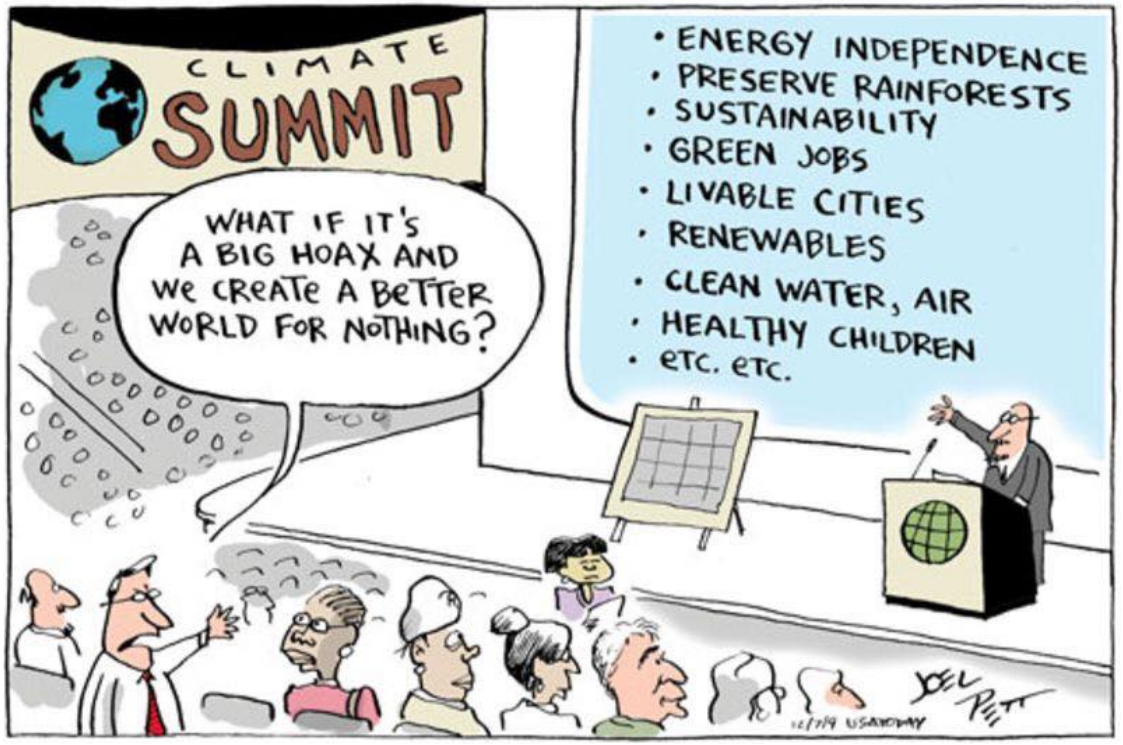
Systems: Stocks, Flows, & Feedbacks



Goals:

1. Define stock, flow, and feedback
2. Explain how the combined history of inflows and outflows determines a stock
3. Predict what happens to stocks and flows when a system is perturbed
4. Construct examples of both amplifying and stabilizing feedbacks.

Climate news

- Hurricane Dorian stalls over the Bahamas

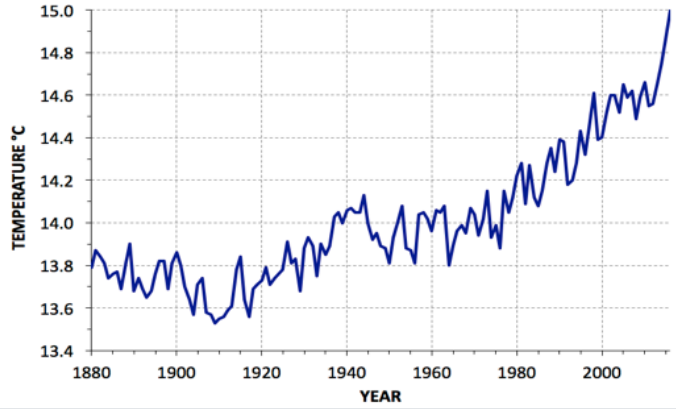
- Here's what the original research looks like:
  - Hall and Kossin – 2019

- Fires in Australia

Question: Why don’t we put the answers to the clicker questions up on canvas?

