overstock, Don't Overgraze
+ various grazing strategies (Planned intensive grazing, mob grazing, strip grazing, etc.)

Treat & Move Rotation
To retain refugia & limit exposure to pasture contamination
+ Treat & Move (Bad!)
+ Treat, Wait, Move
+ Move, Wait, Treat



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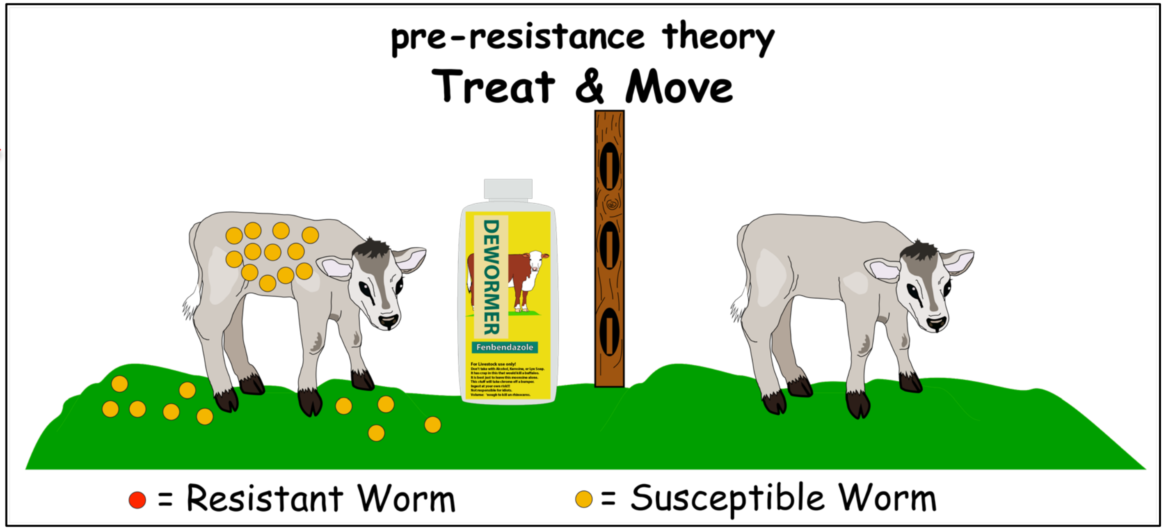
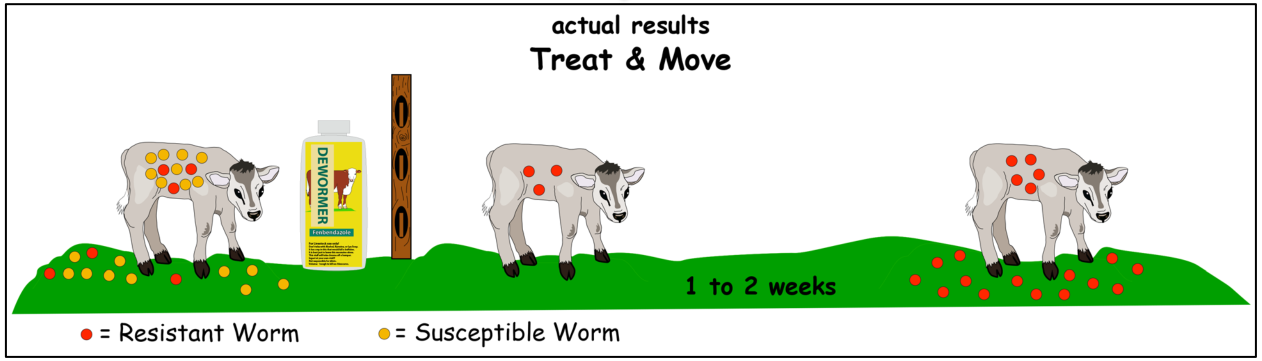
Pasture Maintenance
Target L3s
To eliminate L3s from pasture
+ Pasture rest until L3's die off
+ Take hay off pasture
+ Use Browse with anthelminthic properties

L3s: Treat & Move Rotation

<u>Pasture Rotation</u>

- Treat & Move (Pre-Resistance era)
  - Theory: Remove worms prior to moving to clean pasture will maintain a clean pasture.
  - But it actually removes only susceptible worms, leaving only resistant worms.
  - Thus, only resistant worms contaminate the new pasture. (BAD!!)

