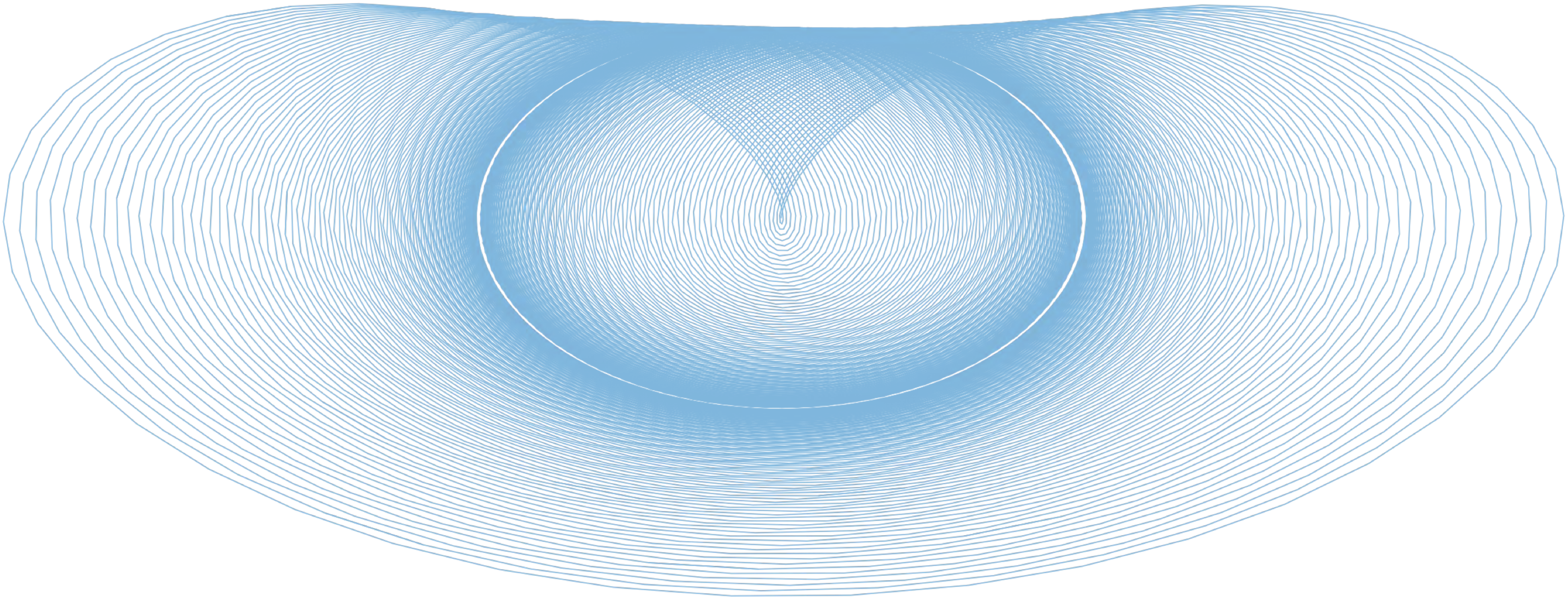
PHYS 1420 (F19)
Physics with Applications to Life Sciences



2019.11.27

Relevant reading:

Kesten & Tauck ch.13.1-13.4

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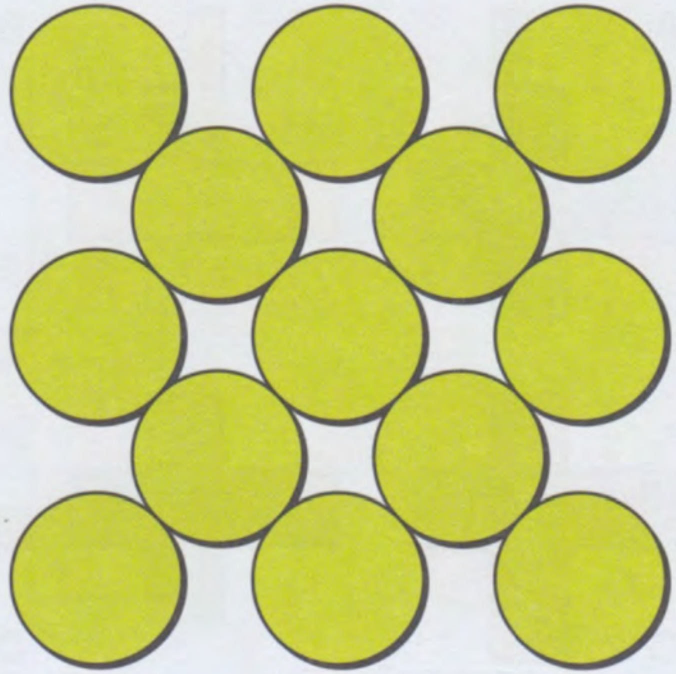
Ref. (re images):

Wolfson (2007), Knight (2017)

117. Coin Squares 3



How many squares of any size and orientation can you find in the shape above? To count, a square must have four coins whose centers lie exactly at its four corners.

9	11	13	15

<u>Announcements & Key Concepts</u> (re Today)

→ Online HW #9: Posted and due 12/6

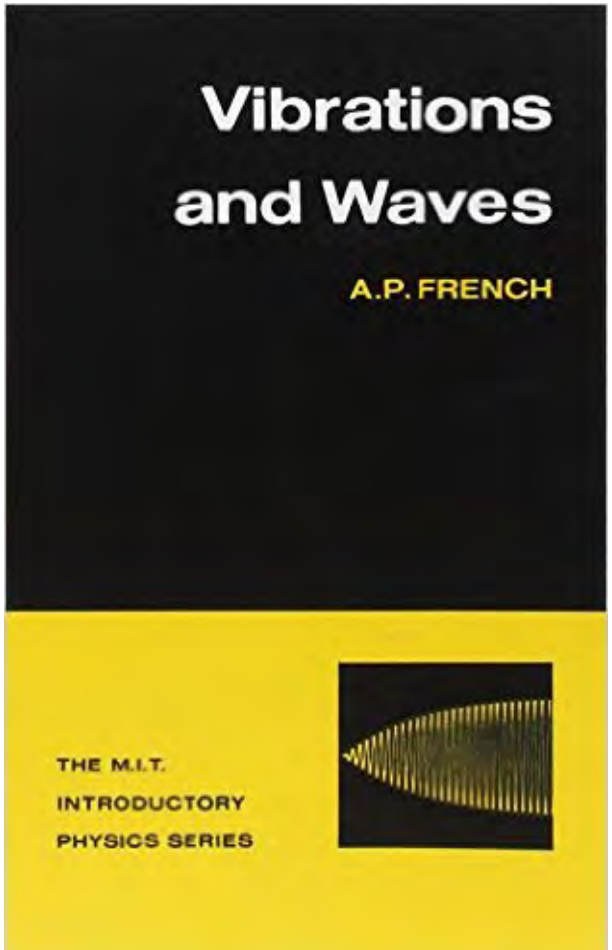
→ Lectures end Monday (no tutorial on 12/4)