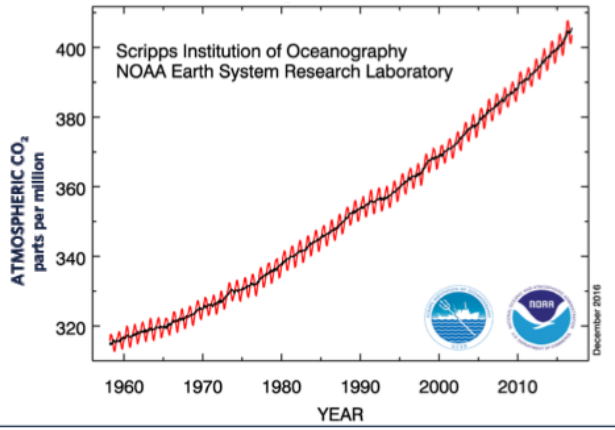
Worksheets from Day 1: Sea ice

AVERAGE GLOBAL SURFACE TEMPERATURE



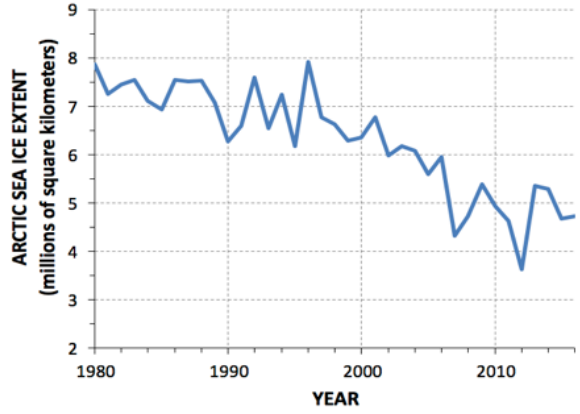
DATA: NASA GISS

ATMOSPHERIC CO_2 AT MAUNA LOA OBSERVATORY



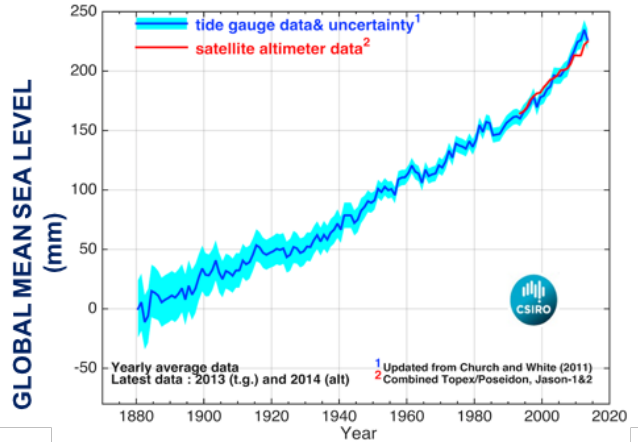
NOAA, EARTH SYSTEM RESEARCH LABORATORY

SEPTEMBER ARCTIC SEA ICE EXTENT



DATA: NSIDC

OBSERVED SEA LEVEL RISE VS IPCC PROJECTIONS



DATA: CSIRO & NASA

Stories: Attempts to connect these different data through various processes. *Common story: "CO2 causes T to rise, which causes sea ice to melt, which causes sea level to rise"* [one problematic link…]

Questions/Comments: Worksheet

1. Sea ice versus land ice
   – impact on sea level

Once this ice melts in this glass, how will the water level be different?
Water level will be _____before.

A. higher than
B. lower than
C. the same as

http://commons.wikimedia.org/wiki/File:Menthaleau.jpg

More on buoyancy

- Suppose that ice was 70% as dense as water. If you froze a block of liquid water, how much of the volume would be above the surface?

  A) 10%
  B) 30%
  C) 50%
  D) 70%
  E) 90%

Questions/Comments: Pre-Class Quiz

Stoichiometry practice

Say we have 100 gigatons of H_2O.
How many gigatons of O is contained within that 100 Gton H_2O?

A.2
B.89
C.98
D.100
E.102

Quiz question involved the mass of C in CO_2. You will need to be able to go back and forth between mass of C and mass of CO_2 in this course.

Caldeira, 2012- Pre class reading

"One of the greatest uncertainties in climate prediction is the amount of CO_2 that will ultimately end up in the atmosphere"

Some text from the Dec 2015 Paris agreement:

Emphasizing with serious concern the urgent need to address the significant gap between the aggregate effect of Parties' mitigation pledges in terms of global annual emissions of greenhouse gases by 2020 and aggregate emission pathways consistent with holding the increase in the global average temperature to well below 2 °C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5 °C,

We'll work with this plot during class. See post-class slides for more.

