Animal Breeding Systems for Small Ruminants

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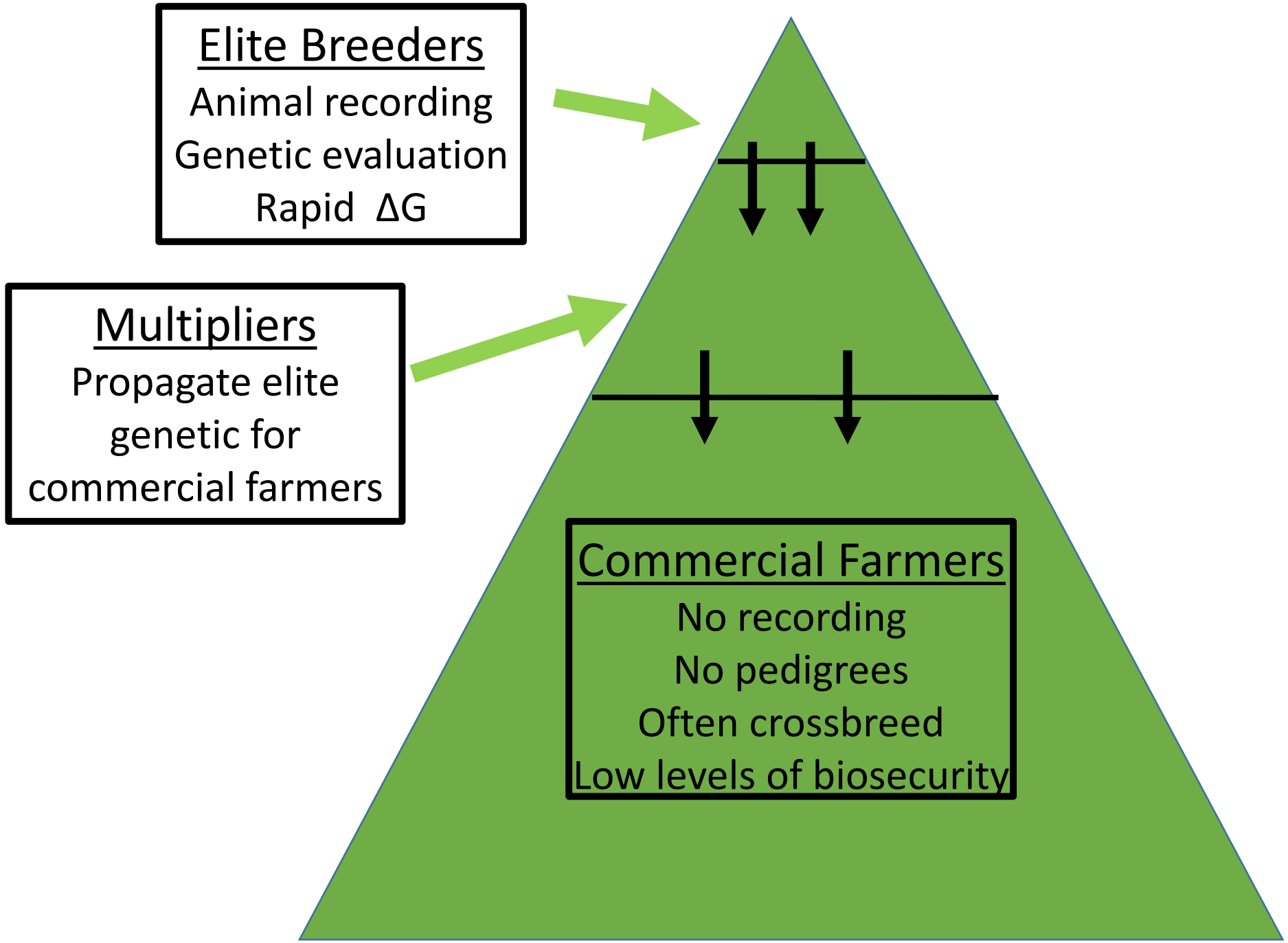