→ Review sessions re final exam to be announced soon

Some relevant underlying concepts of the day…

- What is a *wave*?
- Examples of waves
- Basic considerations of waves
- Standing waves

What is a "wave"?



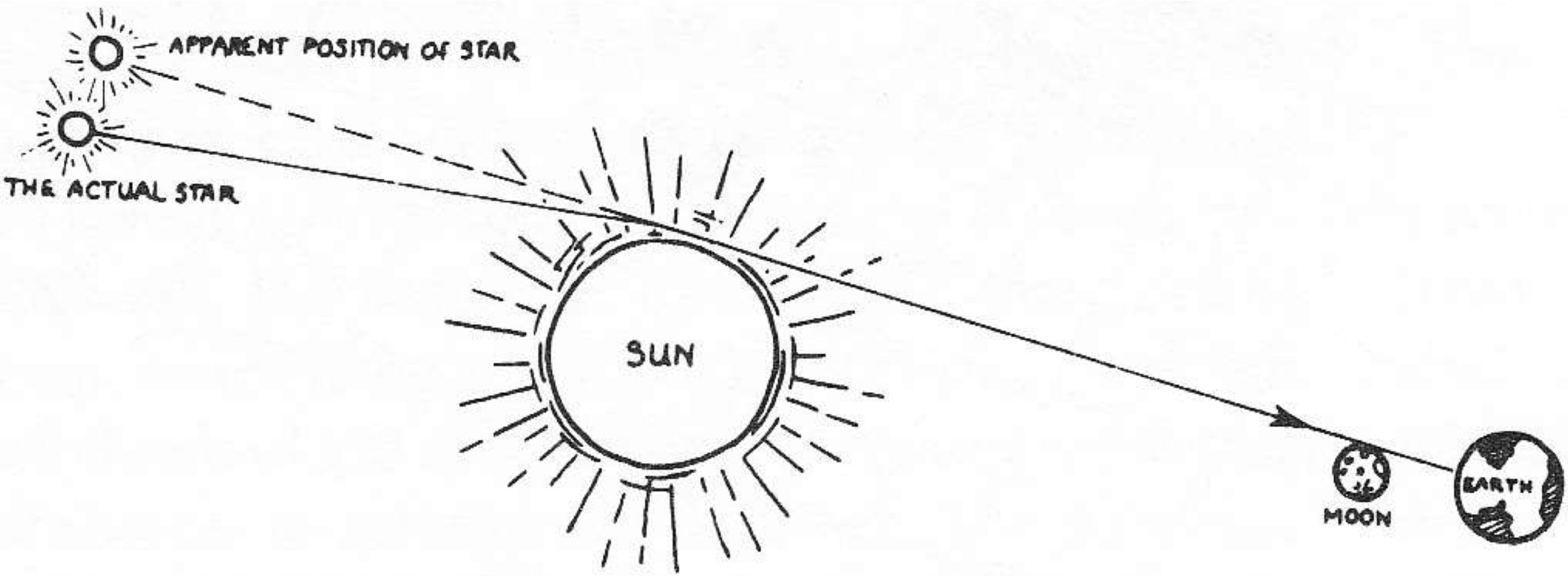
WHAT IS A WAVE?

FOR MANY PEOPLE—perhaps for most—the word "wave" conjures up a picture of an ocean, with the rollers sweeping onto the beach from the open sea. If you have stood and watched this phenomenon, you may have felt that for all its grandeur it contains an element of anticlimax. You see the crests racing in, you get a sense of the massive assault by the water on the land—and indeed the waves *can* do great damage, which means that they are carriers of energy—but yet when it is all over, when the wave has reared and broken, the water is scarcely any farther up the beach than it was before. That onward rush was not to any significant extent a bodily motion of the water. The long waves of the open sea (known as the swell) travel fast and far. Waves reaching the California coast have been traced to origins in South Pacific storms more than 7000 miles away, and have traversed this distance at a speed of 40 mph or more. Clearly the sea itself has not traveled in this spectacular way; it has simply played the role of the agent by which a certain effect is transmitted. And here we see the essential feature of what is called wave motion. A condition of some kind is transmitted from one place to another by means of a medium, but the medium itself is not transported. A local effect can be linked to a distant cause, and there is a time lag between cause and effect that depends on the properties of the medium and finds its expression in the velocity of the wave. All material media—solids, liquids, and gases—can carry energy and information by means of waves, and our study of coupled oscillators and normal modes has paved the way for an understanding of this important phenomenon.

Although waves on water are the most familiar type of wave, they are also among the most complicated to analyze in terms of underlying physical processes. We shall, therefore, not have very much to say about them. Instead, we shall turn to our old standby—the stretched string—about which we have learned a good deal that can now be applied to the present discussion.