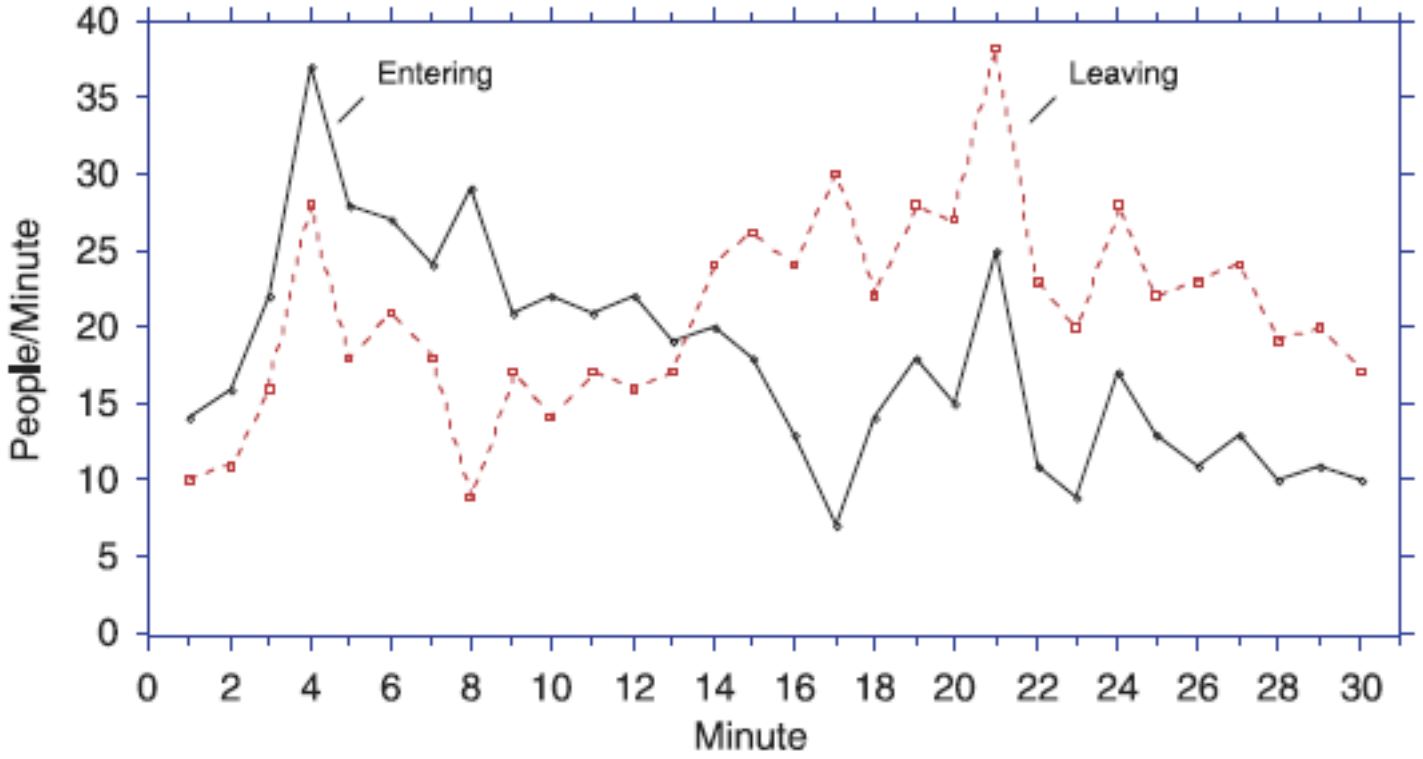
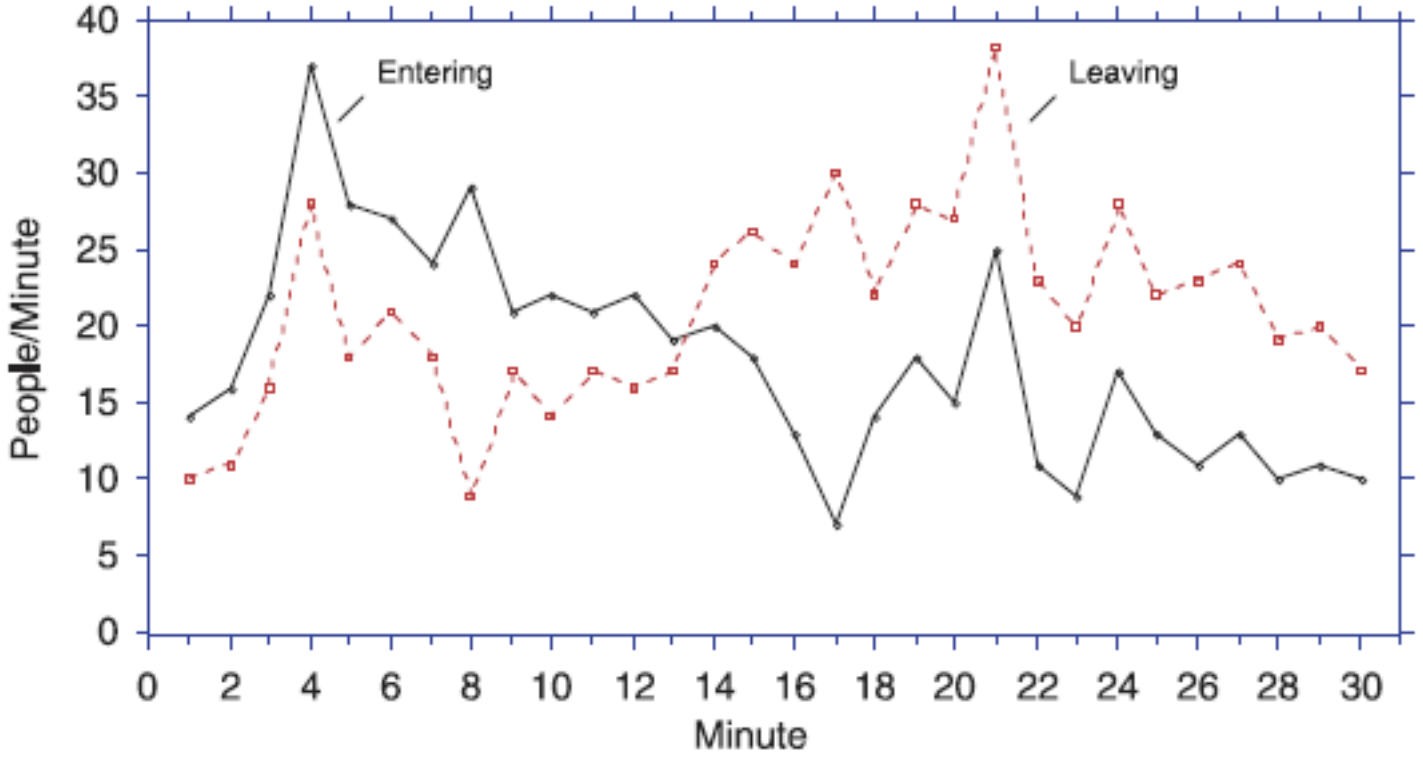