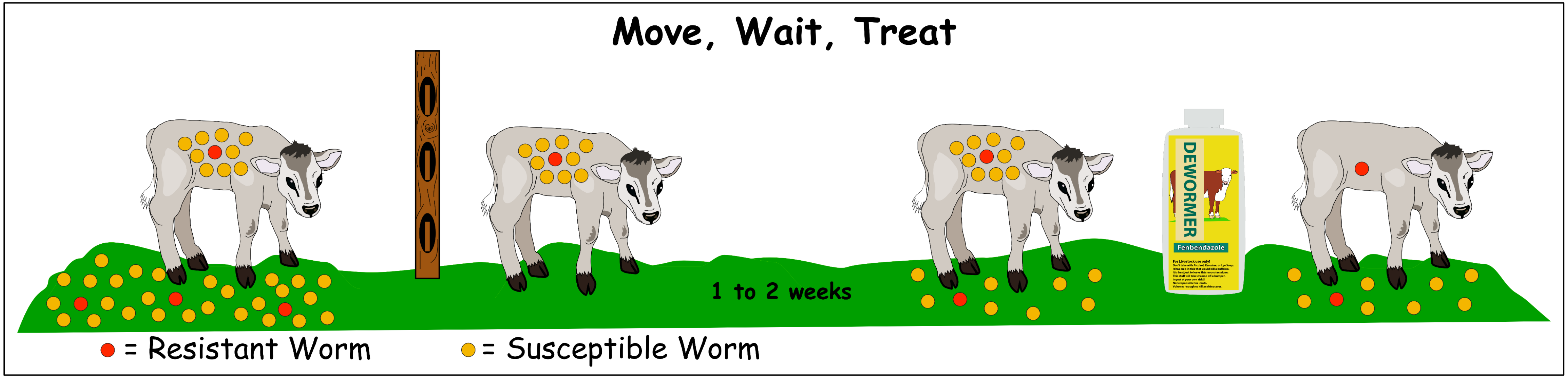




L3s: Treat & Move Rotation

<u>Pasture Rotation</u>

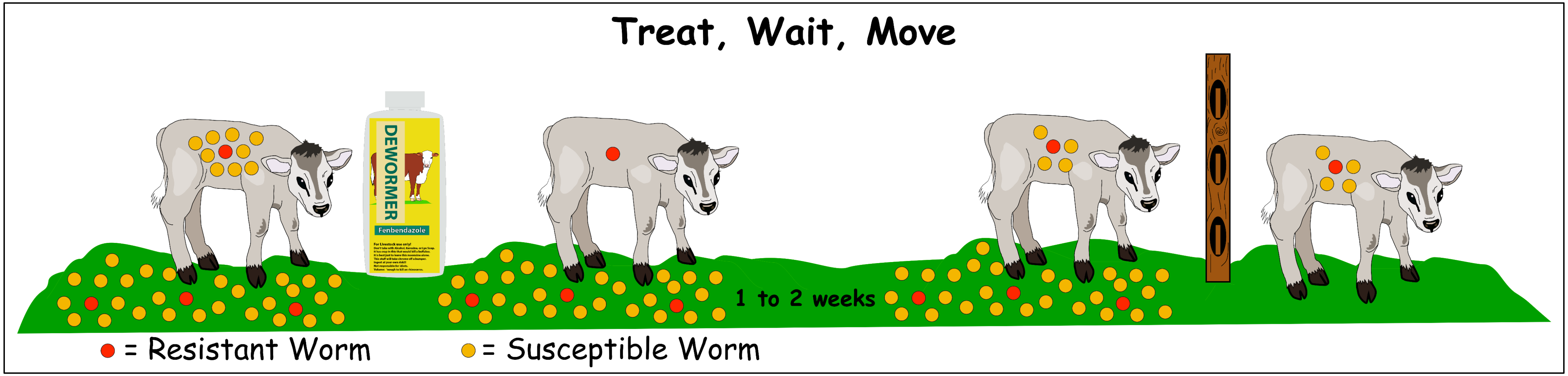
- Move, Wait, Treat (Resistance Era)
  - Move: Removes host from heavily contaminated pasture
  - Wait: Allows contamination of pasture with susceptible worms (refugia)
  - Treat: Limits pathology and excessive pasture contamination



L3s: Treat & Move Rotation

<u>Pasture Rotation</u>

- Treat, Wait, Move (Resistance Era)
  - Treat: Limits pathology and in-host worm population
  - Wait: Allows host to acquire small population of susceptible worms (refugia)
  - Move: Removes host from heavily contaminated pasture



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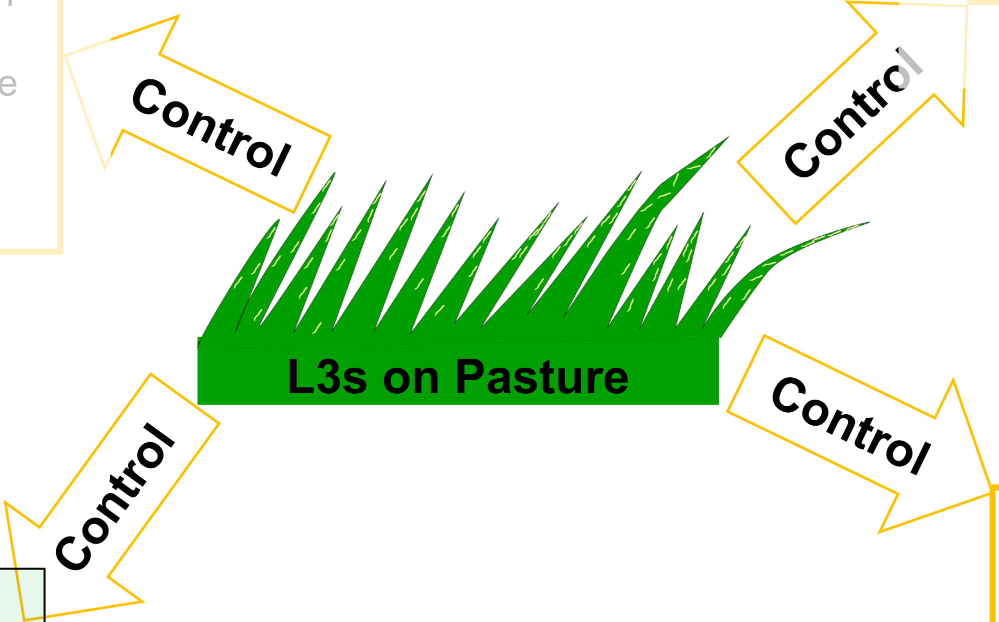