A traveling wave is a broad term, but in a general sense can be defined as occurring when a "condition of some kind is transmitted from one place to another by means of a medium, but the medium itself is not transported"

Examples of waves → EM waves (i.e., light)

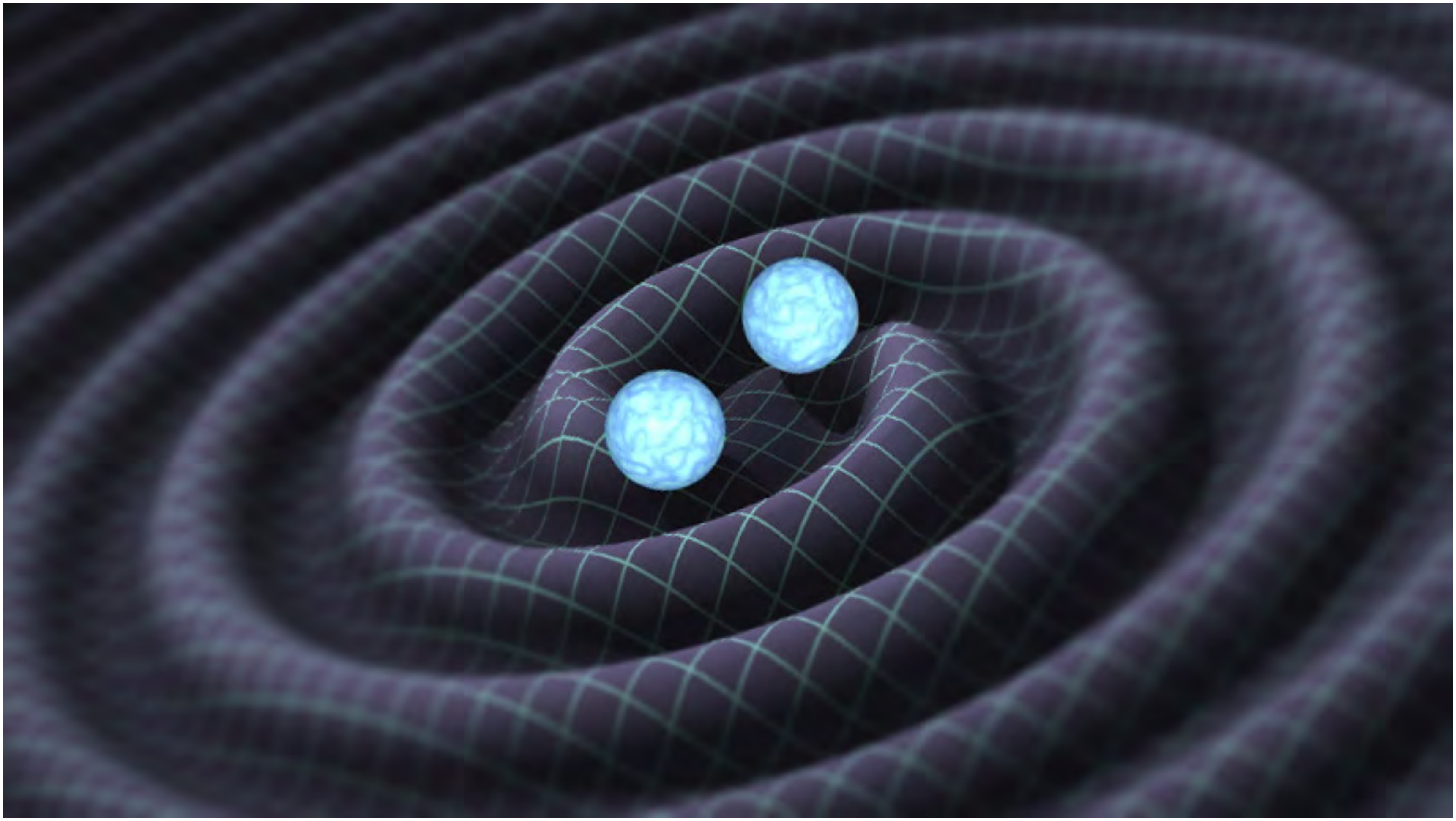


Reminder:
A testable prediction stemming from Einstein's theory of General Relativity

→ And it worked like a charm! Tested in Sept. 1919, Einstein became a rockstar afterwards!