Figure: Cronin & Gonzalez, 2007

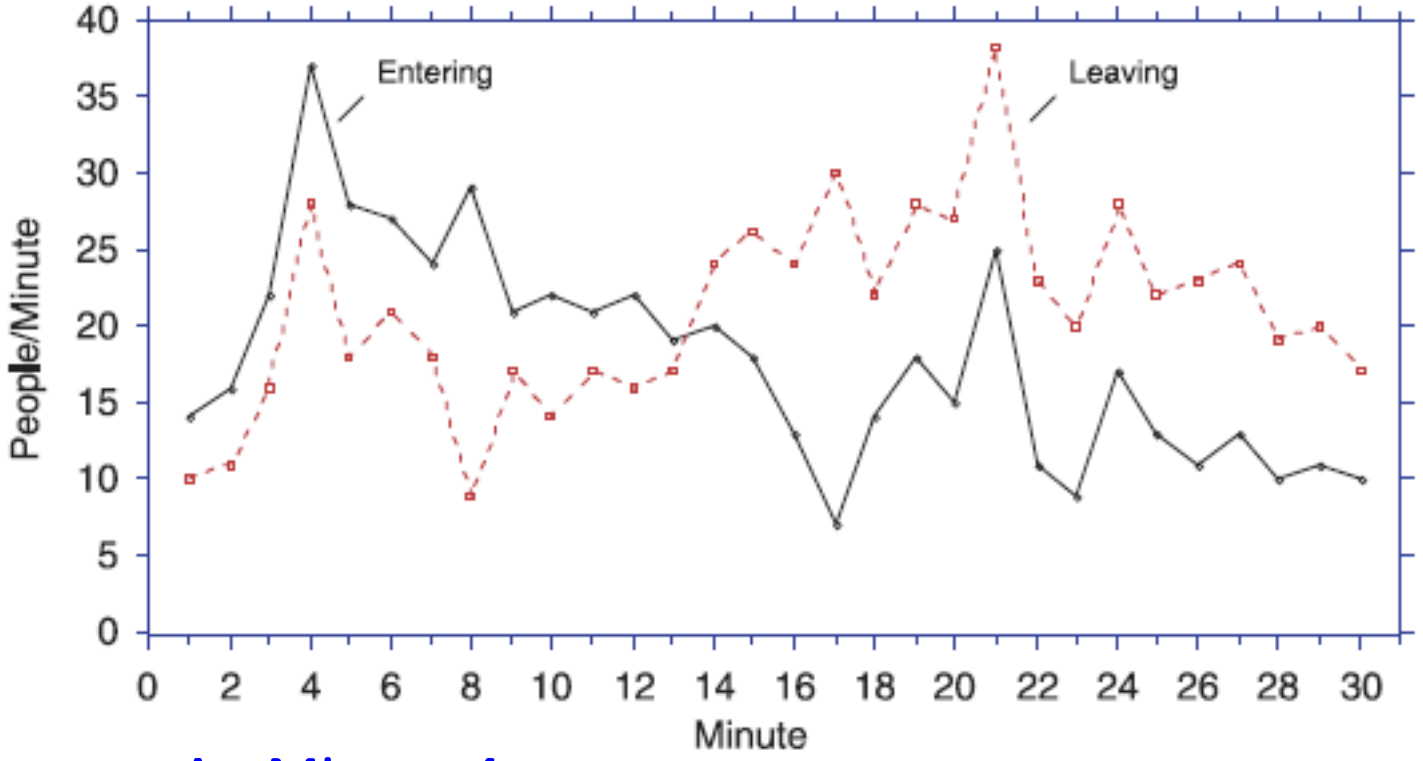
Clicker Q: The graph below shows the numbers of people entering and leaving a store each minute. **During which minute did the most people enter the store**?



A. Minute 4
B. Minute 8
C. Minute 13
D. Minute 21
E. Cannot be determined

Figure: Cronin & Gonzalez, 2007

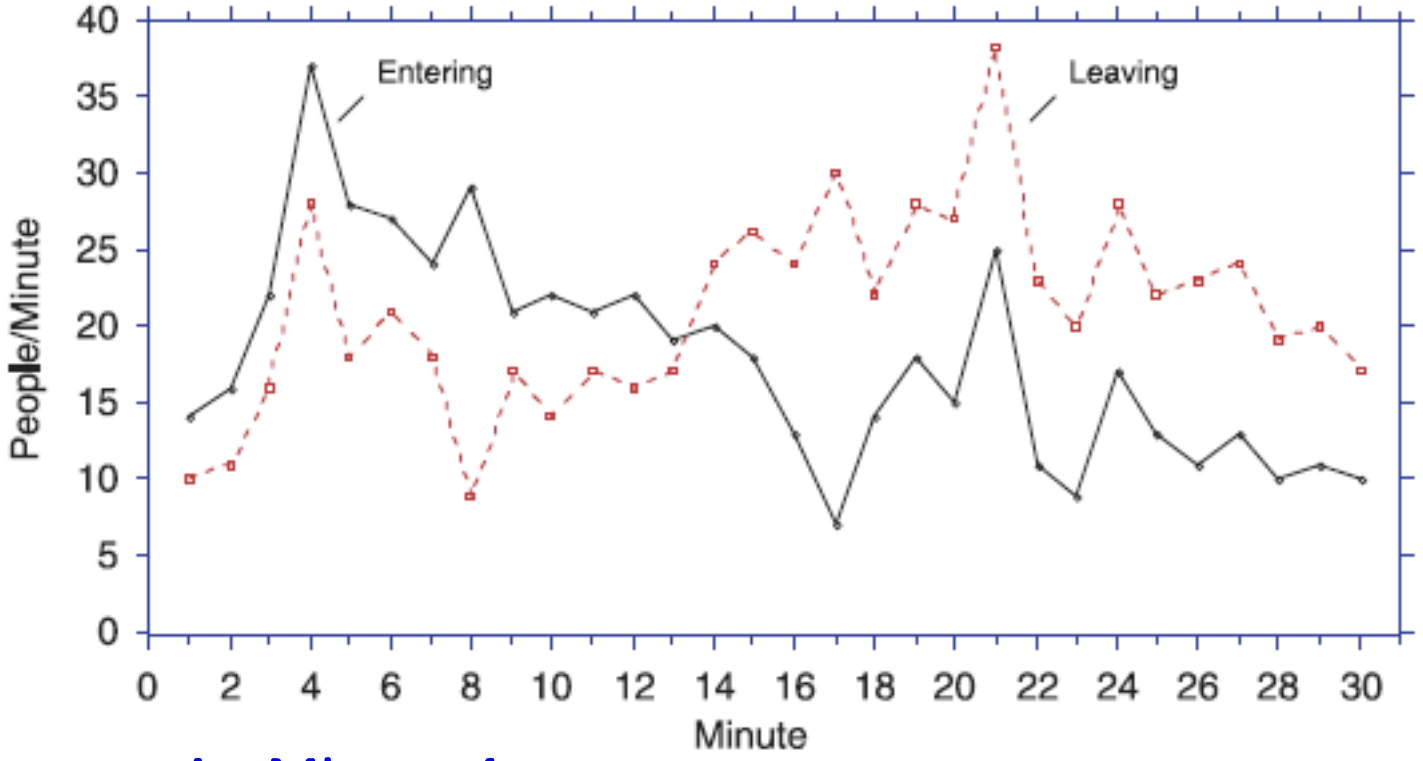
Clicker Q: The graph below shows the numbers of people entering and leaving a store each minute. **During which minute did the most people leave the store**?