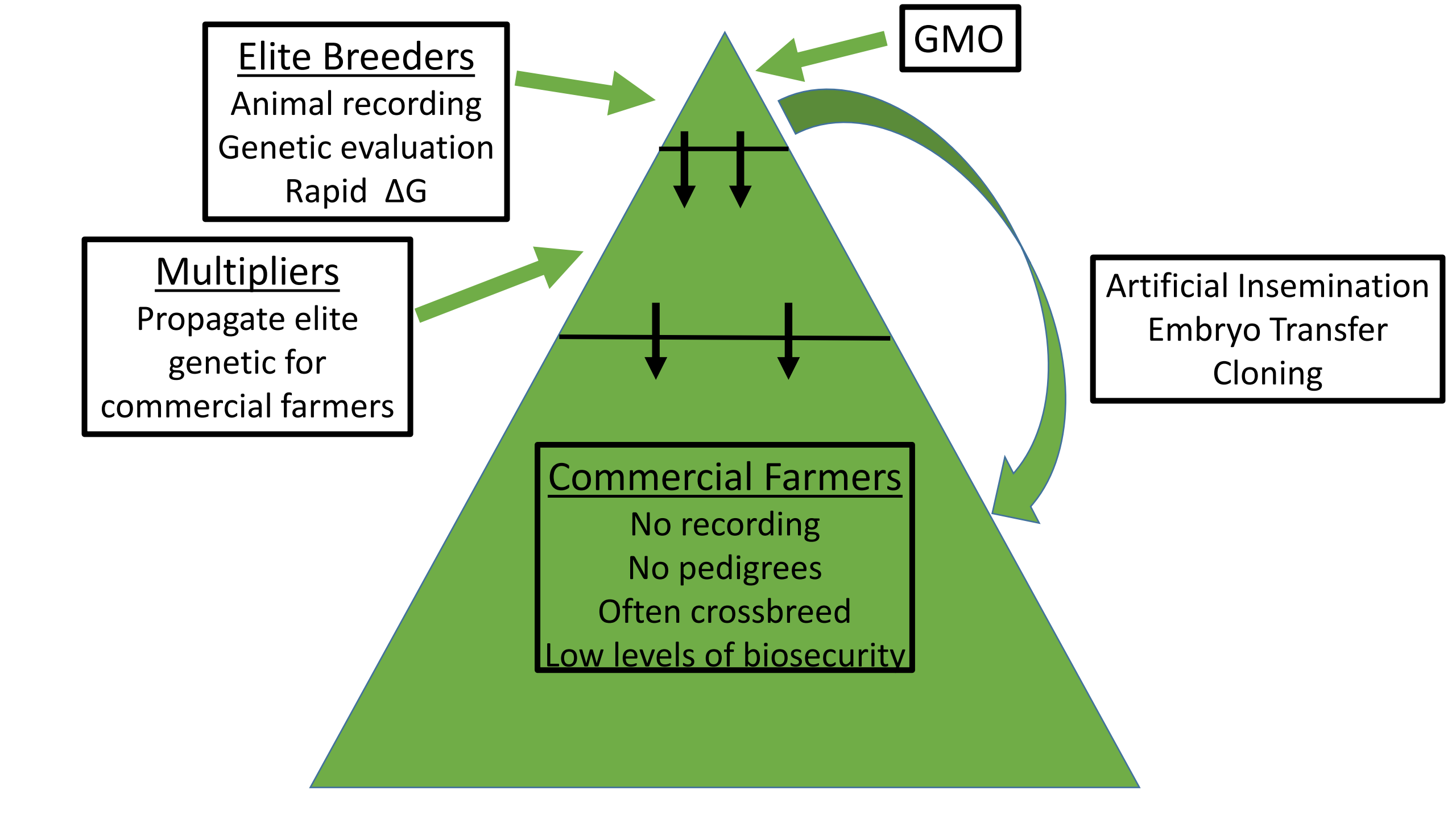
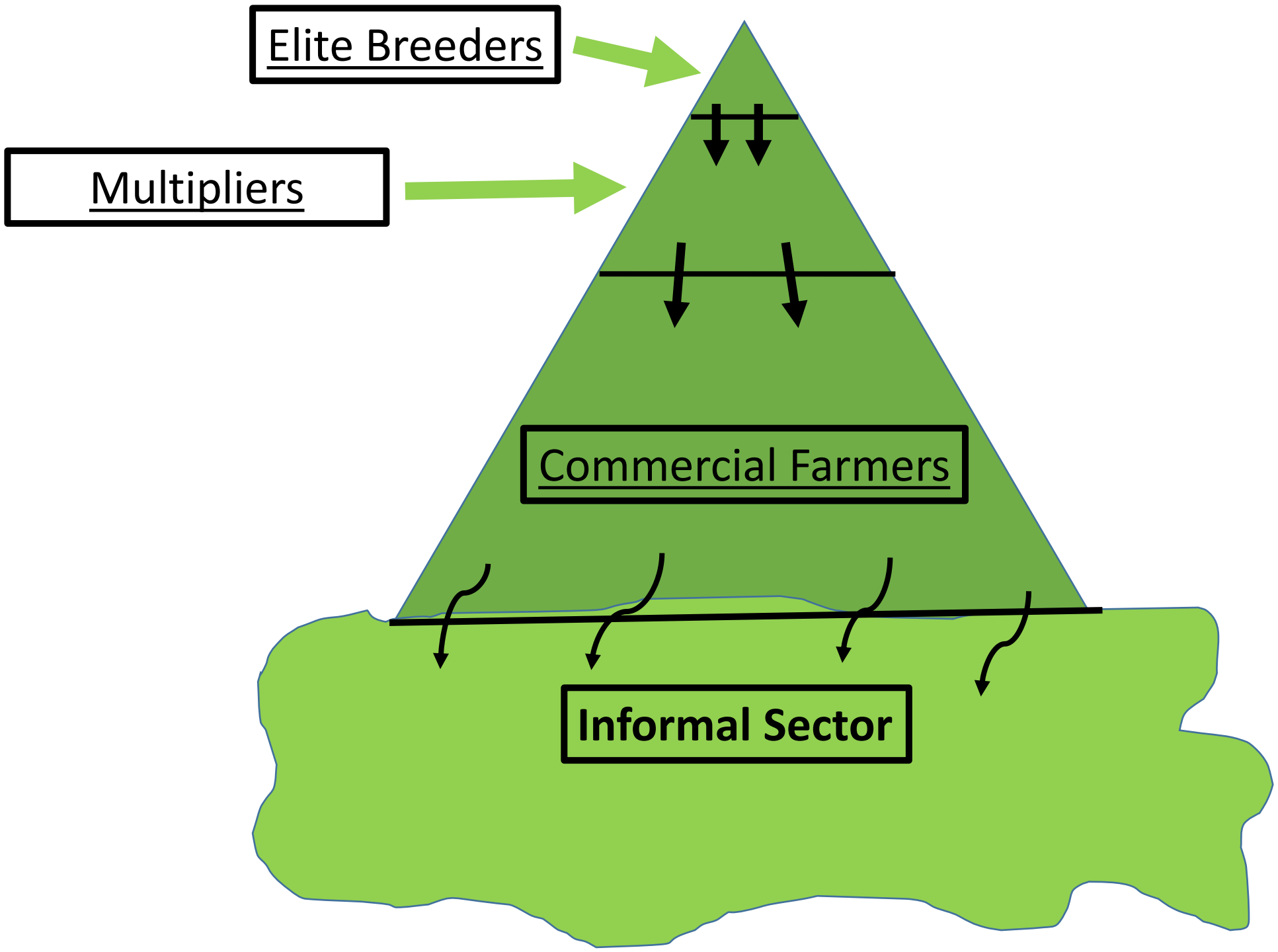