von Baeyer

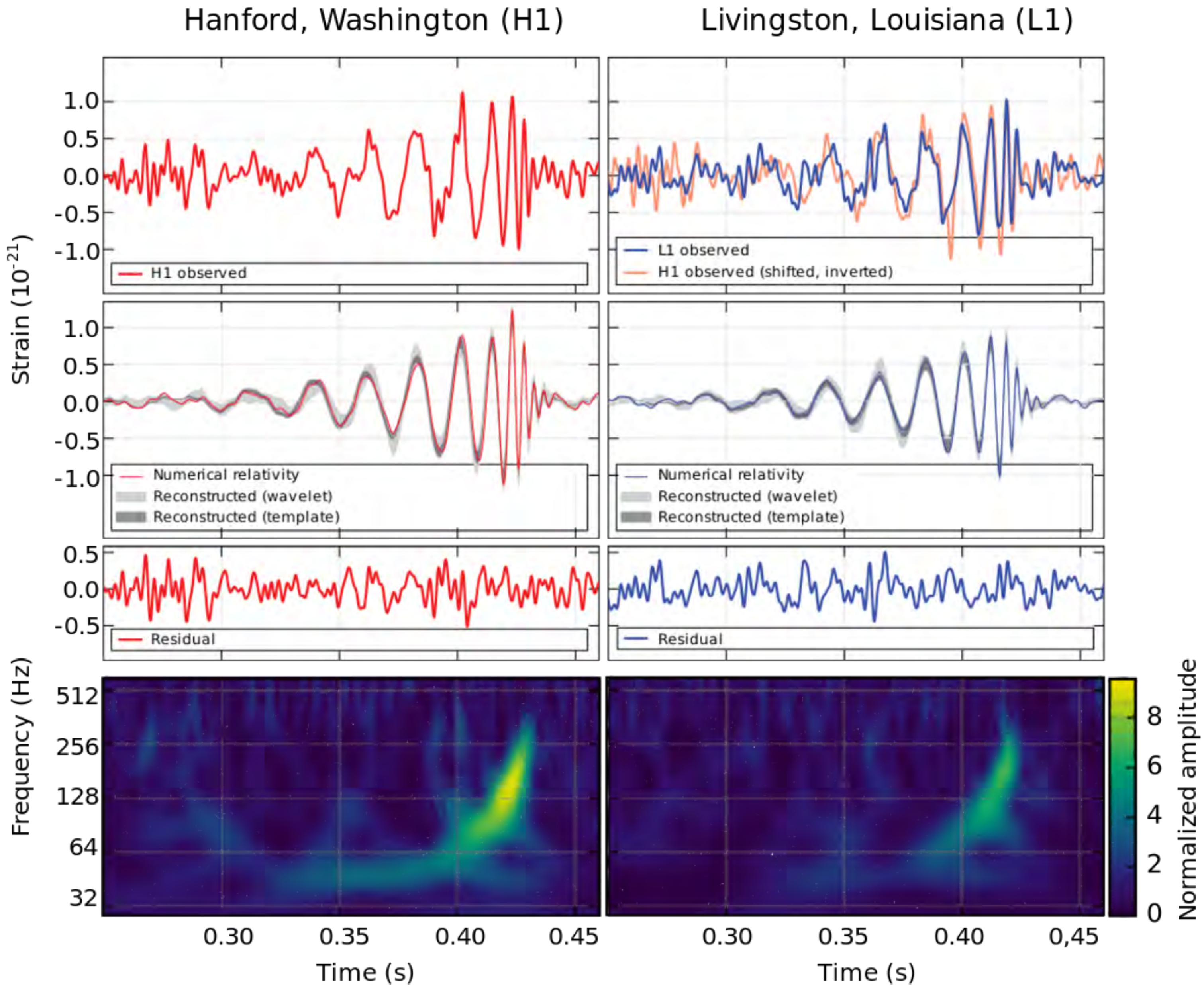
Examples of waves → Gravitational waves



Two black holes collide and form a ripple in spacetime (→ Gravitational Waves)

https://www.ligo.caltech.edu/

"The event" occurred on Sept.14, 2015



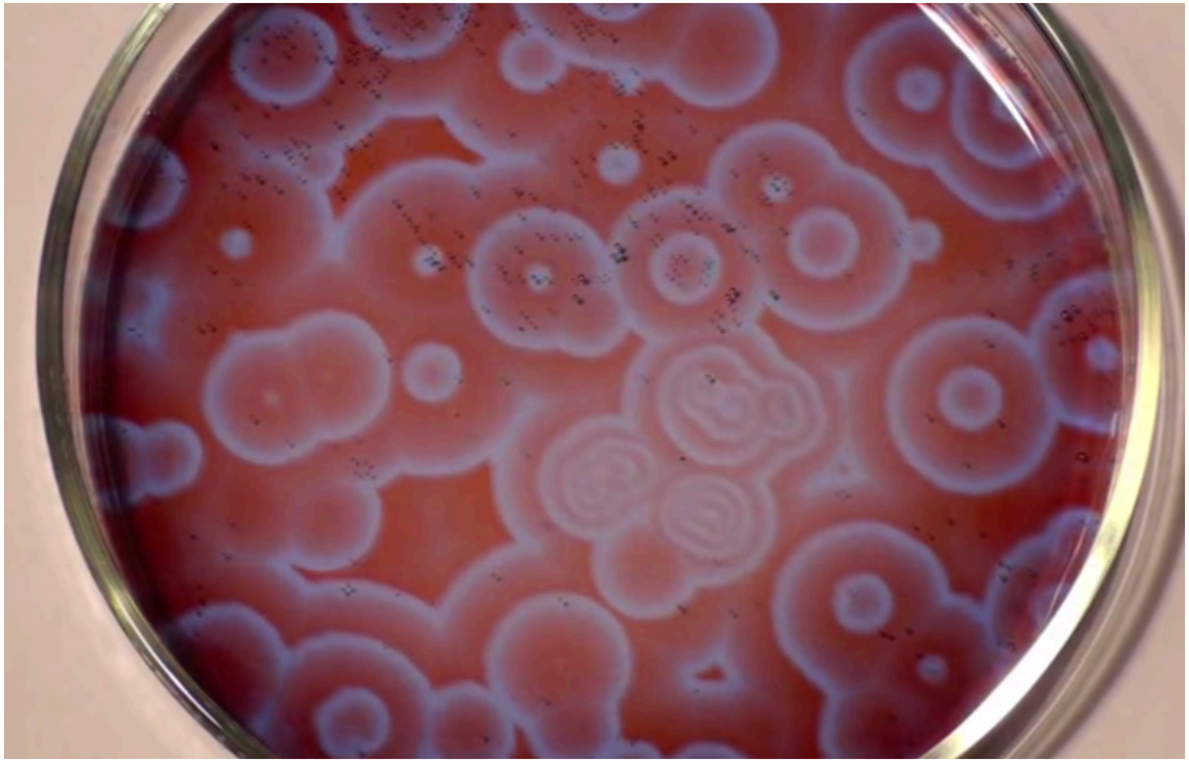
→ Can listen to this! (https://www.youtube.com/watch?v=TWqhUANNFXw)

https://en.wikipedia.org/wiki/First_observation_of_gravitational_waves

Examples of waves → Chemical waves

- “BZ reaction” = *Belousov–Zhabotinsky reaction*

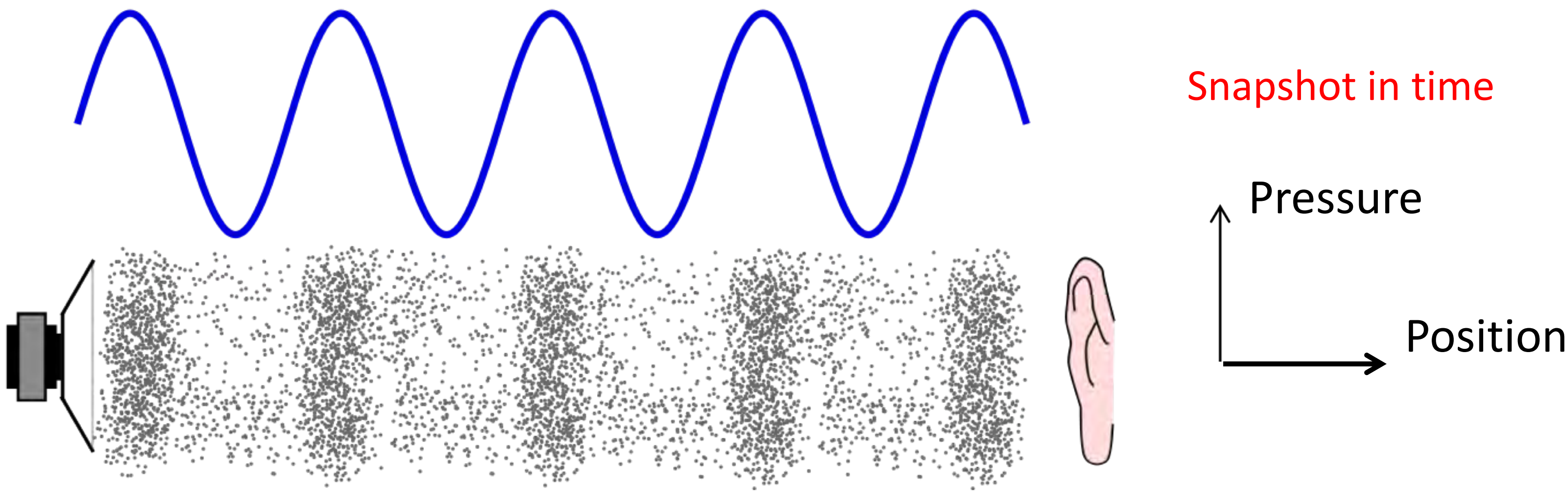
“... is one of a class of reactions that serve as a classical example of non-equilibrium thermodynamics, resulting in the establishment of a nonlinear chemical oscillator. The only common element in these oscillating is the inclusion of bromine and an acid.”