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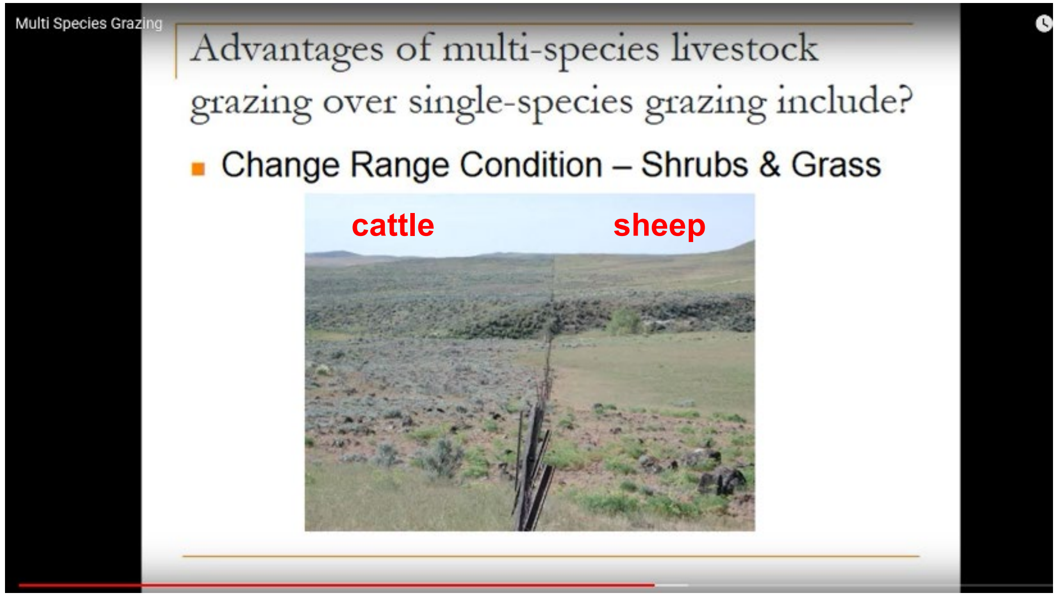
Pasture Maintenance
Target L3s
To eliminate L3s from pasture
+ Pasture rest until L3’s die off
+ Take hay off pasture
+ Use Browse with anthelminthic properties

L3s: Co-Grazing Strategies

<u>Co-grazing (vacuum cleaners)</u>

- Interspecific Co-grazing (Multi-species Grazing)
  - Relies on Host Specificity limitations of the parasite.
    - Parasite's inability to infect a "non-preferred" host species.
    - If L3 is ingested by a non-preferred host; the L3 dies.
  - Examples:
    - Horses (Small Strongyles) & Goats (*Haemonchus*)
    - Horses (Small Strongyles) & Cattle (*Ostertagia*)
    - Cattle (*Ostertagia*) & Sheep (*Haemonchus*)



https://youtu.be/Ljel6sIHXgU Karen Launchbaugh, University of Idaho

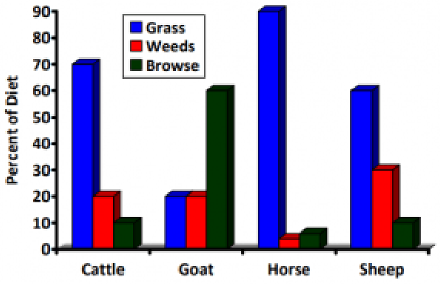
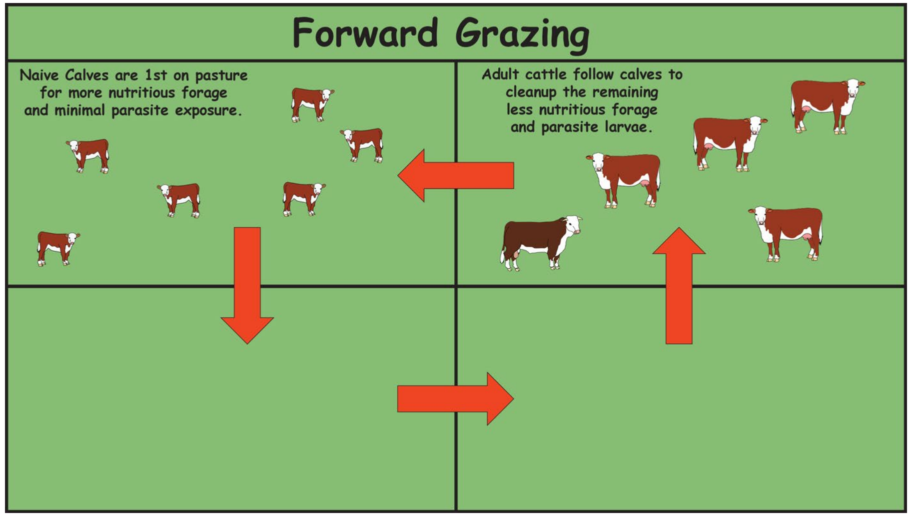


