Nutrition and Life Stages
3rd term 2019-2020
Instructor: Dr. Kristen Hurley
TA: Kaitlyn Harper
Course Description

- Course reviews the stages of human development as a way for understanding human nutrition.
- Lectures and discussion sections focus on life stages through a progression, highlighting the genetic, biological, behavioral, and psychological influences on well-being in that life stage.
- Social and political dimensions to nutrition and health/disease differences within and between populations are also explicitly discussed.
Course Learning Objectives

Upon successfully completing this course, students will be able to:

- Integrate genetics, biology, and nutrition through in-depth study of a nutritional issue across the life stage
- Explain behavioral and psychological factors that affect a population’s health and nutrition
- Explain the social and political determinants of health and how they contribute to population health and nutrition and inequities
- Discuss the means by which structural bias, social inequities and racism undermine health and create challenges to achieving health equity at organizational, community and societal levels
- Communicate audience-appropriate public health content, both in writing and through oral presentation
Course Format

- Sequenced following the progression across the life span
  - Pregnancy / Fetal Development (Dr. Caulfield)
  - Lactation (Dr. Caulfield)
  - Infancy/Childhood (Dr. Hurley)
  - Adolescence (Dr. Schulze)
  - Adulthood (Dr. Talegawkar)
  - Developmental Origins of Health and Disease (Dr. Palmer)

- Format follows a **lecture** and **discussion class** session per life stage topical area

- First class is a lecture and the second class is a participatory discussion session (except for first 2 classes)

- **Required readings** for each topic are discussed in the second session
In Summary, This Class...

- Follows a life course perspective
- Lectures emphasize the genetic, biological, behavioral, psychological, and social and political underpinnings for nutrition and health across the life span and the role of early nutritional influences on health later in life
- Discussion readings are meant to spark interest, discussion, and learning about disease burden, health inequities, policies and programs, and research
- Students are graded for their participation during each discussion session
- Students choose a topic for in-depth study and specific assignments guide their learning towards the final project through which they demonstrate their understanding of the multi-factorial influences on nutrition and health/disease through a written report and oral presentation (see diagram 1)
“proposes that environmental exposures, including biological, physical, social, and behavioral factors, as well as life experiences, throughout the entire life span, influence health outcomes in current and future generations”
Guiding Activities and Deadlines

- In-class topic area quizzes (short, ~ 10-15 mins) taken - Jan 29, Feb 5, Feb 12, Feb 19, Feb 26, March 4. Top 5 out of 6 scores included in final grade

- Paper Title Due - February 3

- Annotated Bibliography Due - February 12
  - 12 or more references pertinent to your paper

- Paper due - March 4

- Presentation - March 9 or 11

- Develop a conceptual framework to guide research, paper and presentation (see syllabus for details)
Nutrition during pregnancy -- outline

A. Introduction
   - Nutrient metabolism in pregnancy - key concepts
   - Paradigms for viewing the materno-fetal dyad

B. Role of placenta, function and nutrient transfer

C. Hormonal changes during pregnancy

D. Physiology of pregnancy
   - Changes in cardiovascular, gastrointestinal, respiratory and other functions
   - Changes in CHO, fat and protein metabolism
   - Changes in micronutrient requirements and plasma concentration of nutrients
E. Changes in food intake, BMR and physical activity
   ► Physiologic adaptations and variations

F. Weight gain during pregnancy
   ► IOM guidelines and adherence to recommendations

G. What is optimal nutrition in pregnancy?
Nutrient Partitioning

- **Homeostasis** - Maintenance of physiological equilibrium, i.e. constant conditions in the internal environment.

- **Homeorrhesis** - Orchestrated changes for the priorities of a physiological state, i.e. coordination of metabolism in various tissues to support a physiological state (e.g. pregnancy, lactation).
Paradigms for considering materno-fetal relationship

- Fetus as a “perfect parasite”
- Mother and fetus in genetic conflict - Haig’s hypothesis and genomic imprinting
- “Harmony Model” - IOM 1990
  - 3 part harmony: mother, fetus and placenta
- Psychophysiological relationship
What types of nutrient adjustments take place?

- Accretion of new tissue
- Deposition in maternal stores
- Redistribution among tissues
- Increased turnover or rate of metabolism

These changes in nutrient metabolism are driven by hormonal changes, fetal demands, and maternal nutrient supply.

Maternal behavioral changes augment physiologic changes.