A. Minute 4
B. Minute 8
C. Minute 17
D. Minute 21
E. Cannot be determined

Figure: Cronin & Gonzalez, 2007

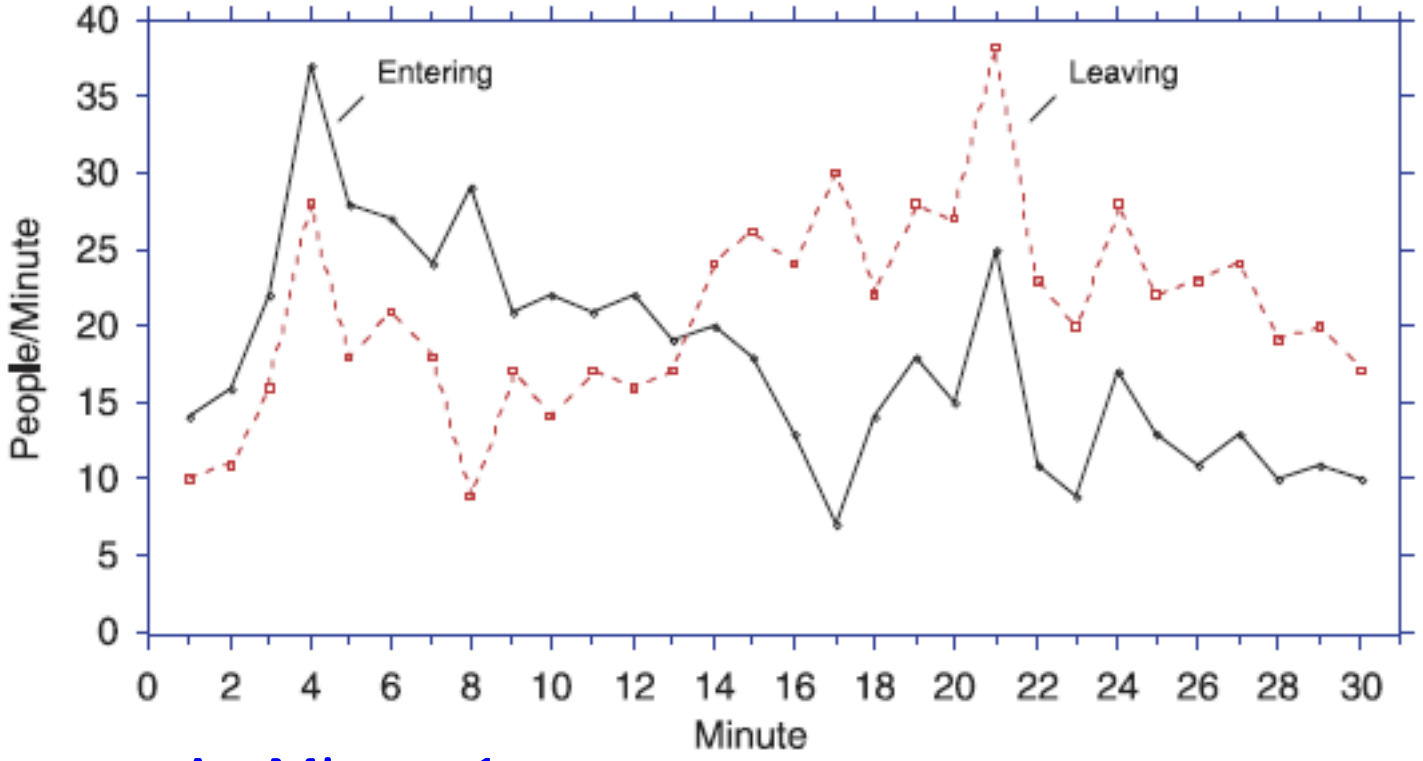
Clicker Q: The graph below shows the numbers of people entering and leaving a store each minute. During which minute were the **MOST** people in the store?



A. Minute 4
B. Minute 8
C. Minute 13
D. Minute 17
E. Cannot be determined

Figure: Cronin & Gonzalez, 2007

Clicker Q: The graph below shows the numbers of people entering and leaving a store each minute. During which minute were the **FEWEST** people in the store?



A. Minute 1
B. Minute 13
C. Minute 17
D. Minute 30
E. Cannot be determined

Figure: Cronin & Gonzalez, 2007

Systems dynamics: Stock & Flow

STOCK: Amount or quantity of something residing in a particular place at a particular time

apples in a basket, water in a glacier, fish in the sea, knowledge in your brain…

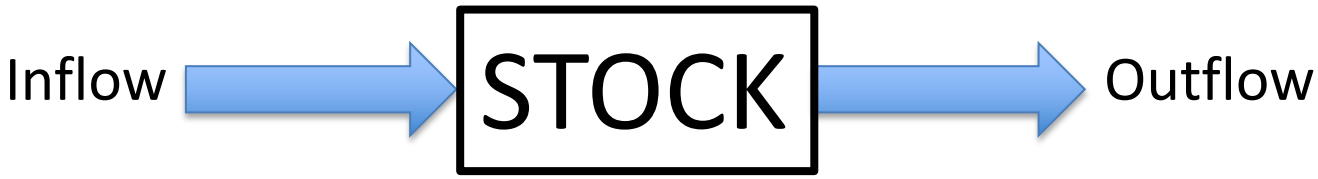
FLOW: The rate at which stuff adds or subtracts from a stock.

Since flow is a RATE, there is always an element of TIME included.

apples picked per hour, water melted per month, fish born per year, knowledge GAINED PER 90MIN EOSC340 CLASS

INFLOW: The rate at which stuff flows IN.

OUTFLOW: The rate at which stuff flows OUT.



