Neuroendocrine and Metabolic Control of Ingestion and Reproduction

Jill Schneider
Department of Biological Sciences
Orchestrating The Appetites

Jill Schneider
Department of Biological Sciences
Pre-class Quiz
Which is most true?

1. Hormones
   - A. Regulate body weight
   - B. Set behavioral priorities

2. Estradiol and testosterone are
   - A. Sex hormones
   - B. Ingestive behavior hormones

3. Leptin is produced in adipose tissue cells and
   - A. Induces satiety
   - B. Increases sexual desire
Energy Homeostasis
(Not Body Weight Homeostasis
Not Food Intake Homeostasis)

THESE ARE OLYMPIC ATHLETES

Homoios = similar

Stasis = fixed
Bull Elephant Seal-Feeding Season

7 months of fishing and fattening

Insulin and insulin sensitivity high
Bull Elephant Seal-Breeding Season

Fasts for 3 months while fighting for territories and mating

Loses $\frac{1}{3} - \frac{1}{2}$ of his body weight

Insulin and insulin sensitivity low
If we knew what makes them fast for 3 whole months.....

If we knew the internal physiological signal that triggered their Return to the feeding grounds.....
Signals

7 months of fishing and fattening

Low Sex Hormones (Testosterone)
Insulin and insulin sensitivity high
Bull Elephant Seal-Breeding Season

Fasts for 3 months, fighting and mating

Loses $\frac{1}{3} - \frac{1}{2}$ of his body weight

Sex hormones high

Insulin and insulin sensitivity low
What can we learn from elephant seals?

**Homeostasis in fuels**

**Fluctuation in body weight and food intake**

There must be a continuous supply of fuels for life. To accomplish this, body fat must fluctuate. In seals it fluctuates wildly.

There must be signals (hormones? Fuels?)
### Homeodynamics vs homeostasis in body weight:
What they say about the purpose of hormones that control food intake

<table>
<thead>
<tr>
<th>Purpose of Homeostatic Mechanisms:</th>
<th>Purpose of Homeodynamic Mechanisms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increase the chances of survival</td>
<td>Increase survival and Reproductive success</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>How Homeostasis works</th>
<th>How Homeodynamics works</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compensate for surfeits and deficits in the available energy (too little energy, get hungry and eat.....too much body fat...inhibit the drive to eat)</td>
<td>Compensates for deficits and surfeits in fuels</td>
</tr>
<tr>
<td></td>
<td>Anticipates future energetic demands of reproduction and unpredictable energetic future</td>
</tr>
</tbody>
</table>
Allostasis or Homoedynamics: “Homeostasis Is Achieved Through Change”

- Food intake is *increased*, body fat is gained, and food is hoarded in anticipation of food shortages and the energetic costs of reproduction.

- Body fat is *lost* when energetic costs outstrip food intake.

- The level of body fat will *change* with age and life history stage.
Reproductive system inhibited by food deprivation

Deficits in Fuel Availability

Ovaries, testes

NO estradiol
Low estradiol increases food intake/weight gain
High Estradiol Inhibits Food Intake

Ovaries, testes

Estradiol
As a General Rule (with exceptions)

Most hormones that inhibit food intake stimulate some aspect of reproduction.

Most hormones that stimulate food intake inhibit some aspect of reproduction.
### just a few examples

#### Sex
- Estradiol +
- Dopamine +
- Opiates –
- Kisspeptin+
- GnIH –
- Insulin/IGF+,-
- Leptin +
- Ghrelin-
- NPY –

#### Ingestive
- NPY +
- Ghrelin +
- Leptin –
- Insulin-,+
- GnIH +
- Kisspeptin-
- Opiates +
- Dopamine –
- Estradiol -

Why is the Brain Organized This Way?

Why do hormones affect both hunger for food and desire for sex?
Reminder
Reproduction is Energetically Costly
Energy Supply and Demand

Fluctuate!
Estradiol

Obesity in mice with no receptor for Estradiol (right)

Give a normal mouse estradiol
- eats less
- loses body weight

Body weight gain after menopause
Profound Fluctuations in Ovarian Hormones over the Menstrual Cycle
Simple Assumptions

Plasma Estradiol

• High mid cycle

Low after menopause

Food Intake

• decreases

Post menopausal overeating

Body Weight

• decreases

Post menopausal Weight gain

Simple Assumptions
The Data
What-what? Changes in Caloric Intake Over the Menstrual Cycle are Subtle or Nonexistent (Fessler 2003)
Ovarian Steroids Fluctuate Over the Hamster Estrous Cycle

Syrian hamsters exhibit extremely regular estrous cycles

After Lisk (1985)
Hamster Estrous Cycle

Reproductive Hormones

Food Intake

- LH
- Estrus
- Vaginal discharge
- Progesterone
- Estradiol

6-h Food Intake (g)

Days of the Estrous Cycle
“Reasons”

Humans are “emancipated”
From the effects of gonadal hormone

Humans have “higher cognitive functions”
That “override” hormones

Humans lie about their food intake
Of Hamsters and Humans

When these traits evolved, energy not available continuously.