There is a lot of heterogeneity in “normal”, but there are limits.
The Placenta - An endocrine organ

- Placental weight increase follows an elongated sigmoidal curve
- The placenta increases in circumference and thickness until the 4th month and then increases only in circumference
- The villous surface increases from 830 to 125,000 cm²
- Functions
  - Nutrient, blood and O₂ transfer to the fetus
  - Hormonal secretion which induces physiological changes in the maternal organism
Hormones of pregnancy

<table>
<thead>
<tr>
<th>Hormone</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human chorionic gonadotropin (hCG)</td>
<td>Maintains the corpus luteum</td>
</tr>
<tr>
<td>Human placental lactogen (hPL), CSH</td>
<td>Biologically similar to GH and represents a type of growth factor for the fetus/placenta; affects CHO and lipid metabolism</td>
</tr>
<tr>
<td>Estrogen (estrone, estradiol, estriol)</td>
<td>Influence uterus and other reproductive hormones; affect CHO, lipid and bone metabolism</td>
</tr>
<tr>
<td>Progesterone</td>
<td>Source: Corpus luteum &amp; placenta; relaxes smooth muscles of GI and urinary tracts, and uterus, prevents milk secretion in pregnancy</td>
</tr>
</tbody>
</table>
All of these hormones of pregnancy are of corpeus luteum and placental origin.
To facilitate increase in nutrient and water absorption

- ↓Intestinal motility → ↑gastric emptying time (heartburn and constipation)
- Decreased smooth muscle tone resulting in increased water absorption
- Increased intestinal absorption of nutrients such as iron, calcium, vitamin B12
- ↑Colonic absorption of H₂O and Na (controlled by angiotensin and aldosterone that are elevated in pregnancy) at 12-20 wk of gestation
Changes in renal function occur to maintain increased metabolic and circulatory demands of the maternal body and to support excretion of fetal waste products (creatinine, urea)

- ↑ in effective renal plasma flow by 50-80% (mostly in first trimester)
- ↑ Glomerular filtration rate by 50%
- ↑ Urinary excretion of glucose, aa, other nutrients (unrelated to plasma concentrations)
  - Increases at end of pregnancy suggesting decreased ability to re-absorb nutrients
Changes in GFR and renal plasma flow during pregnancy and postpartum

Note that increased GFR remains during postpartum period
Fetal needs of $O_2$ and nutrients require a progressive increase in uteroplacental blood flow

- $\uparrow$Cardiac output: Blood pumped by heart/min
  - During pregnancy: 6.9 L/min
  - Non pregnant woman: 5.2 L/min
- Cardiac output = f(heart rate+stroke volume)
  - Early increase is due to increased stroke volume
  - Heart rate $\uparrow$ gradually from 70 to 85 /min
  - Newer estimates suggest increase of about 7 /min
Recent results suggest changes in blood pressure and heart rate are not as large as previously thought.

Loerup et al. BMC Medicine 2019: meta-analysis of data from 36,000 women in 20 countries.
# Estimated Cardiac Output Distribution in Non-Pregnant and Healthy Pregnant Women Near Term

## Blood flow (ml/min)

<table>
<thead>
<tr>
<th>Circulation</th>
<th>Nonpregnant</th>
<th>Pregnant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cerebral</td>
<td>675</td>
<td>675</td>
</tr>
<tr>
<td>Coronary</td>
<td>210</td>
<td>250</td>
</tr>
<tr>
<td>Liver</td>
<td>800</td>
<td>1,350</td>
</tr>
<tr>
<td>Splanchnic</td>
<td>450</td>
<td>500</td>
</tr>
<tr>
<td>Renal</td>
<td>1,000</td>
<td>1,300</td>
</tr>
<tr>
<td>Skeletal Muscle</td>
<td>1,090</td>
<td>1,100</td>
</tr>
<tr>
<td>Skin</td>
<td>470</td>
<td>625</td>
</tr>
<tr>
<td>Uterus</td>
<td>20</td>
<td>500</td>
</tr>
<tr>
<td>Other organs</td>
<td>500</td>
<td>600</td>
</tr>
<tr>
<td>Cardiac Output</td>
<td>5,215</td>
<td>6,900</td>
</tr>
</tbody>
</table>

Rosso, P, Nutrition and metabolism during pregnancy 1990
Blood volume $\uparrow = \uparrow$ plasma volume ($\sim 43\%$) + $\uparrow$ # of red blood cells ($\sim 30\%$)

Increases on average from 2.5 L to 3.6 L (high individual variation)

How does plasma volume increase in pregnancy?

