BIPN100  Human Physiology 1
Bill Kristan, Ph.D.
Web site:  http://classes.biology.ucsd.edu/bipn100B.FA15/
[Not on TED]

1. **Sections**: Yes, there are sections this week, starting Friday.

2. **Dr K's office hours**:
   - In office  Tuesdays  2:30 - 3:30 PM  3122A Pacific Hall (office)
   - Group  Fridays  11- noon  3501 Pacific Hall (conference room)

3. **Dr K's Review, problem-solving session**:
   Math, physics, chem review; problem-solving  5:30–7 PM  Wednesdays or Thursdays  3500 Pacific Hall

4. **TA sections, office hours**:

<table>
<thead>
<tr>
<th>Section</th>
<th>Day</th>
<th>Time</th>
<th>Location</th>
<th>IA</th>
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<tbody>
<tr>
<td>A02</td>
<td>Fri</td>
<td>8:00-8:50am</td>
<td>WLH 2206</td>
<td>If needed</td>
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<tr>
<td>A06</td>
<td>Fri</td>
<td>11:00-11:50am</td>
<td>SEQUO 148</td>
<td>Winjet Chou</td>
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<tr>
<td>A07</td>
<td>Fri</td>
<td>12:00-12:50pm</td>
<td>SEQUO 147</td>
<td>Saatchi Patell</td>
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<tr>
<td>A08</td>
<td>Fri</td>
<td>1:00-1:50pm</td>
<td>WLH 2115</td>
<td>Justine Liang</td>
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<tr>
<td>A09</td>
<td>Fri</td>
<td>2:00-2:50pm</td>
<td>WLH 2206</td>
<td>Hao Shi</td>
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<tr>
<td>A10</td>
<td>Fri</td>
<td>3:00-3:50pm</td>
<td>HSS 1128A</td>
<td>If needed</td>
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<tr>
<td>A01</td>
<td>Mon</td>
<td>9:00-9:50am</td>
<td>WLH 2115</td>
<td>Tim Macaulay</td>
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<tr>
<td>A03</td>
<td>Mon</td>
<td>4:00-4:50pm</td>
<td>WLH 2208</td>
<td>Mallorie Nguyen</td>
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<td>A04</td>
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<td>5:00-5:50pm</td>
<td>WLH 2208</td>
<td>Donel Purcella</td>
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<tr>
<td>A05</td>
<td>Mon</td>
<td>6:00-6:50pm</td>
<td>WLH 2115</td>
<td>Kyra Rashid</td>
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Material covered in lecture #1:

1. Physiology is the science of the intact, living organism.
   Physiological explanations are **mechanistic**, not **teleological**.
   Causal relationships are shown by testing **correlation**, **necessity**, & **sufficiency**

2. Big idea in physiology is **homeostasis**: what it is, how it works.

3. Most body systems **regulate** parameters by **control** of organ function.
   **Feedback systems** are an efficient way to summarize regulation.
   Boxes (“blocks”) indicate organs, usually.
   Arrows indicate signals, usually neural or endocrine.
   + and – signs indicate the relationships between input and output signals

**Negative feedback vs. positive feedback:**
   Regulation is by negative feedback.
   Positive feedback leads to extreme conditions.
Examples of positive feedback loops.

This one has no negative signs:

![Diagram of positive feedback loop with no negative signs.](image)

This one has two negative signs that effectively cancel each other:

![Diagram of positive feedback loop with two negative signs.](image)
Examples of positive feedback loops.

--in the coordinate format

This one has no negative signs:

![Diagram](image1)

This one has two negative signs that effectively cancel each other:

![Diagram](image2)
Comparing unit (thermostat) Temperature sensed
Controller (furnace)
Controller (air conditioner)
Sensor (thermometer)
Set point (thermostat setting)

Fig. 1.12
Too hot:

Set point (thermostat setting) + Comparing unit (thermostat) - Controller (air conditioner) + Controller (furnace) + Controlled variable (air temp.) - Temperature sensed + Sensor (thermometer)
Too cold:

Set point (thermostat setting) + Comparing unit (thermostat)

Temperature sensed + Controller (furnace) + Controlled variable (air temp.)