In most wild habitats:
- Energy availability fluctuates
- Energy demands fluctuate
Syrian Hamsters
*(Mesocricetus auratus)*

- Live alone in burrows
- Hot days; cold nights; harsh dessert
- No food in winter
- Travel long distances for food
- 90-min of activity at dawn and dusk
  - Spend *all* of this time hoarding
- **Ingestive behavior**
  - food hoarding (appetitive)
  - food intake (consummatory)
Human Hoarders

Medium Hoarding

High Hoarding
Syrian Hamsters
(ingestive behavior)

- Live in burrows
- 90-min of activity at dusk
- **Ingestive behavior**
  - food hoarding (appetitive)
  - food intake (consummatory)
Syrian Hamsters
SEX BEHAVIORS

- 4-day estrous cycle
- Sex behavior
  male preference (appetitive)
  vaginal scent marking day 3
  lordosis (consummatory)
  day 4
Are the effects of ovarian steroids masked by...

- lack of sexy males?
- an overabundance of food?
- Experimenter not paying attention to the right behaviors i.e., MOTIVATION?
  - Motivation can be assessed by measuring
  - Appetitive behaviors
Ingestive and Sexual Motivation in a “Semi-natural” Environment

Male Preference = \[(\text{Time Male} - \text{Time Food}) / \text{Total Time}\]

Total Food Hoarded in 90 Minutes
Does Food Restriction Unmask Effects of Ovarian Steroids?

8 DAYS of Respective Diets
1. N = 10 Food limited = 25% food restricted
2. N = 10 Fed Ad libitum

4 Days of Testing
(every day of the estrous cycle)

Test for appetitive & Consummatory ingestive And sex behavior
**Males and Food Restriction** *Unmask* Effects of Ovarian hormones on MALE PREFERENCE

**MALE PREFERENCE:**
Time male – Time Food
Total Time (900 sec)

This is appetitive Behavior (a window Into motivation)
Males and Food Restriction *Unmask* Effects of Ovarian Hormones on FOOD HOARDING

Food Hoarding \( g/90\text{-min} \)

Food Intake \( g/90\text{-min} \)

Appetitive!

Consummatory (no change over the Cycle)
- Mild food restriction and ovarian hormones had no significant effects on food intake (consummatory behavior)

- Mild food restriction unmasked the effects of ovarian hormones on food hoarding (appetitive behavior)
  - APPETITIVE INGESTIVE BEHAVIOR is a window into motivation
Males and food restriction

*Unmask* Effects of Ovarian Hormones
Alternative to body weight homeostasis

- Hormonal control of food intake is
- not always about maintaining your weight
- about getting food now
- so you will have it later
  - When food is scarce
  - When energy demands are high
Alternative to Body weight Homeostasis

- Hormonal control of food intake is
- not always about maintaining body weight
- about getting food now
- So when good mating partners arrive you will hold plentiful resources and be inclined to stop eating long enough to reproduce
Hormones orchestrate the appetites for food and sex

- to optimize reproductive success
- in environments where energy availability fluctuates
- This is not obvious when females live in enclosed spaces, warm temps, no males, no exercise, with unlimited food
- These mechanisms did not evolve in animals with no mating partners and unlimited food
Food Eaten (self rating score) Over the Menstrual Cycle

Number of Cravings (self rating score)

Brown et al., 2008
HUMAN RELEVANCE

Caloric Intake over the Menstrual Cycle From Fessler, 2008

Unlimited Food

Levels of Binge Eating in Women with Bulimia

Food Limited

ovulation

menstruation

Klump et al., 2010

Fig. 2. Levels of binge eating (●●●), estradiol (●●), and progesterone (−−−−−) across the menstrual cycle in study 2. Mean Z scores represent 5-day rolling averages calculated within subjects, then averaged across participants (n=9 female twins).
Post-class Quiz
Which is most true?

1. Hormones
   - A. Regulate body weight
   - B. Set behavioral priorities

2. Estradiol and testosterone are
   A. Sex hormones
   B. Ingestive behavior hormones

3. Leptin is produced in adipose tissue cells and
   A. Induces satiety
   B. Increases sexual desire
Hormones

- Have reciprocal and Opposite effects on Energy Intake and Reproduction

- **Hormones that stimulate eating** (hyperphagia)
  - Inhibit reproductive processes

- **Hormones that stimulate reproductive processes**
  - Inhibit eating and body weight storage
Reproduction and Ingestive Behavior

- Reciprocal Interactions
- Gonadal hormones influence food intake
  - Estradiol decreases food intake and food hoarding
- Low energy (low leptin) inhibit reproduction
- High energy (availability of fuels, leptin) stimulates reproduction
Homeostasis Through Change

Sex Hormones and Ingestive Hormones: couple mating and fertility

Ingestive Hormones: keep body weight in some healthy range

Orchestrate the appetites for food and sex in order to optimize reproductive success in environments where food availability fluctuates