- Requires body fluid and electrolyte retention
- Increased colonic absorption of $H_2O$ and Na
- Achieved by $\uparrow$ Na and $H_2O$ reabsorption in the renal tubules (controlled by renin-angiotensin system stimulation of aldosterone)
- Driven by progesterone

Plasma volume expansion is correlated with obstetric performance
Increase in plasma volume (%)

Aguree and Gernand 2019: Meta-analysis of published studies
Plasma volume, erythrocyte volume and hematocrit throughout pregnancy (mean % change)

Vricella 2017
Expanded red cell mass: erythropoiesis

- Increased production of red blood cells occurs more slowly and to a lower degree than the expansion in plasma volume.

- Signal to begin increased production is not known; may be due to erythropoietin (EPO) and other placental hormones (progesterone).
  - EPO is produced in response to hypoxia.
  - EPO is used to treat anemia.

- Sometimes referred to as “Physiologic anemia of pregnancy”
  - Cut offs for anemia in pregnancy are lower than non-pregnant state and vary by trimester (11/10.5/11 g/dL).
No demonstrable change in the first half of gestation

Resting ventilation: VE \( \uparrow \sim 48\% \) (gas exchange \( \uparrow \) from 6 to 8 L/min) due to expanded tidal volume as respiratory rate remains constant

- Functional residual capacity \( \downarrow \) by 18\% (\( \downarrow \) respiratory reserve volume + \( \downarrow \) residual volume)

Increase caused by progesterone

VE increase exceeds the increase in O\(_2\) consumption of \(~21\%\)

“Hyperventilation” of pregnancy

VE, ventilatory equivalent or pulmonary ventilation is a function of tidal volume \( \times \) RR (breaths/min)
Biochemical and mechanical influences on pulmonary function during pregnancy

Figure 1 Flow diagram summarising the most important effects of biochemical (left) and mechanical (right) pregnancy-induced factors on pulmonary function, ventilatory pattern and gas exchange. $P_{O_2}$: oxygen tension; $P_{CO_2}$: carbon dioxide tension; FRC: functional residual capacity; ERV: expiratory reserve volume; TLC: total lung capacity; IC: inspiratory capacity; VC: vital capacity; $\uparrow$: increased; $\downarrow$: decreased; $\approx$: no change.
Pregnancy is characterized by maternal insulin resistance

Insulin secretion increases in response to increased insulin resistance of some maternal peripheral tissues

Mild fasting hypoglycemia and postprandial hyperglycemia and hyperinsulinemia

This results in increased rates of lipid fuel oxidation and glucose is spared for fetal use

Greater adipose lipolysis improves availability of liver of substrates to form TG which increase in circulation as VLDL

Fuel requirements of the fetus: In the 3rd trimester, 50-70% of fetal calories are derived from glucose
Normal pregnancy - a state of insulin resistance

FGIR: Fasting glucose to insulin ratio
QUICKI = 1/(log FPG + log FSI)
HOMA: homeostatic model assessment

Fasting glucose ~ same
Fasting insulin - increases
HOMA - increase

Sonagra et al; J Clin Diag Res 2014
Estrogen causes an initial increase in triglycerides, HDL, and VLDL.

TG cannot cross the placenta - but increases lead to promotion of energy storage.

These fat stores can be mobilized during fasting, converted to fatty acids and cross the placenta.

Later in pregnancy LDL ↑ and HDL ↓. The cholesterol component of LDL is used to make placental hormones.
Lipid concentrations before, during and after pregnancy

Wiznitzer et al 2009
Protein metabolism

- Proteins are broken down to amino acids which cross the placenta

- Plasma amino acid declines by 15-25%, maybe reflecting increase in placental uptake

- Serum albumin declines until ~25th wk of gestation and then remains constant

- Albumin is a carrier for some nutrients, thus, concentrations of some circulatory nutrients decline (e.g. Ca, Zn)
Serial changes in BMR during pregnancy relative to a pre-pregnant baseline in 9 studies (Allen, King, Lonnerdal, 1994)

The reasons for the differences in BMR are still not understood.
Based on median TEE change/wk of 8 kcal (range: -57 to 107 kcal)

Energy deposition of 180 kcal/d

EER for pregnant women 19-50 y
- 1st trimester: Adult EER + 0
- 2nd trimester: Adult EER + 160 kcal (8 kcal/wk x 20 wk) + 180 kcal = 340 kcal/d
- 3rd trimester: Adult EER + 272 kcal (8 kcal/wk x 34 wk) + 180 kcal = 452 kcal/d