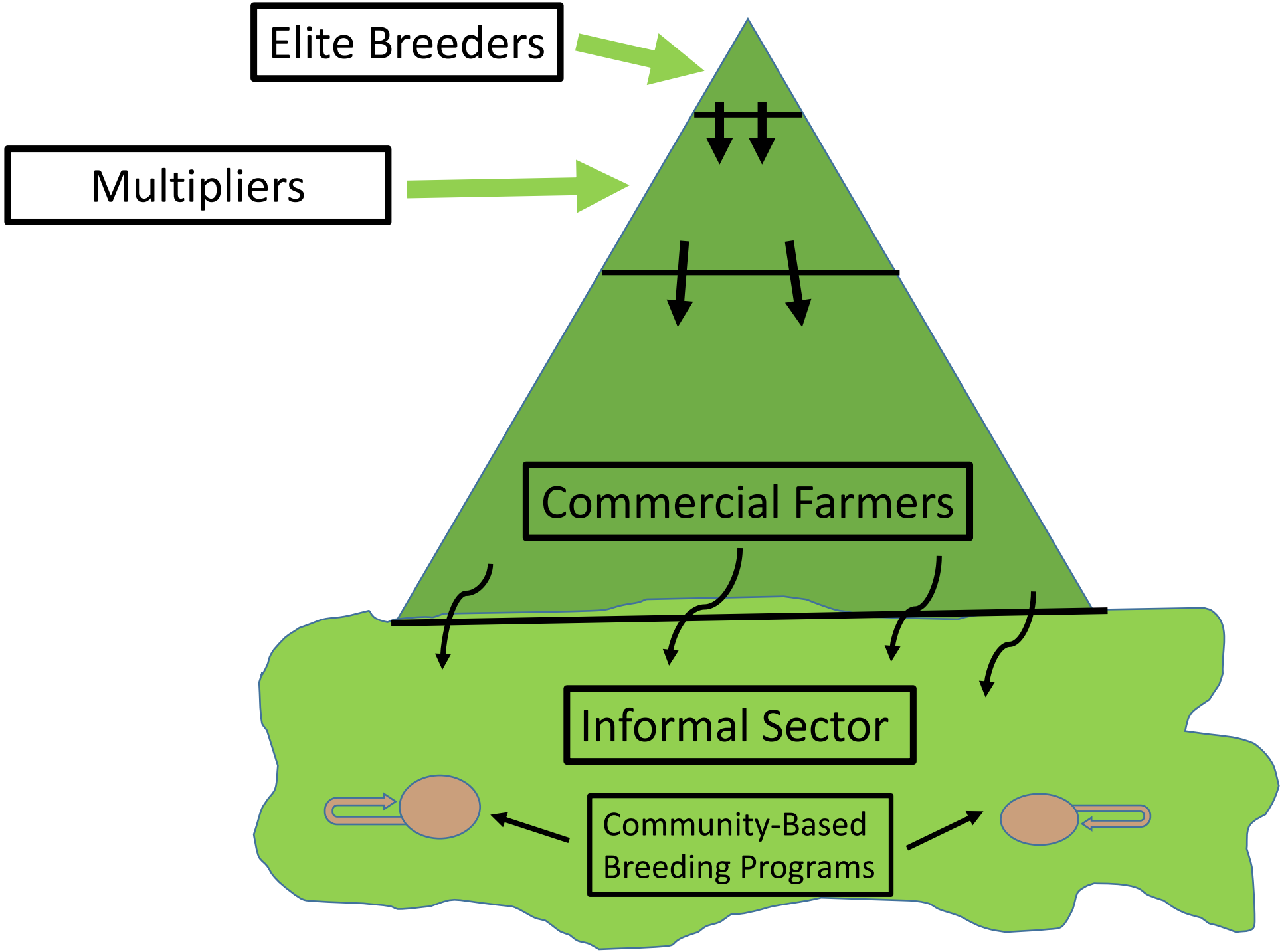
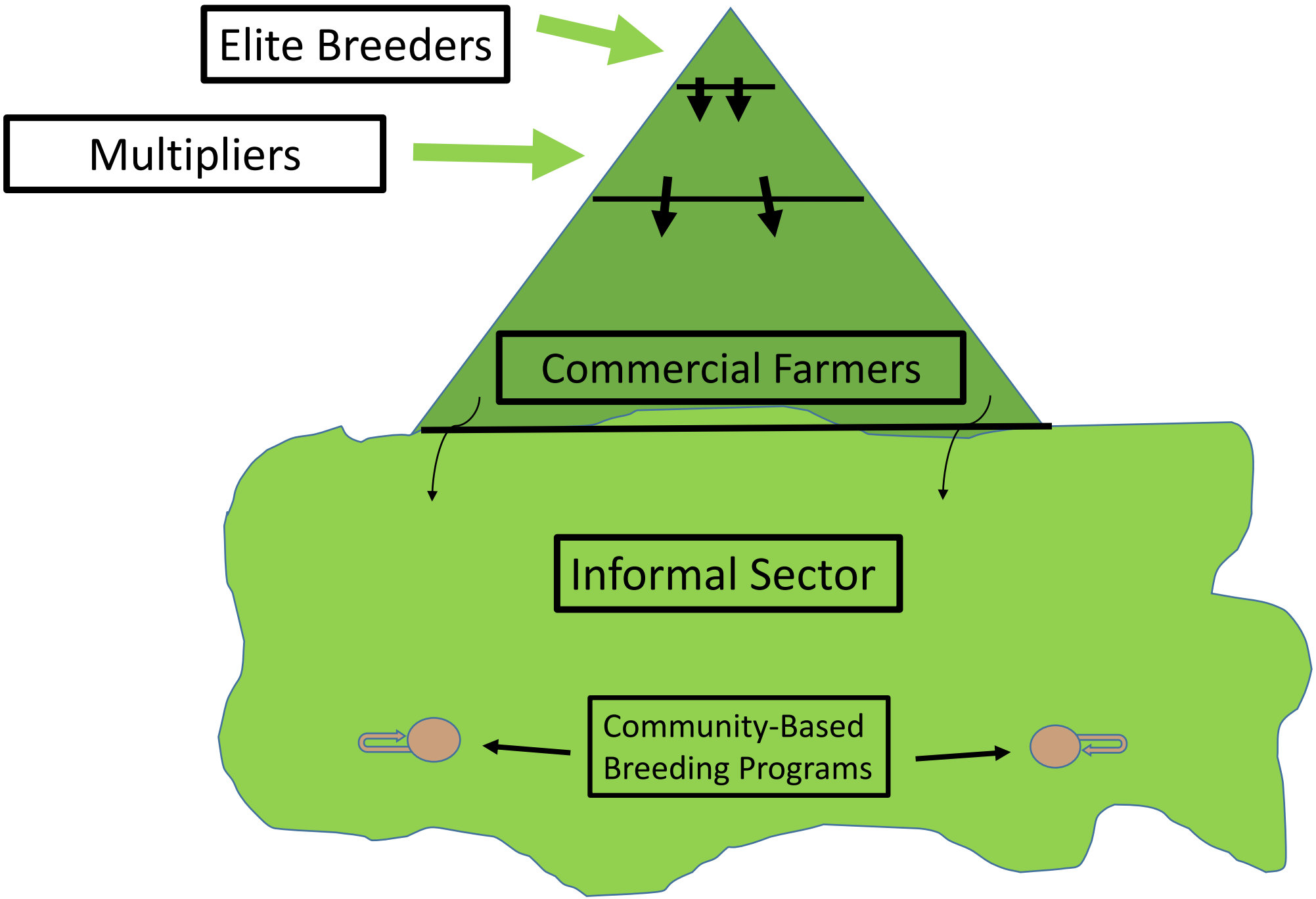