Figure 1. Dietary preference of different livestock species. Source: AnPeischel, 2005.

L3s: Co-Grazing Strategies

<u>Co-grazing (vacuum cleaners)</u> (continued)

- Intraspecific Co-Grazing (Same-species Grazing)
  - Relies on Age-Related Immunity (Acquired Immunity)
    - Older animals of the parasite's preferred species have developed immunity against the parasite.
    - If the L3 is ingested by an older immuned animal the L3 is killed.
    - Older animal acts as a vacuum cleaner to "suck up" L3 larvae to decrease the number ingested by the younger more susceptible animal.
  - Example:
    - Cow-calf Grazing
      - Cow/calf operations utilize the cow as a "vacuum cleaner" to help protect the calves at their side.
    - Forward Grazing (aka First-Last Grazing)
      - Fresh uncontaminated pasture is first grazed by growing calves. When the calves are removed; then older cows are grazed on that pasture.
        - Older immune animals act as vacuum cleaners to clean-up pasture after young have seeded it with L3's.
        - Also good for growing calves to get the fresh, more nutritious forage.
        - BAD ! If older on pasture first, then older would seed L3's on pasture for the younger, more susceptible animals. BAD !



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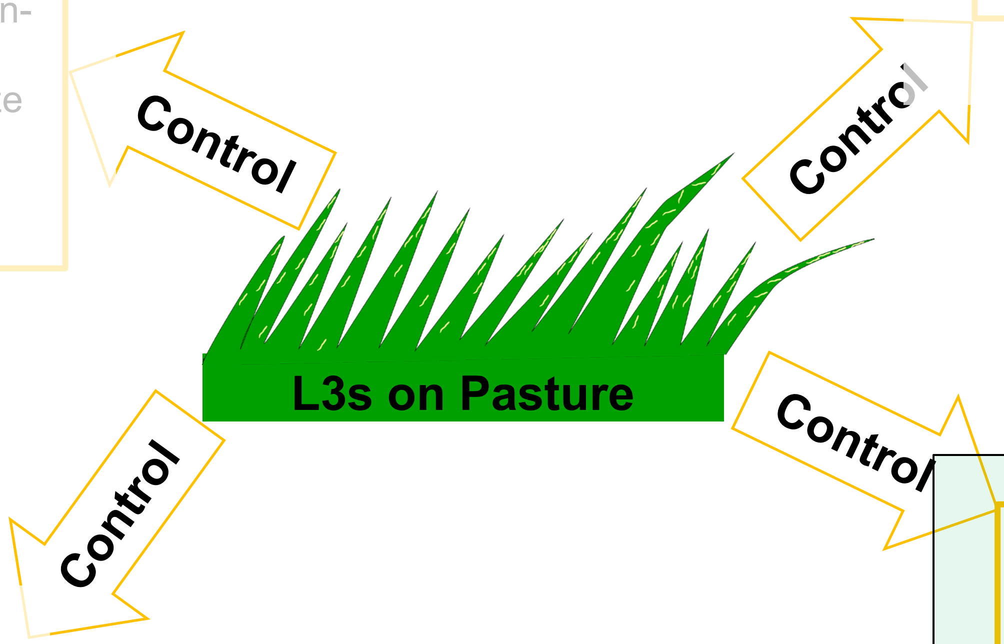

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Pasture Maintenance
Target L3s

