Principles of Animal Genetics and Breeding

ADVS 4560
PART 1: ANIMAL BREEDING FROM THE TOP DOWN

ADVS 4560
Introduction

• Definition of “Animal Breeding”

  – What it is: Animal Breeding is the application of the principles of genetics with the goal of improvement of domestic animals.

  – What it is not: Animal Breeding is not the actual process of achieving sexual or asexual reproduction in animals (e.g., artificial insemination, embryo transfer, cloning). However, these processes are necessary to achieve the goals of animal breeding.
Introduction

Fundamental Questions of Animal Breeding

1) What is the Best Animal? (Chp. 1)
2) How do you breed for the best animal once you have defined it? (Chp. 2)
CHAPTER 1: What is the “Best” Animal?

Describe Animals According to **appearance** or **performance**

<table>
<thead>
<tr>
<th>Perception</th>
<th>Appearance</th>
<th>Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Observable by the senses (usually visual)</td>
<td>Measurable (quantifiable)</td>
</tr>
<tr>
<td>Characterization</td>
<td>Descriptive</td>
<td>quantitative</td>
</tr>
</tbody>
</table>
Defining “Best” Animals

• Each character thus described is called a Trait
  – Traits are abstract concepts, such as coat color, speed, weaning weight, litter size, etc.

• The actual expression of a trait in an individual is called a Phenotype
  – ‘Coat color’ is a trait
  – ‘red’, ‘black’, or ‘white’ are phenotypes for the coat color trait.
### Defining “Best” Animals

**TABLE 1.1 Examples of Traits and Phenotypes**

<table>
<thead>
<tr>
<th>Trait</th>
<th>Possible Phenotypes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Presence of horns</td>
<td>Horned, polled, dehorned</td>
</tr>
<tr>
<td>Height at withers</td>
<td>16 hands, 14–2</td>
</tr>
<tr>
<td>Yearling weight</td>
<td>850 lb, 1,225 lb</td>
</tr>
<tr>
<td>Placing</td>
<td>First, third, last</td>
</tr>
<tr>
<td>Shell color</td>
<td>White, brown</td>
</tr>
<tr>
<td>Quarter-mile time</td>
<td>19.3 sec, 20.8 sec</td>
</tr>
<tr>
<td>Calving ease</td>
<td>Assisted, unassisted</td>
</tr>
<tr>
<td>Litter size</td>
<td>5, 11, 14</td>
</tr>
</tbody>
</table>
Defining “Best” Animals

• Phenotype for a quantifiable trait is often called “Performance”

  – Example: “This horse has demonstrated outstanding performance by running a quarter-mile race in 19.3 seconds.” (i.e., phenotype for 0.25 mi speed is 19.3 seconds)
Defining “Best” Animals

• The Animal breeder’s main objective is to change Animal Populations genetically in the direction of the most desirable phenotypes/performance

  – To accomplish this, it is necessary to understand what are the most desirable Genotypes, because $P = G + E$ (Phenotype = Genotype + Environment)
Defining “Best” Animals

– Genotype can refer to

• The genes affecting a particular trait (coat color, weaning weight) or

• The genes affecting a complex that is of interest, such as a “tropically adapted” genotype (in this latter sense, we can refer to Biological Type(s))
Analyzing the System

• To answer the question, “What is the best animal?” it is necessary to define a context in which the phenotype/performance can be evaluated and the key traits involved can be identified.

• A **Systems Approach** is one way to define context.
  – There are many possible systems that can be conceptualized.
  – The Animal Breeder must define one that is relevant.
Analyzing the System

- Consider a single farm or ranch as a system

  - The System components might be categorized as

    - Animals (genotype)
    - Physical Environment
    - Fixed Resources and Management
    - Economics
Analyzing the System

• A change in one component of the system can have an influence on other system components (i.e., they interact).

  – **Example 1**: A significant change in the **pricing formula for milk (Economics)** can change the **Genotype (Animal)** which is most profitable (Genotype x Economics Interaction).