The STOCK, at any moment, is the result of the **COMBINED HISTORY** of INFLOW and OUTFLOW

Systems dynamics: Stock & Flow

The **RATE AT WHICH THE STOCK CHANGES**, is the difference between the INFLOW & the OUTFLOW

$$\frac{d(stock)}{dt} = Flow_{in} - Flow_{out}$$

If $Flow_{in} = Flow_{out}$
→ no change in stock over time
→ EQUILIBRIUM

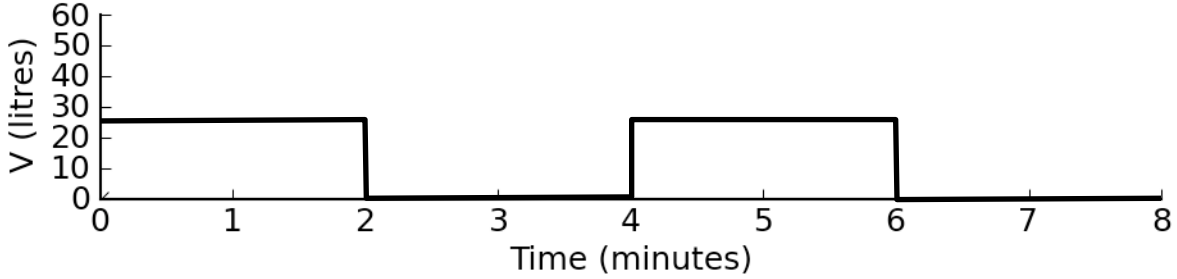
If $Flow_{in} \neq Flow_{out}$ → stock will change over time

Stock & Flow Worksheet

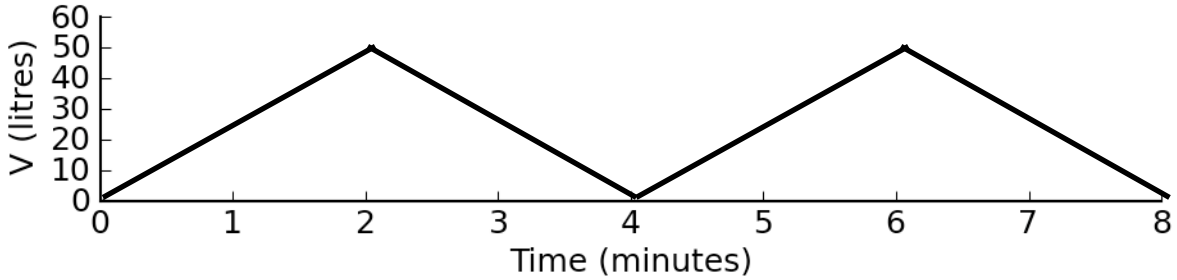
Work in pairs or 3s. Once you have a pair or a 3, raise your hands and we'll get you a worksheet

Worksheet PROBLEM 1 clicker:

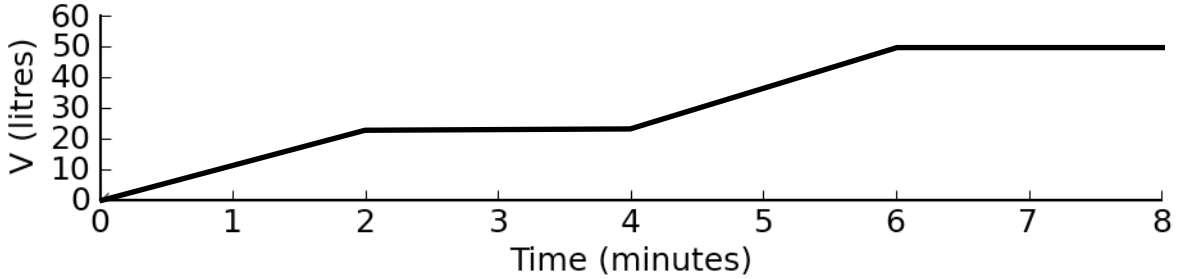
A



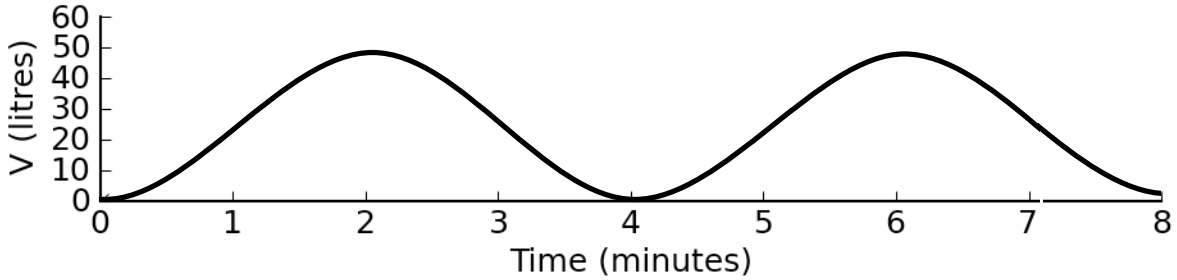
B



C



D

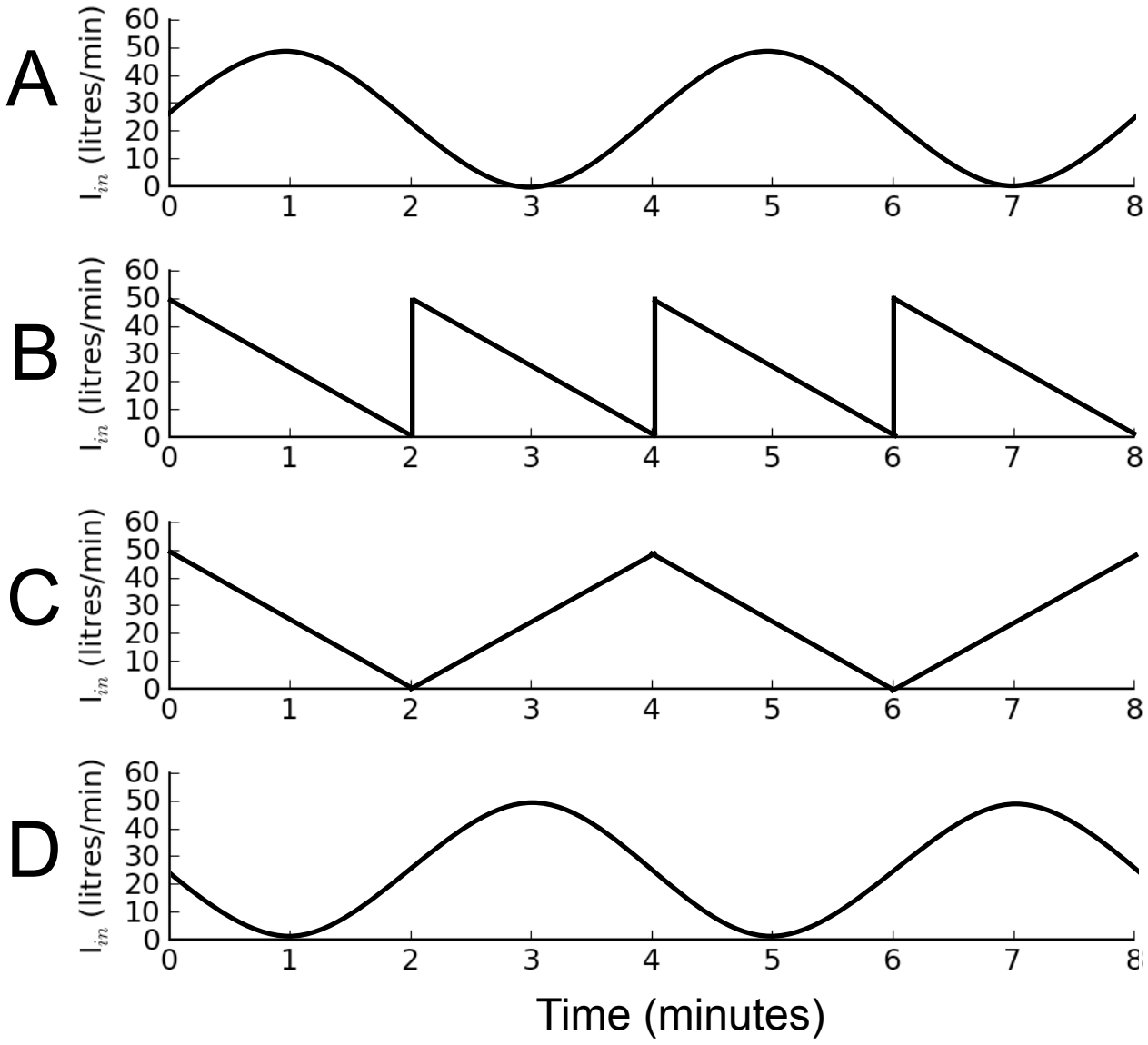


Worksheet PROBLEM 2 clicker:

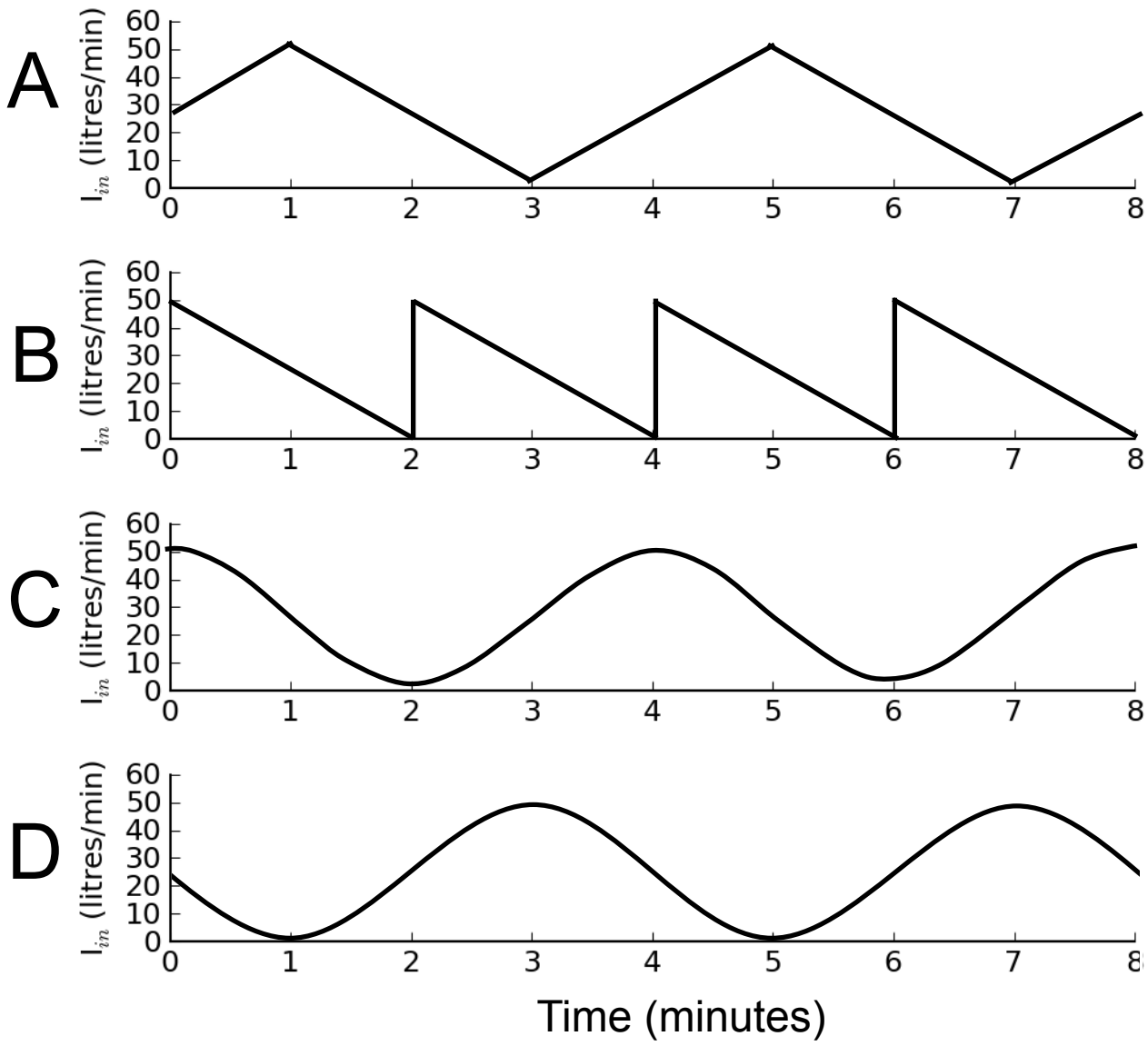
Worksheet problem 2:
At what minute are inflow and outflow equal?