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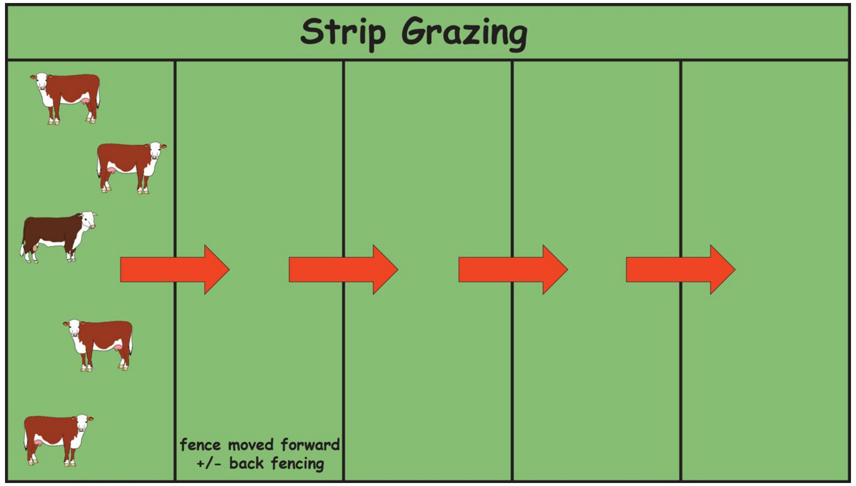
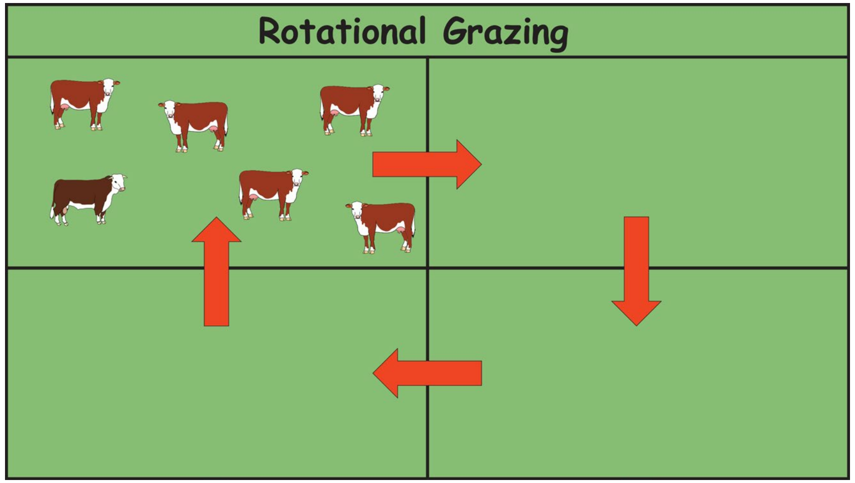
+ Pasture rest until L3’s die off
+ Take hay off pasture
+ Use Browse with anthelminthic properties

L3s: Pasture Maintenance

Rest pastures



(Use back fencing to rest the pastures left behind)



Take Hay off pastures

L3s desiccate as hay dries.

Forage with anthelmintic properties

Lespedeza, chicory, bird's-foot trefoil, etc.

https://attra.ncat.org/publication/tools-for-managing-internal-parasites-in-small-ruminants-sericea-lespedeza/

Pasture Management

Matching: Match each type of pasture management with its associated characteristic.

___ **1.** Requires much fencing for multiple small pastures.

___ **2.** Seldom move herd

___ **3.** Avoids Overgrazing

___ **4.** Limits Excessive Pasture Contamination with Parasites

___ **5.** Not good for Pasture Health nor Parasite Control

___ **6.** Allows better recovery of Forage

___ **7.** Move herd when grass is eaten down to 4 inches.

A. Continuous Grazing

B. Planned Intensive Grazing

L3s: Treat & Move Rotation

<u>Multiple Choice:</u> Choose the best answer.

___ **1.** Which "Treat-&-Move Strategy" is most likely to produce a monoculture population of Resistant Nematodes?

___ **2.** Which "Treat-&-Move Strategy" inhibits the development of Refugia?

A. Treat & Move
B. Treat, Wait, & Move
C. Move, Wait, & Treat

L3s: Co-grazing Strategies

<u>Matching:</u> Match each type of co-grazing with its associated characteristic.