  – **Example 2**: A long term **weather variation** (extended drought) can change the **Genotype** that performs best (3-way interaction, Physical Environment x Genotype x Economics).
Analyzing the System

• **Genotype x Environment Interactions** often play a critical role in determining **what is the best animal for a given environment**

– A classic example of this kind of interaction involves **Biological Type and Climate**:

<table>
<thead>
<tr>
<th>Genotype (Biological Type)</th>
<th>Environment (Climate)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperate adapted</td>
<td>Temperate climate</td>
</tr>
<tr>
<td>Tropical adapted</td>
<td>Tropical climate</td>
</tr>
</tbody>
</table>
Analyzing the System

**FIGURE 1.1** Example of a genotype by environment interaction.
Analyzing the System

• Knowledge of Interactions involving animal Genotypes is needed to develop practical goals for breeding programs (= Breeding Objectives)

  – Cattle breeders in Tropics must pay more attention to parasite/disease resistance
  – Cattle breeders in Temperate zones can afford to pay less attention to parasite resistance, and thus can apply greater stress on “productive traits,” e.g., rate of gain, feed efficiency, carcass quality, etc.
Analyzing the System

• Question:

Why can’t animal breeders “have it all?” i.e. the best parasite/disease resistance and the best productive traits in the same animal(s).
Analyzing the System

• Conceptualizing Interactions
  – Use the terms “Relative” and “Depends” in describing interactions:
    • Relative performance of different Genotypes Depends on the Environment in which they exist
    • Can this statement be turned around and still make sense?
    • NO: dependency does not make sense both ways; Environments are not determined by animal Genotypes.
Analyzing the System

• Conceptualizing Interactions, Cont.
  – An Interaction cannot exist unless there are at least 2 levels of each factor involved.

• Would it be correct to describe the relationship between Growth Rate and Level of Feed in Fig. 1.4 as an Interaction?

FIGURE 1.4  Example of an environmental effect, in this case the effect of level of feed on growth rate. Note how different this graph appears from the graph of an interaction in Figure 1.3.
Analyzing the System

• **NO:** only one Genotype is involved
  
  – To have G x E interaction, you need a second genotype and must show that the difference between genotypes is not the same across environments.

• This is an example of the influence of Environment (level of feeding) on the expression of Phenotype (growth rate) within a single Genotype

\[ P = G + E \]
Questions

• Graph (a): Is this an example of an interaction?
  – Yes

• Graph (b): Is this an example of an interaction?
  – Yes
Questions

• Graph (c): Is this an example of an interaction?
  – Yes

• What would a graphic representation of a non-interaction look like?
  – Parallel lines
Breeding Objectives and Industry Structure

• To define “Best Animal” in context, one must understand the Breeding Structure of the animal industry involved

  – Typical Breeding Structure consists of:
    • **Elite Breeders and Multipliers**: Seedstock Producers that generate and supply superior seedstock genetics (breeding stock, semen, embryos) to End Users
    • **End Users**: Commercial Producers who supply end (market) products to processors and consumers

  – Seedstock producers should be focused on meeting the needs of End Users.
Breeding Objectives and Industry Structure

- Elite Breeders
- Multipliers
- End Users
Questions

• Is actual Breeding Structure as clear cut as in the diagram?
  – NO, there is intergrading and overlapping between the levels.

• Historically, have Seedstock Producers always focused on meeting the needs of End Users?
  – NO, they sometimes follow fads and fancies related to pedigrees and show ring success.
Questions

- What is not good in this show winning animal?

Fig. 1-4. Grand Champion, Junior Division steer, American Royal Livestock Show. Owned by Richard Dressen, Guthrie, Oklahoma. (Courtesy, Richard Dressen; photo by Smith)
Change vs. Stasis

• Does Animal Breeding always involve changing animals in some way in order to improve them?

**NO**: Sometimes maintaining a constant or unchanging state in the animal (Stasis) is the preferred option.
Change vs. Stasis

• **Example:** hock set (rear leg conformation)
  – If legs are too straight (post legged) it results in increased incidence of lameness.
  – If legs have too much “set” (sickle hocked) the freedom of movement is impaired.
  – The ideal set of leg for optimum function is an intermediate angle
Change vs. Stasis

- Ideal position
- Stands under (sickle hocked)
- Post legged (leg too straight)
Change vs. Stasis

• For an **Intermediate Optimum**, genetic improvement consists **not** of unidirectional change (more, less) in every individual but in increasing the proportion of all animals that express the optimum phenotype.

  – Improvement = Increased Uniformity