Elite Breeders
Animal recording
Genetic evaluation
Rapid ΔG
Multipliers
Propagate elite genetic for commercial farmers
Commercial Farmers
No recording
No pedigrees
Often crossbreed
Low levels of biosecurity


Elite Breeders
Animal recording
Genetic evaluation
Rapid ΔG
GMO
Multipliers
Propagate elite genetic for commercial farmers
Artificial Insemination
Embryo Transfer
Cloning
Commercial Farmers
No recording
No pedigrees
Often crossbreed
Low levels of biosecurity


Elite Breeders
Multipliers
Commercial Farmers
Informal Sector


Elite Breeders
Multipliers
Commercial Farmers
Informal Sector
Community-Based
Breeding Programs


Elite Breeders
Multipliers
Commercial Farmers
Informal Sector
Community-Based
Breeding Programs

Candidates for Gene Manipulation in Small Ruminants—Production Traits

- Litter size: objective is to increase the frequency of twins without producing litters of 3 or more
- Muscularity: increase muscle growth to enhance lean meat yield
- Fiber (cashmere, wool) production: increase fiber production without also increasing fiber diameters (fineness)
- Color: modify color inheritance to facilitate management of crossbreeding programs
- A2 milk (cattle) to take advantage of perceived health benefits

Candidates for Gene Manipulation in Small Ruminants Production Traits

- Most of these changes involve a loss in regulatory control, or an effective “knock-out” of an otherwise functional gene that, under past conditions, had selective value for the species.
- This is easier than doing a precise base substitution, as any (most?) disruptions will do.
- But multiple disruptions are possible, creating regulatory challenges, even if effects on the animal are identical.
- Losses of regulatory control often require compensating increases in environmental control to take advantage of the enhanced performance potential.