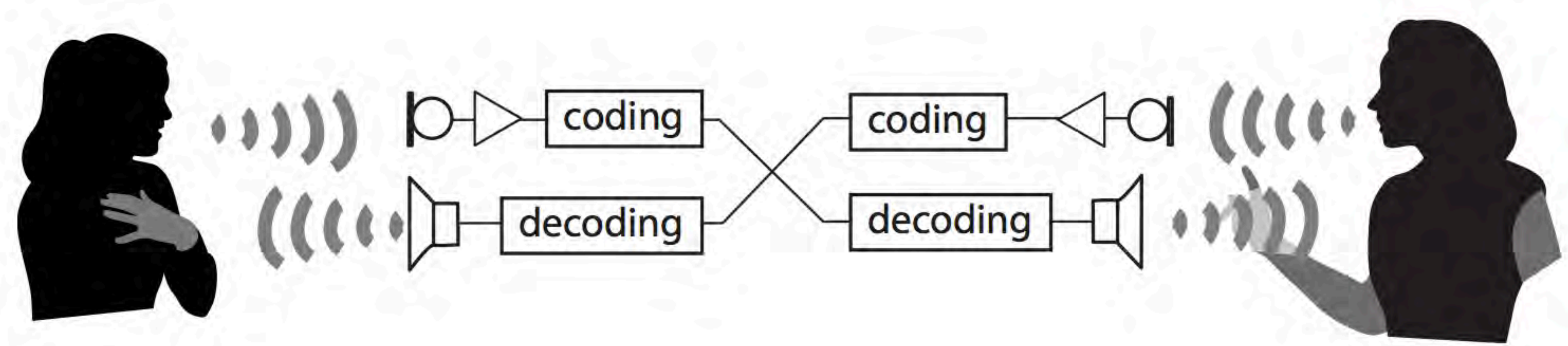
https://www.youtube.com/watch?v=3JAqrRnKFHo

https://en.wikipedia.org/wiki/Belousov%E2%80%93Zhabotinsky_reaction

Examples of waves → Sound waves



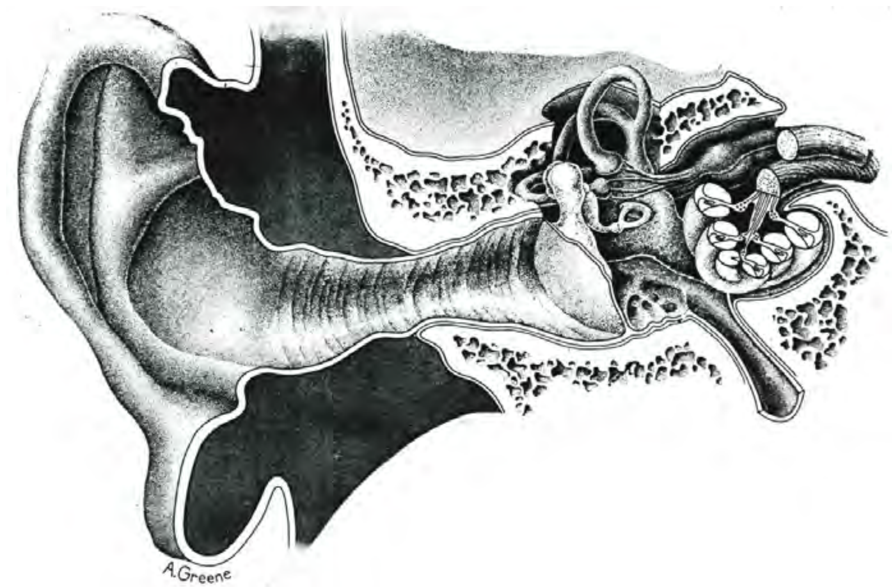
The "speech chain"