A. 0
B. 1
C. 2

Worksheet PROBLEM 2 clicker:

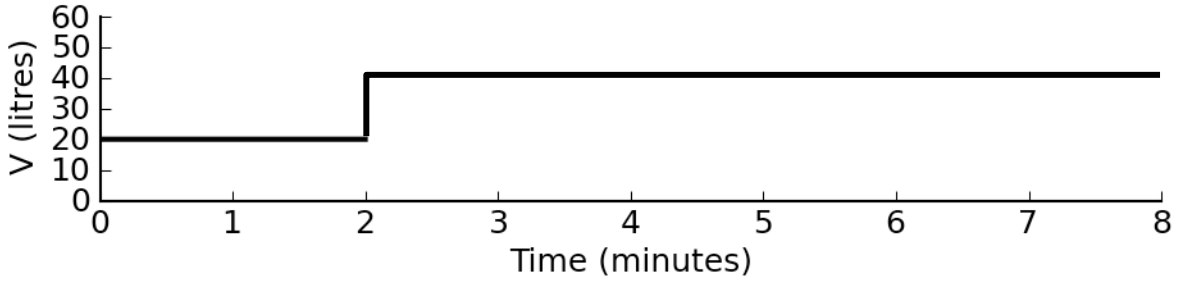


Worksheet PROBLEM 2 clicker:

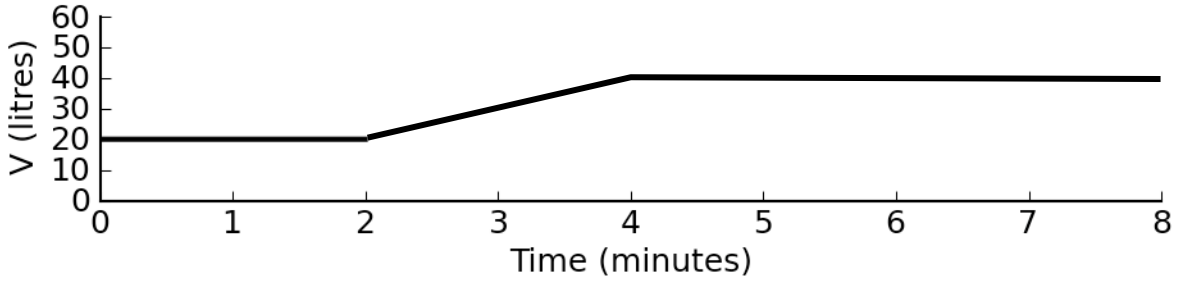


Worksheet PROBLEM 3 clicker:

A



B



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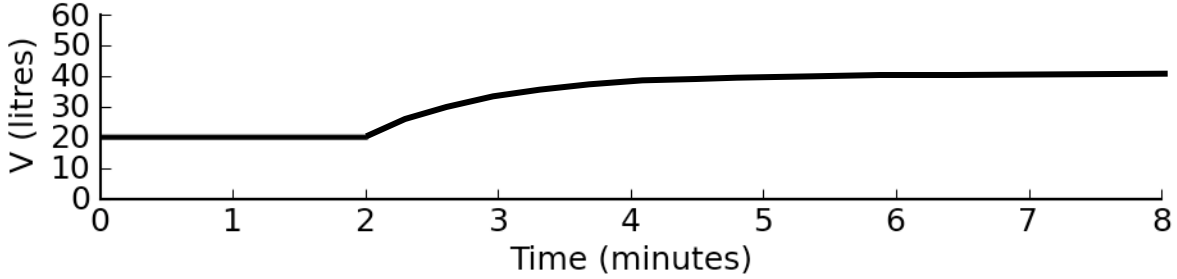
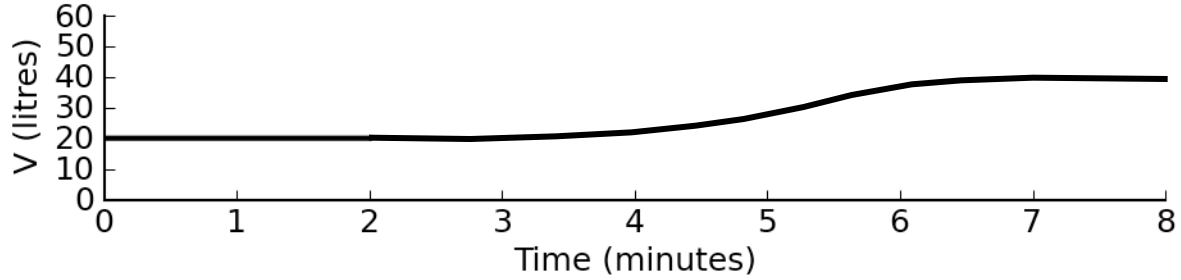


D



Summary

1. Earth's climate system is essentially a whole bunch of interconnected stocks, flows, and feedbacks.
2. The combination of inflows and outflows over time determines a stock.
3. Both stocks and flows can be perturbed. When a perturbation happens, the system responds.
   - Perturbations in stocks can influence flows, which in turn can influence stocks again.
   - Perturbations in flows can influence stocks, which in turn can influence flows again.
4. Amplifying feedbacks destabilize a system by reinforcing perturbations. Stabilizing feedbacks counteract perturbations and help move a system toward a stable state.