TEE=total energy expenditure; EER=estimated energy requirement
Increased energy intakes with pregnancy but little change in macronutrient distribution with pregnancy of US women 2001-2014

Table 2. Data on Total Usual Intakes of Energy and Macronutrients for US Women Aged 20 to 40 Years by Pregnancy Status in the National Health and Nutrition Examination Survey, 2001-2014

<table>
<thead>
<tr>
<th>Dietary Component</th>
<th>Nonpregnant and Nonlactating Women, Mean (SE) (n = 5523)</th>
<th>Pregnant and Nonlactating Women, Mean (SE) (n = 1003)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy, kcal/d</td>
<td>1928 (11)</td>
<td>2232 (42)</td>
</tr>
<tr>
<td>Carbohydrate, g/d</td>
<td>242 (1.7)</td>
<td>294 (7.0)</td>
</tr>
<tr>
<td>% of Total energy</td>
<td>50.1</td>
<td>52.1</td>
</tr>
<tr>
<td>Added sugars, tsp/d</td>
<td>18.9 (0.3)</td>
<td>21.2 (0.9)</td>
</tr>
<tr>
<td>% of Total energy</td>
<td>15.4</td>
<td>14.3</td>
</tr>
<tr>
<td>Total fat, g/d</td>
<td>72.5 (0.7)</td>
<td>83.6 (2.1)</td>
</tr>
<tr>
<td>% of Total energy</td>
<td>32.7</td>
<td>33.0</td>
</tr>
<tr>
<td>Saturated fat, g/d</td>
<td>23.9 (0.2)</td>
<td>28.3 (0.8)</td>
</tr>
<tr>
<td>% of Total energy</td>
<td>10.7</td>
<td>11.1</td>
</tr>
<tr>
<td>Protein, g/d</td>
<td>71.4 (0.6)</td>
<td>81.9 (1.8)</td>
</tr>
<tr>
<td>% of Total energy</td>
<td>15.1</td>
<td>14.9</td>
</tr>
<tr>
<td>Alcohol, g/d</td>
<td>7.2 (0.4)</td>
<td>0.6 (0.2)</td>
</tr>
<tr>
<td>Dietary fiber, g/d</td>
<td>14.2 (0.2)</td>
<td>17.3 (0.5)</td>
</tr>
</tbody>
</table>

Bailey et al., 2019
Dietary studies of pregnant women in LMIC generally indicate diets lower in protein and fat and higher in carbohydrates (as % energy)

- US women in pregnancy reported:
  - 15% energy from protein
  - 33% energy from fat
  - 52% energy from CHO

Lee et al, 2012
Micronutrient requirements and changes in circulating concentrations in pregnancy (diet of moderate bioavailability for zinc and iron)

<table>
<thead>
<tr>
<th>DRI</th>
<th>Females</th>
<th>Pregnancy</th>
<th>Change during pregnancy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vitamin A (μg RE)</td>
<td>700</td>
<td>770</td>
<td>None, but declines in malnourished popn.</td>
</tr>
<tr>
<td>Vitamin D (IU)</td>
<td>600</td>
<td>600</td>
<td>↑ In late gestation</td>
</tr>
<tr>
<td>Vitamin E (mg)</td>
<td>15</td>
<td>15</td>
<td>↑</td>
</tr>
<tr>
<td>Vitamin K (μg)</td>
<td>90</td>
<td>90</td>
<td>Little data</td>
</tr>
<tr>
<td>Folate (μg DFE)</td>
<td>400</td>
<td>600</td>
<td>↓ Decline maybe due to hemodilution</td>
</tr>
<tr>
<td>Thiamine (mg)</td>
<td>1.1</td>
<td>1.4</td>
<td>No change, few studies, but deficiency unlikely in healthy populations</td>
</tr>
<tr>
<td>Riboflavin (mg)</td>
<td>1.1</td>
<td>1.4</td>
<td></td>
</tr>
<tr>
<td>Niacin (mg)</td>
<td>14</td>
<td>18</td>
<td>-</td>
</tr>
<tr>
<td>Vitamin B-12 (μg)</td>
<td>2.4</td>
<td>2.6</td>
<td>↓ By 25-50% due to hemodilution</td>
</tr>
<tr>
<td>Vitamin B-6 (mg)</td>
<td>1.3</td>
<td>1.9</td>
<td>↓ Higher than that explained by hemodilution, due to hormonal factors</td>
</tr>
<tr>
<td>Vitamin C (mg)</td>
<td>75</td>
<td>85</td>
<td>↓ Mainly due to hemodilution</td>
</tr>
<tr>
<td>Iodine (μg)</td>
<td>150</td>
<td>220</td>
<td>UI decreases; deficiency may occur</td>
</tr>
<tr>
<td>Iron (mg)</td>
<td>18</td>
<td>27</td>
<td>↓ Due to hemodilution and deficiency</td>
</tr>
<tr>
<td>Zinc (mg)</td>
<td>8</td>
<td>11</td>
<td>↓ Due to hemodilution and deficiency</td>
</tr>
<tr>
<td>Calcium</td>
<td>1000</td>
<td>1000</td>
<td>↓ until 34 wk and then a small ↑ until term</td>
</tr>
</tbody>
</table>
Components of gestational weight gain (Pitkin, 1976, see in IOM 2009)