Controller (air conditioner) - Sensor (thermometer) +
What if an incompetent electrician hooked up the thermostat backwards, so that, instead of this:
What if an incompetent electrician hooked up the thermostat backwards, so that, you had this:

![Diagram of a thermostat system](image)

- **Set point** (thermostat setting)
- **Comparing unit** (thermostat)
- **Controller** (furnace)
- **Controller** (air conditioner)
- **Controlled variable** (air temp.)
- **Sensor** (thermometer)
- **Temperature sensed**

When the air temperature is too low ($S - T < 0$), the air conditioner turns on and the furnace turns off....

...and the room gets colder!

When the air temperature is too high ($S - T > 0$), the air conditioner turns off and the furnace turns on.

...and the room gets warmer!

So the system goes to an extreme—maximal hot or cold--whatever the air temperature is!
A perturbation signal affects one or more of the components without being affected by any of them.

Perturbations can be used to test whether a feedback loop is positive or negative:

1. Give a perturbation to one component.
2. Follow the arrows around a loop, counting up all the negative signs.
   - if there are 0 or an even number of negative signs, it is a positive feedback loop.
   - if there are an odd number of negative signs, it is a negative feedback loop.
There can be signals going out to components that are not part of the feedback loop; For example, component #4 is called an **indirectly controlled component**.

An example:
Component #3 could be the room temperature, and you are #4.
Comparing unit (thermostat) Temperature sensed Controller (furnace) Controlled variable (air temp.)

Controller (air conditioner)

Sensor (thermometer)

Fig. 1.15

An example:
Component #3 could be the room temperature, and you are #4.

The system senses—and, therefore, regulates—the room temperature.....
you benefit as the **indirectly controlled component**.
Mammalian neurons come in many shapes and sizes

- Retinal bipolar cell
- Thalamic neuron
- Cerebellar Purkinje neuron
- Spinal motor neuron

Lecture #2: Electrical properties of neurons: Resting potential, action potential
Neurons generate four kinds of potentials we need to consider:

1. Resting potential (all cells)
2. Action potential (neurons, muscle fibers, some hormonal cells)
3. Synaptic potential (neurons and muscle fibers)
4. Receptor potential (only sensory neurons)
Neurons generate four kinds of potentials we need to consider:

1. Resting potential (all cells)

2. Action potential (neurons, muscle fibers, some hormonal cells)

3. Synaptic potential (neurons and muscle fibers)

4. Receptor potential (only sensory neurons)
Forces acting on an ion ($X^+$) in a channel permeable only to that ion:

Force toward EC = chemical concentration gradient = $RT \ln \frac{[X]_{out}}{[X]_{in}}$

Force toward IC = electrical concentration gradient = $z_x F V_m$

At equilibrium, the forces are equal: $RT \ln \frac{[X]_{out}}{[X]_{in}} = z_x F V_m$
At equilibrium, the forces are equal: 

$$RT \ln \frac{[X]_{\text{out}}}{[X]_{\text{in}}} = z_x F V_m$$

Solve for $V_m$: 

$$V_m = \frac{RT}{z_x F} \ln \frac{[X]_{\text{out}}}{[X]_{\text{in}}} = E_x$$

This is the **Nernst Equation**

- the equilibrium $V_m$ gets a special name $E_x$ which is called 
  “the X equilibrium potential”
  (the potential at which ion X is at equilibrium)

The Nernst Equation is usually written in log to the base 10 rather than ln, 
and the constants are lumped together. At mammalian body temperature:

$$E_x = \frac{61}{z} \log \frac{[X]_{\text{out}}}{[X]_{\text{in}}}$$
We relate ionic equilibrium potentials to the resting potential through **Ohm’s Law**:

\[ V = IR \]

A current through a resistor produces a voltage. A voltage across a resistor produces a current.

Sometimes it is more convenient to consider conductance (G), which is the inverse of resistance:

\[ G = \frac{1}{R} \]

Rewrite Ohm’s Law:

\[ I = \frac{V}{R} = VG \]

How much current flows across a channel?