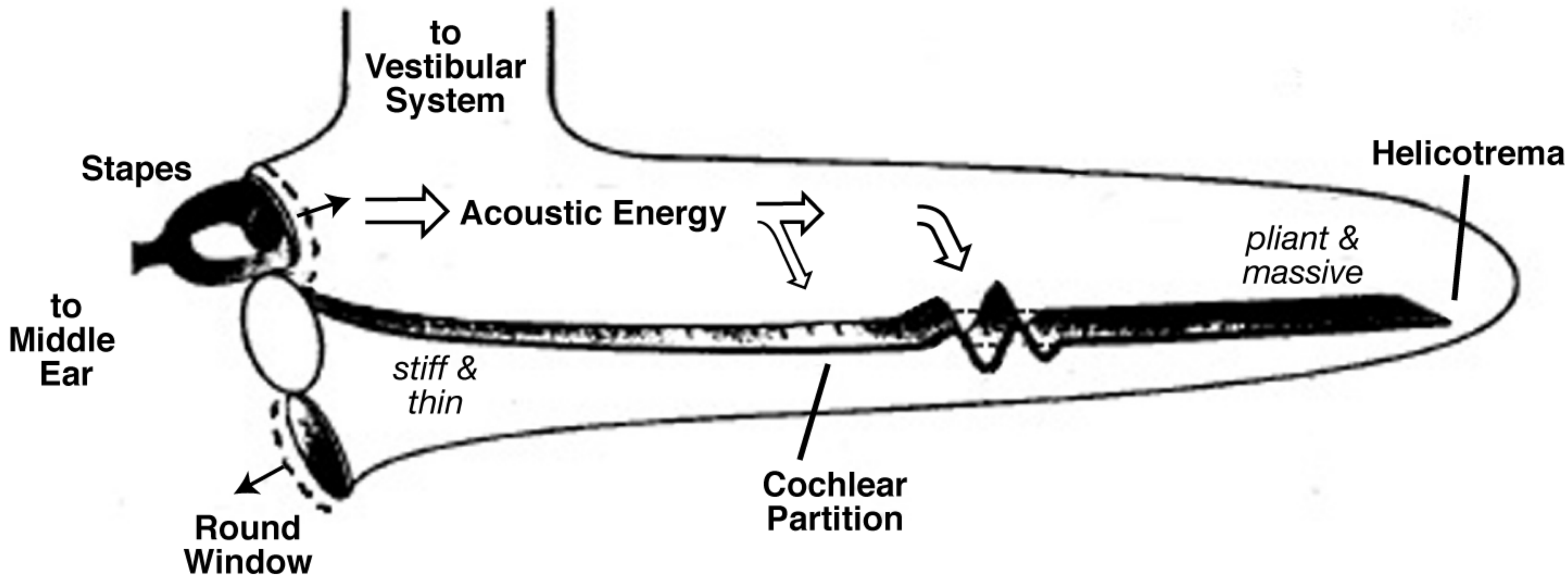
→ You create waves when you speak!

Pulkki & Karjalainen (2015)

Examples of waves → Cochlear waves



Basilar membrane traveling waves



Geisler (1996)

Examples of waves → Seeing babies

This ultrasound image is an example of using high-frequency sound waves to "see" within the human body.

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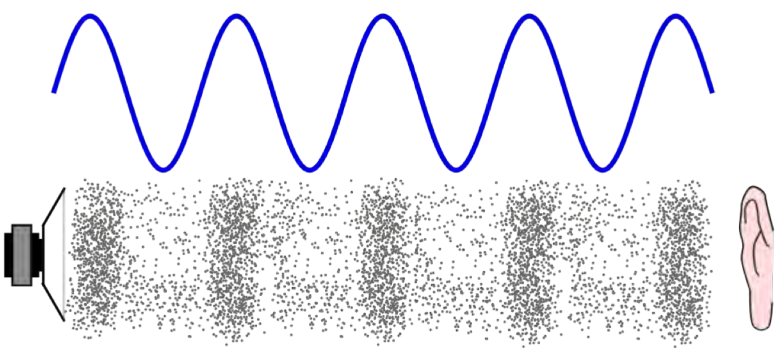


Actually acoustic (i.e., pressure) waves!

→ Modern ultrasound can image in 3-D

Examples of waves → Action potentials

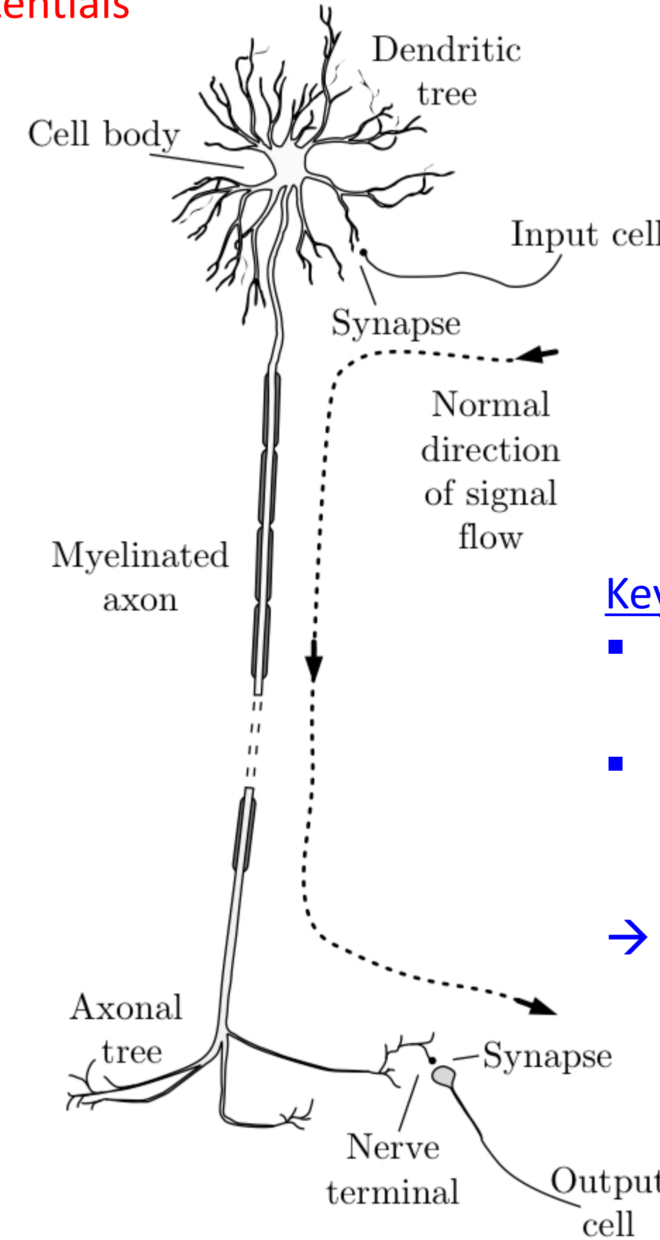


Figure 1.22

Neurons ("fibers")
= Information highway

→ Action potentials (or spikes) is a primary means for *information* to propagate through the body