Weight gain recommendations have changed greatly over time, reflecting obstetric belief systems about goals, obstetric complications (dystocia, pre-eclampsia) and universality.
Maternal pre-pregnancy weight (or BMI) modifies the effect of weight gain on size at birth (Abrams and Laros (1986))

This led to BMI-specific weight gain recommendations in the 1990s
## Recommended Total Weight Gain Ranges for Pregnant Women - IOM 2009

Body mass index (BMI) = weight (kg)/ height (m^2)

<table>
<thead>
<tr>
<th>BMI Category</th>
<th>Recommended Total Gain, lb</th>
<th>Rate of weight gain in 2\textsuperscript{nd} or 3\textsuperscript{rd} trimester, lb/wk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Underweight ((&lt;18.5))</td>
<td>28-40</td>
<td>1.0 (1.0-1.3)</td>
</tr>
<tr>
<td>Normal (18.5-24.9)</td>
<td>25-35</td>
<td>1.0 (0.8-1.0)</td>
</tr>
<tr>
<td>High (25.0-29.0)</td>
<td>15-25</td>
<td>0.6 (0.5-0.7)</td>
</tr>
<tr>
<td>Obese ((\geq30.0))</td>
<td>11-20</td>
<td>0.5 (0.4-0.6)</td>
</tr>
</tbody>
</table>

NOTE: many countries have adopted these recommendations
Challenge of gaining recommended amounts for normal, overweight and obese women in US (and elsewhere) (IOM 2009)

Excess weight gain and postpartum weight retention are drivers of maternal overweight globally.
Recommended components during pregnancy to reduce weight gain/achieve recommended gains

These are similar to those of pre-conceptional period to obtain healthy weight/BMI

- Caloric restriction
- Structured meal plans
- Behavior therapy
- Body weight monitoring
- Diet monitoring (assessment/feedback)
- Continued patient provider contact
- Physical activity to limit weight gain may be less important
A review and meta-analysis of RCT to limit weight gain with diet and/or physical activity intervention (i-WIP Collaborative Group, 2017) (note: these studies do not include underweight women)

**WHAT IS ALREADY KNOWN ON THIS TOPIC**

Increased weight gain in pregnancy is associated with maternal and fetal complications

Interventions based on diet or physical activity or both in pregnancy minimise gestational weight gain

Interventions based on diet and physical activity may have a potential role in preventing adverse pregnancy outcomes

**WHAT THIS STUDY ADDS**

Diet and physical activity based interventions consistently reduce gestational weight gain across various subgroups of women categorised by age, parity, body mass index, ethnicity, and pre-existing medical condition

The reduction in odds of adverse maternal and offspring composite outcomes with diet and physical activity is not significant, and does not vary across various subgroups of women

Interventions significantly lower the odds of caesarean section and have no effect on offspring outcomes
Increased energy requirements on average are 350-450 kcal/d during 2\textsuperscript{nd} and 3\textsuperscript{rd} trimesters of pregnancy.

Based on adequacy of micronutrient intakes before pregnancy and increased requirements during pregnancy, a shift to greater nutrient density of overall diet and/or in the extra food for pregnancy is needed to meet requirements.

Three main maternal complications of pregnancy are gestational hypertension (GHT), pre-eclampsia and gestational diabetes (GDM).

Evidence suggests that dietary patterns before and during pregnancy that are higher in vegetables, fruits, whole grains, nuts, legumes, fish, and vegetable oils and lower in meat (perhaps red meat and processed meat) and refined grains are associated with reduced risk of hypertension, including preeclampsia and GHT as well as GDM.

The words higher or lower are related to observed intakes among primarily Caucasian women.

However these are general characterizations of a broader literature on the components of healthy diets.