Each channel is like a resistor across the membrane, with the voltage provided by the resting potential:

\[ V = 0 \]

Force-flux equation

\[ I_x = (V_m - E_x) G_x \]
Three major ions determine the membrane potential at rest:

Resting potential ($V_{rest}$) is determined by their 3 equilibrium potentials:

$$V_{rest} = \frac{G_K}{\sum G} E_K + \frac{G_{Na}}{\sum G} E_{Na} + \frac{G_{Cl}}{\sum G} E_{Cl}$$

Chord conductance equation

More ion types? Just add more terms.
Resting potential \( V_{\text{rest}} \) is given by:

\[
V_{\text{rest}} = \frac{G_K}{\sum G} E_K + \frac{G_{\text{Na}}}{\sum G} E_{\text{Na}} + \frac{G_{\text{Cl}}}{\sum G} E_{\text{Cl}}
\]

where \( \sum G = G_K + G_{\text{Na}} + G_{\text{Cl}} \).

If \( E_x \) for Na\(^+\), Cl\(^-\), and K\(^+\) in a cell are:

- \( E_{\text{Na}} = +60 \) mV
- \( E_{\text{Cl}} = -70 \) mV
- \( E_K = -90 \) mV

and:
- \( G_K = 80 \) pS
- \( G_{\text{Na}} = 15 \) pS
- \( G_{\text{Cl}} = 5 \) pS
Resting potential: 

\[ V_{\text{rest}} = \frac{G_K}{\sum G} E_K + \frac{G_{Na}}{\sum G} E_{Na} + \frac{G_{Cl}}{\sum G} E_{Cl} \]

\[ V_{\text{rest}} = \frac{80}{100} (-90) + \frac{15}{100} (60) + \frac{5}{100} (-70) = -66.5 \text{mV} \]

\( E_x \) for Na\(^+\), Cl\(^-\), and K\(^+\) in a cell are:

- \( E_{Na} = +60 \text{mV} \)
- \( E_{Cl} = +0.02 \text{nA} \)
- \( E_{K} = +1.88 \text{nA} \)

\( V_{\text{rest}} = -66.5 \text{mV} \)

\( l_{x} = (V_{m} - E_{x}) G_{x} \):

- \( l_{Na} = -1.90 \text{nA} \)
- \( l_{Cl} = +0.02 \text{nA} \)
- \( l_{K} = +1.88 \text{nA} \)
\[ I_X = (V_m - E_X) G_X \]

where \((V_m - E_X)\) is the "driving force" and \(G_X\) is the pathway.

\(I_{Na}\) is large (-1.90 nA) because \((V_m - E_{Na})\) is large even though \(G_{Na}\) is small.

\[
\begin{align*}
G_K &= 80 \text{ pS} \\
G_{Na} &= 15 \text{ pS} \\
G_{Cl} &= 5 \text{ pS} \\
I_{Na} &= -1.90 \text{ nA} \\
I_{Cl} &= +0.02 \text{ nA} \\
I_K &= +1.88 \text{ nA}
\end{align*}
\]
\[ I_X = (V_m - E_X) \times G_X \]

where \((V_m - E_X)\) is the “driving force” and \(G_X\) is the pathway.

\(G_K = 80\) pS
\(G_{Na} = 15\) pS
\(G_{Cl} = 5\) pS

\(I_{Na} = -1.90\) nA
\(I_{Cl} = +0.02\) nA
\(I_K = +1.88\) nA

\(E_{Na}\) is the membrane potential at +60 mV.

\(E_{K}\) is the membrane potential at -90 mV.

\(E_{Cl}\) is the membrane potential at -70 mV.

\(V_m\) is the membrane potential at 0 mV.

\(I_K\) is also large (+1.88 nA) because \(G_K\) is large even though \((V_m - E_K)\) is small.
\[ I_X = (V_m - E_X) G_X \]

where \((V_m - E_X)\) is the “driving force” and \(G_X\) is the pathway.

- \(I_{Cl} = +0.02 \text{ nA}\)
- \(G_K = 80 \text{ pS}\)
- \(G_{Na} = 15 \text{ pS}\)
- \(G_{Cl} = 5 \text{ pS}\)
- \(I_{Na} = -1.90 \text{ nA}\)
- \(I_{Cl} = +0.02 \text{ nA}\)
- \(I_K = +1.88 \text{ nA}\)