Key Ideas

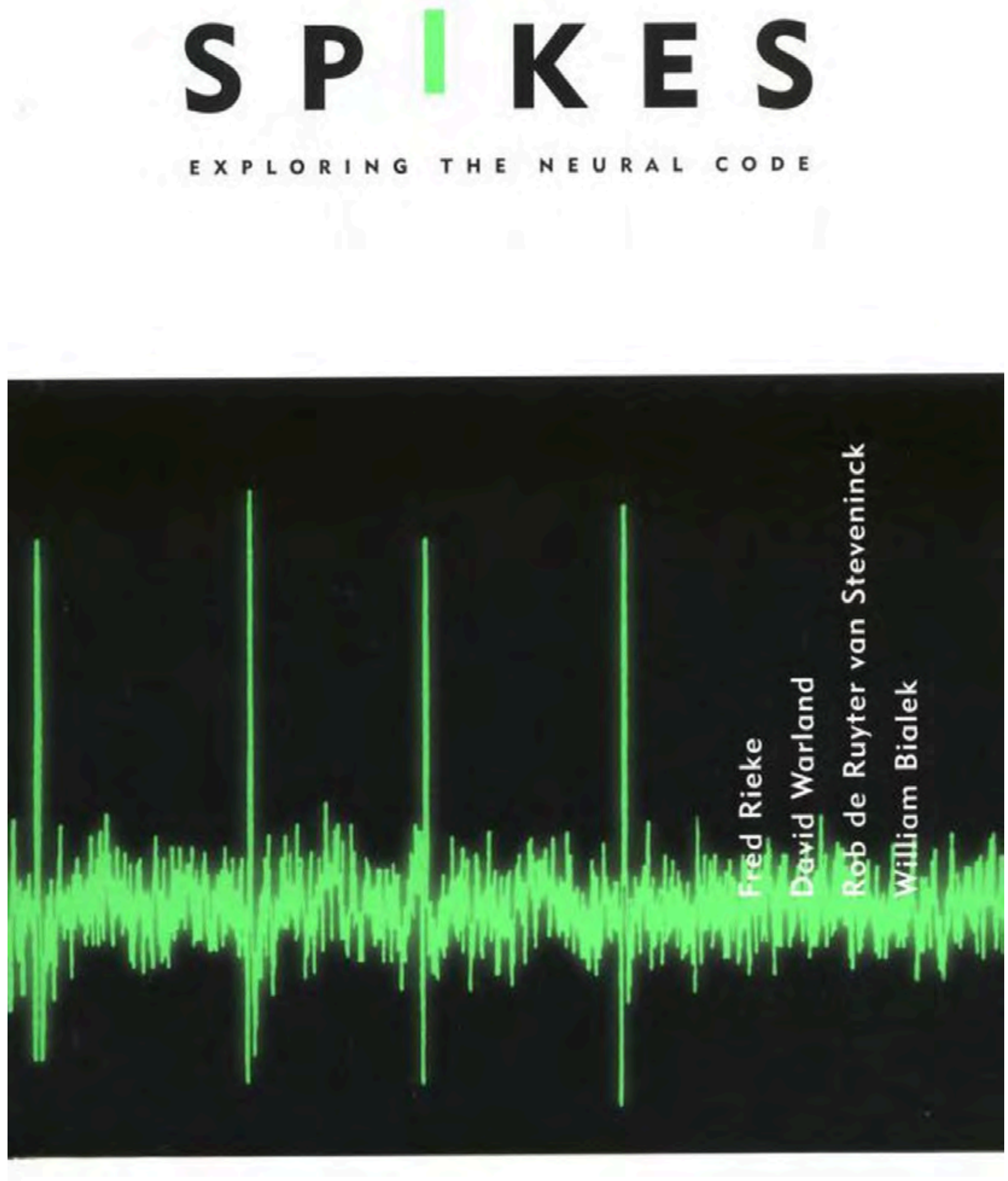
- Electrical properties of cells are important
- Diffusion sets foundation for transport across cell membrane

→ *Action potentials*

Weiss (1996)

Examples of waves → Action potentials

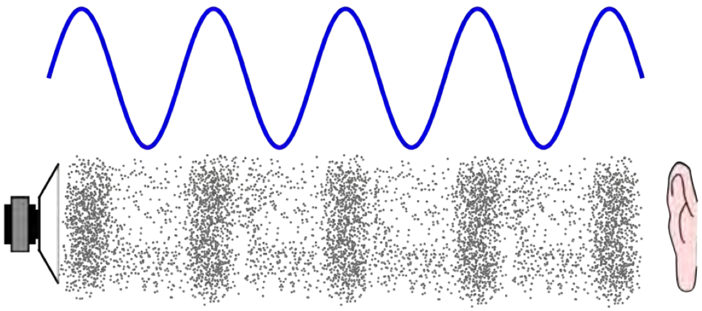
"Neural code"



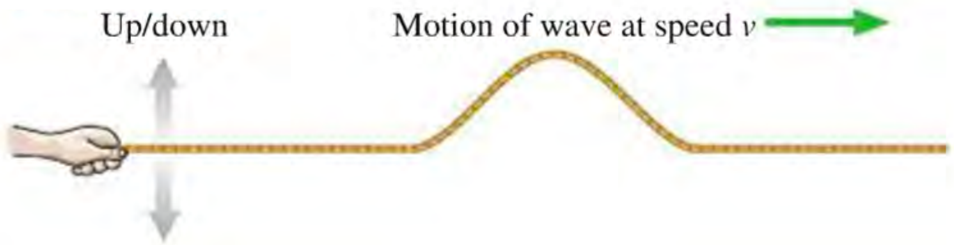
Types of waves

- So now we have seen some examples of waves, but more generally, what "types" of waves are there?