Candidates for Gene Manipulation in Small Ruminants Production Traits

Litter Size

- Litter size: objective is to increase the frequency of twins without producing litters of 3 or more.
- Loss-of-function mutations in several genes can increase ovulation rates and, potentially, litter size in sheep, with likely homologues in goats.
- Candidate target genes include BMPR-1B (Booroola), BMP-15 (sex-linked), GDF-9 (multiple mutations). Many of these mutations can result in litters of 3 to 5 lambs, which is not desirable.
- Homozygotes for some, but not all, mutations in BMP-15 and GDF-9 are sterile, so careful breeding management is required for utilization. New GDF-9 mutation from Brazil has both a modest effect and no homozygote sterility.
- Garole - Deccani story

Candidates for Gene Manipulation in Small Ruminants Production Traits

Muscularity

- Primary candidate for manipulation is myostatin, which normally regulates muscle growth.
- Several loss-of-function mutations in cattle produce the “double-muscled” condition. Similar mutations exist in sheep and goats, but generally with smaller effects and possible effects of genetic background.
- Potential for more intensive study of myostatin sequences in sheep and goats to identify better candidates for manipulation.
- Advantages can only be captured if the nutrition of the animal is adequate.
- Callipyge story.

Texel

- Found in the Netherlands & Belgium
- Possesses a mutation in the regulatory region of the myostatin gene that results in partial loss of normal regulation of muscle growth

Candidates for Gene Manipulation in Small Ruminants Production Traits

Fiber Production

- Primary candidate for manipulation is fibroblast growth factor 5 (FGF-5), which normally regulates hair growth.
- Naturally occurring mutations exist in several species.
- Studies in China have documented greater growth of both hair and cashmere in young cashmere goats, without compensating increases in fiber diameter.
- Potential value will depend on the interactions of fiber weight and fiber quality in defining value, e.g., Australian Merino.
- Increasing the length of the cashmere does have economic value.
- Potential homologues in alpaca?

Candidates for Gene Manipulation in Small Ruminants Production Traits

Color

- Crossbreeding is often problematical in developing countries because of inadequate control over mating plus the tendency to retain attractive (i.e., big) but poorly adapted individuals as breeding females.
- Depending on the color of the local females, a sire breed for crossing could be developed with a color marker (e.g., dominant black in sheep) that would mark the crossbred offspring.

A2 Milk

- A2 variant of the beta-casein milk protein.
- Potential to create A2 milk lines from elite Holstein cattle.

Both of these would require precise, targeted manipulations, not just loss-of-function.

Potential for Gene Manipulation in Small Ruminants Health and Disease

- Disease resistance/resilience can be complex and multifactorial (gastrointestial parasites; trypanosomiasis).
- Manipulation of immune function can have unanticipated effects.
- Limited biosecurity in pastoral production.
- Can disease-resistant GM animals become a reservoir of disease for non-GM individuals or species?
  - Pasteurellosis in Bighorn sheep, avian influenza in wild waterfowl?
- Does resistance to one disease impair resistance to others?
  - Ovine progressive pneumonia/Maedi-visna?
- Scrapie story.
- Regulators need independent input from both specialists and generalists

Conclusions
Regulatory Issues in Evaluating GM Animals

- Human health risks
  - Modest (very modest?) for production traits
  - Avoid creating vectors for potentially zoonotic diseases
- Environmental impacts
  - Unanticipated impacts from use of GM and gene drive to dramatically reduce populations of disease vectors (mosquito, Tsetse fly, ticks, etc.).
  - Domestic animals as reservoirs of diseases for wild relatives?
- Animal health and welfare
  - Direct effects on animal welfare: genetic sterility, reduced resilience to certain diseases, increased frequency of embryo loss or congenital genetic defects (all highly speculative)
  - Indirect effects on animal welfare through inadequate nutrition or management.