___ **1.** Relies on Host Specificity limitations of the parasite.

___ **2.** Relies on Age-Related Immunity (Acquired Immunity) of the host.

___ **3.** Horse & Goats grazed together

___ **3.** Calves on a pasture first, followed by adult Cows

___ **5.** L3s ingested by and die within a non-susceptible host.

___ **6.** Cow with Calf at her side

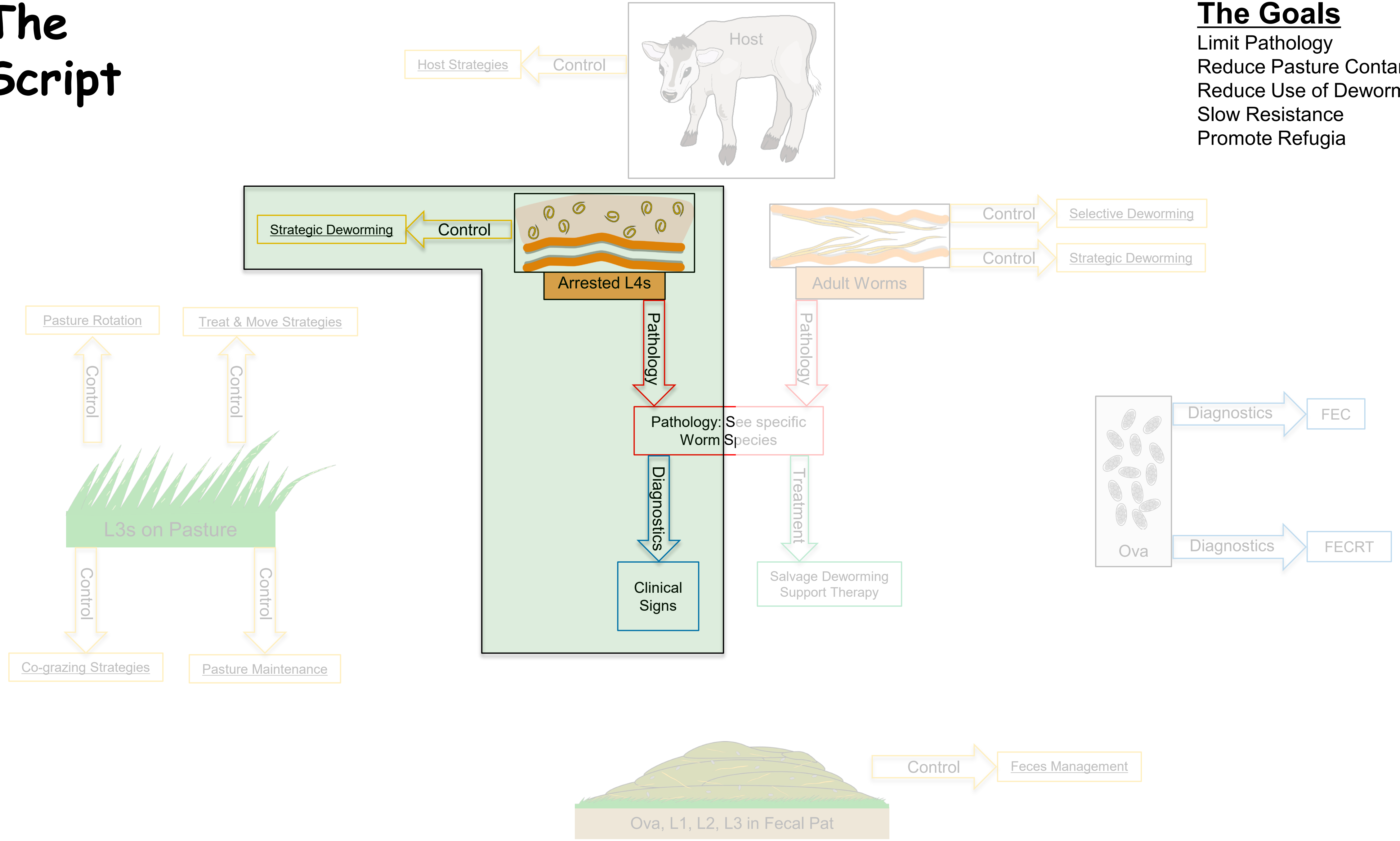
A. Interspecific co-grazing

B. Intraspecific co-grazing

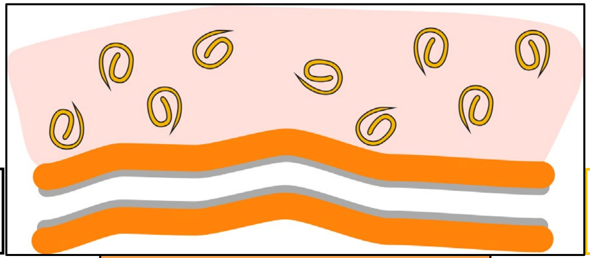
C. Both

The Script

The Goals
Limit Pathology
Reduce Pasture Contamination
Reduce Use of Dewormers
Slow Resistance
Promote Refugia



The Arrested L4s



Arrested L4s

Info

Consequences

Various triggers reactivate arrested larvae to excyst, migrate to gut lumen & become adult worms.

Source of Spring Rise and Periparturient Rise

Control

Strategic Deworming

Target Arrested L4's

To limit pasture contamination

+ Limits Periparturient Rise, Spring Rise

+ Treat at end of grazing season

(Few deworms effective v/s arrested larvae)

(Beware of post-treatment pathology due to loss of premunition)

Pathology

Pathology: See specific Worm Species

Diagnostics

Clinical Signs

Treatment

Salvage Deworming

Support Therapy

Arrested L4: Consequences

Reactivation of Arrested L4s

Spring Rise (male & female hosts)

- Unknown factors: (winter-stress -> decreased host immunity?, Innate Parasite timing ??)
- Treat herd at end of grazing season
  - Remove arrested L4's to prevent over-wintering of L4's within the host.
  - Use a larvicide (like Moxidectin)
- Treat herd early in grazing season
  - Remove emerging larvae & adults to limit contamination of spring pastures to be grazed by naïve young.
  - Use an adulticide (most dewormers)

Periparturient Rise (female hosts)

- Decrease in female host immunity due to stress of pregnancy and lactation
- From 2 weeks before to 8 weeks after parturition (approx. 10 weeks total)
- Treat dame Before & After parturition
  - Treat to kill emerging larvae & adults to limit contamination of spring pastures to be grazed by naïve young.
  - Use an adulticide (most dewormers)

Arrested L4: Consequences

Premunition

- A parasitological feed-back mechanism in which the adult population in the lumen inhibits the reactivation and emergence of the arrested larvae from the gut mucosa
- The danger of deworming is that the sudden death of the adult population in the gut lumen removes the premunition, resulting in massive numbers of arrested larvae emerging and doing pathologic damage to the intestine (tissue trauma, inflammation, diarrhea, hypoproteinemia).
  - Utilize steroids with dewormer to decrease inflammation.

Arrested L4: Strategic Deworming

Treatment for Arrested L4

- Arrested Larvae are Hypobiotic. So, they are not metabolically active, which means they are not affected by most dewormers.
  - Moxidectin is effective against arrested larvae and reduces inflammation.
  - Extended Fenbendazole treatments are effective against arrested larvae but does not reduce inflammation.
  - (Most dewormers are effective against **reactivated** L4s, young adults and mature adults; but **not arrested L4s**)

Arrested L4s

Multiple Choice: Choose the best answer.

___ 1. Which Life Cycle Stage encysts in the tissues of the host, then later reactivates to be the source of Spring Rise and Periparturient Rise?

A. Ova **B.** L1s **C.** L2s **D.** L3s **E.** L4s **F.** Adults

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Matching: Match each parasitological event with its associated characteristic.

___ **1.** L4s re-activate and become adult worms that produce eggs that contaminate spring pastures.

___ **2.** Treat herd at the end of grazing season with larvicide to reduce over-wintering arrested L4s.

___ **3.** Reactivation of L4's after removal of adult worm population.

___ **4.** Treat dame before and after parturition.

___ **5.** Herd shows this rise at the beginning of the grazing season.

A. Both A & B

B. Periparturient Rise

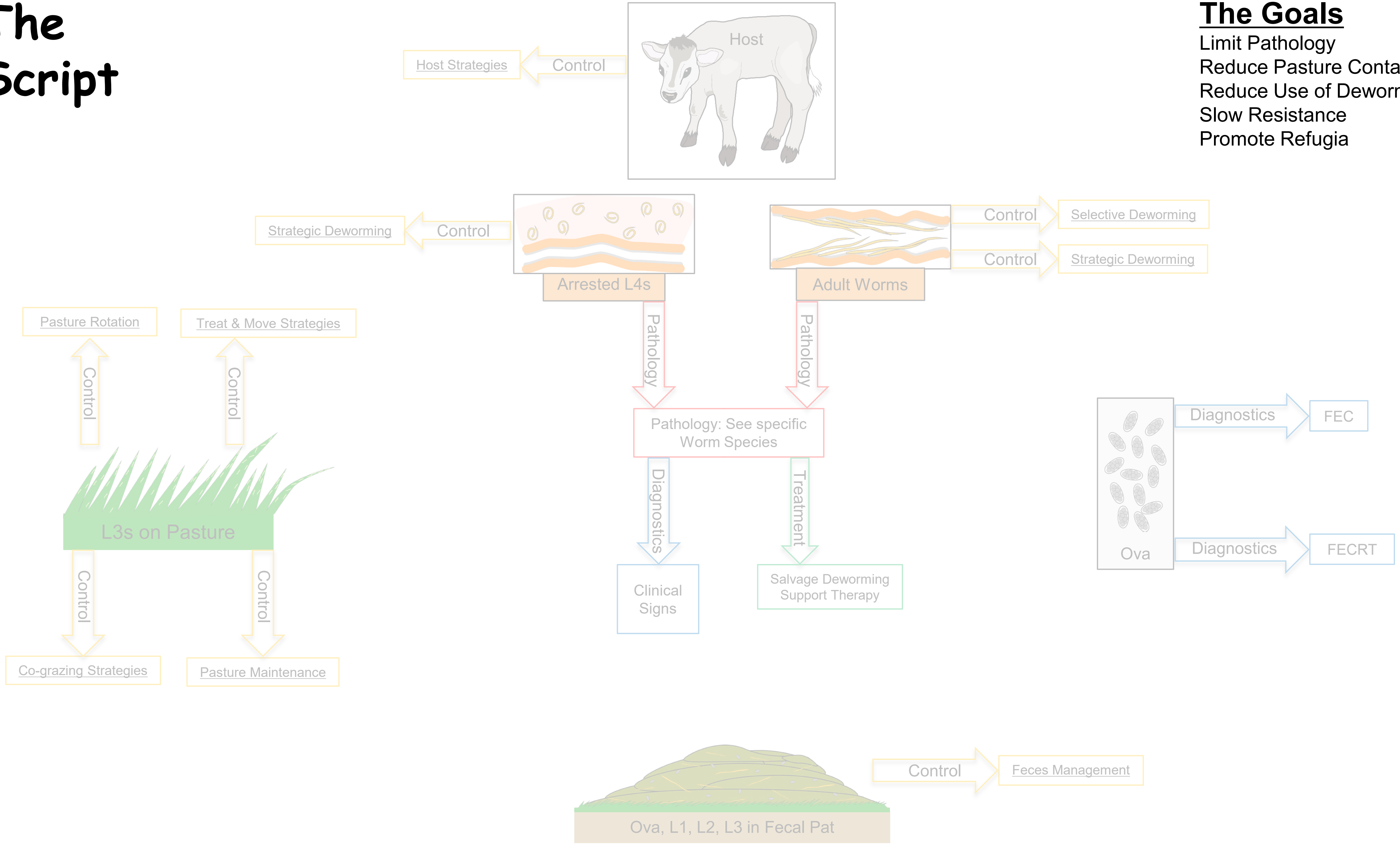
C. Spring Rise

D. Loss of Premunition

The Script

The Goals

Limit Pathology
Reduce Pasture Contamination
Reduce Use of Dewormers
Slow Resistance
Promote Refugia



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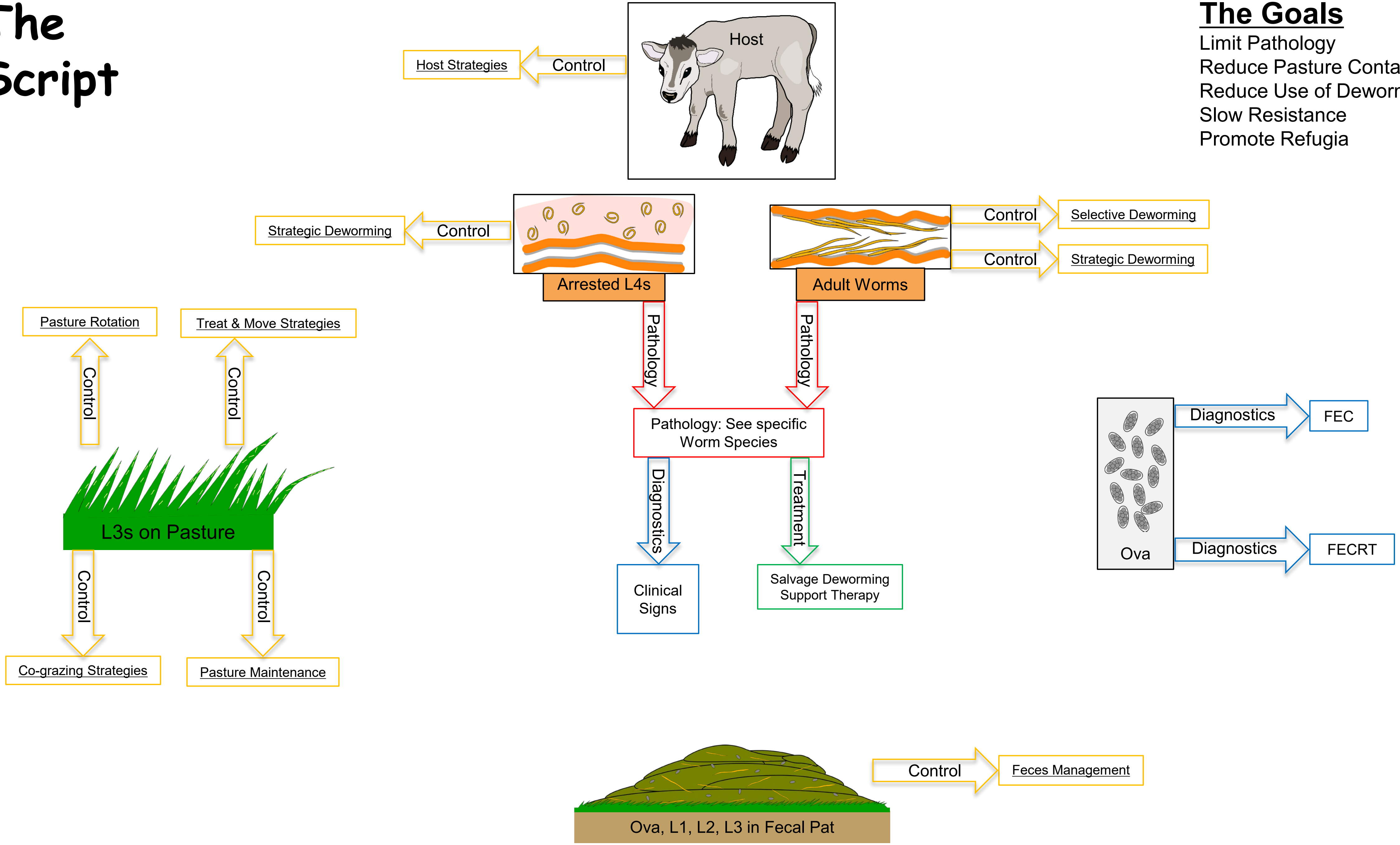

VETERINARY PARASITOLOGY GROUP

HOST

PARASITE

IgE

CVM-NCSU