Longitudinal/Compression



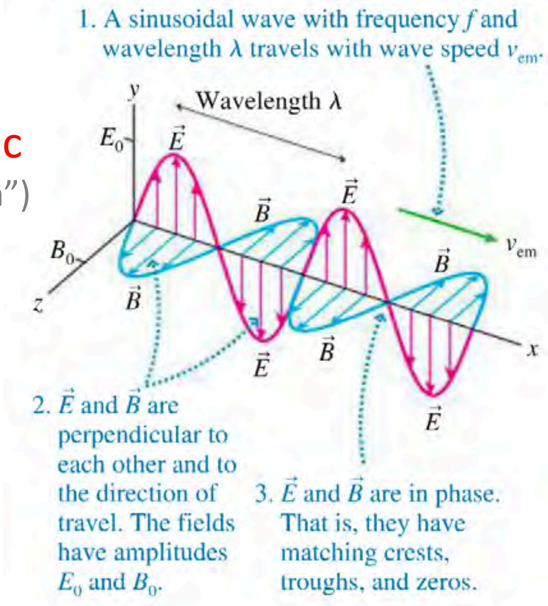
Transverse



Standing

Electromagnetic

(Note: No "medium")



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Question

J. Acoust. Soc. Am. **123**, 3507 (2008);

Acoustic communication in Panthera tigris: A study of tiger vocalization and auditory receptivity revisited

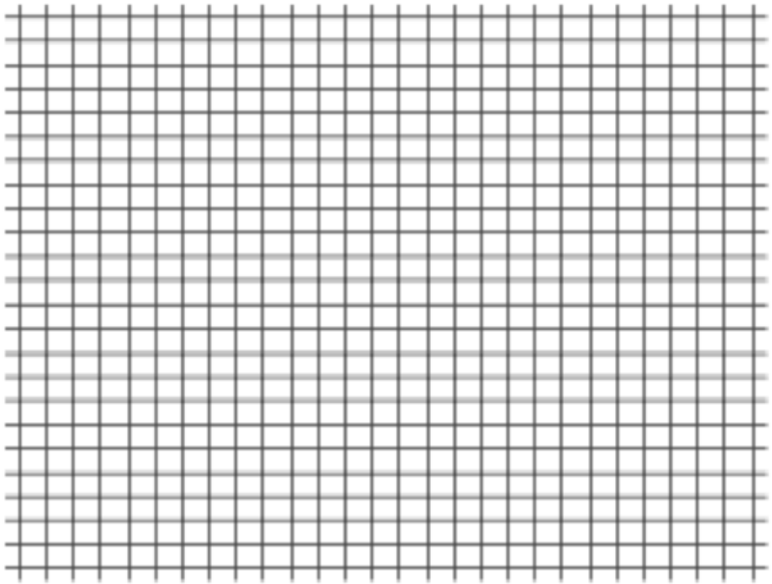
Edward Walsh[1], Douglas L. Armstrong[2], Julie Napier[3], Lee G. Simmons[4], Megan Korte[5] and Joann McGee[6]

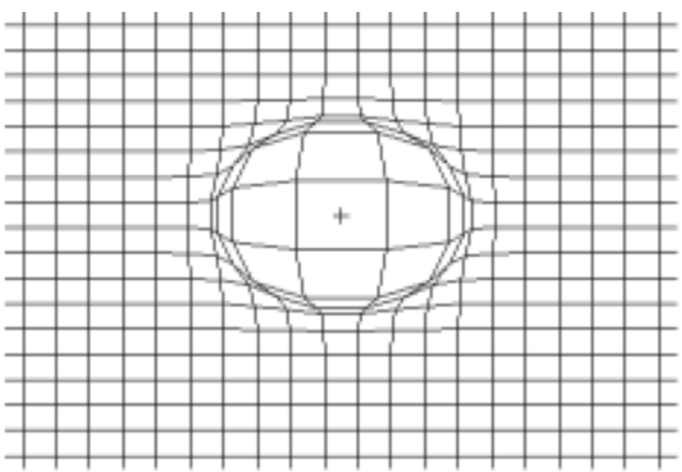
Preliminary findings reported at the 145th meeting of the Society suggested that confrontational tiger roars contain energy in the infrasonic portion of the electromagnetic spectrum. This discovery generally supported the proposition that free ranging individuals may take advantage of this capability to communicate with widely dispersed conspecifics inhabiting large territories in the wild. Preliminary ABR findings indirectly supported this view suggesting that although tigers are most sensitive to acoustic events containing energy in the 0.3 to 0.5 kHz band, they are most likely able to detect acoustic events in the near-infrasonic and infrasonic range based on the assumption that felid audiograms exhibit uniform shapes. In this study, the spectral content of territorial and confrontational roars was analyzed and relevant features of ABR based threshold-frequency curves were considered in relation to the acoustical properties of both roar types. Unlike the confrontational roar, infrasonicenergy was not detected in the territorial roar; however, like the confrontational roar, peak acoustic power was detected in a frequency band centered on˜ 0.3 kHz. In addition, ABR recordings acquired in a double walled sound attenuating chamber recently installed at the Henry Doorly Zoo suggest that acoustic sensitivity is significantly underestimated under "field" conditions.

→ What is wrong here?

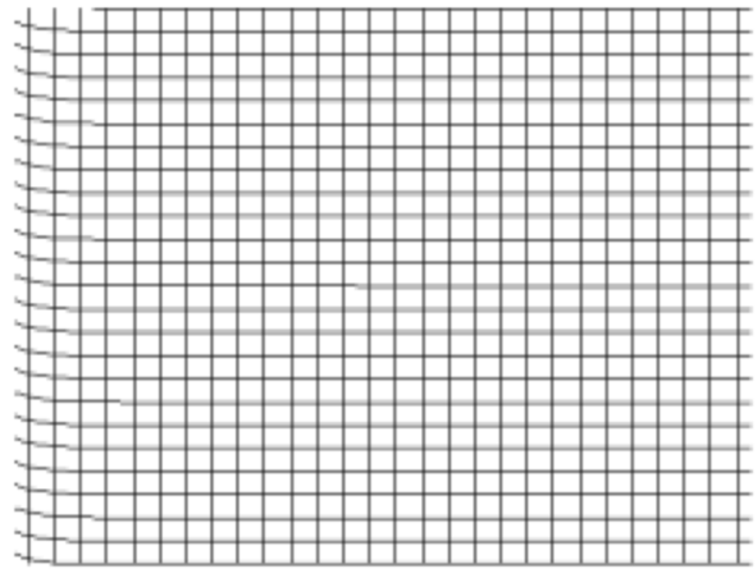
Types of waves

Longitudinal wave





Transverse wave



https://en.wikipedia.org/wiki/Longitudinal_wave
https://en.wikipedia.org/wiki/Transverse_wave

Types of waves

A **transverse wave** is a wave in which the displacement is *perpendicular* to the direction in which the wave travels. For example, a wave travels along a string in a horizontal direction while the particles that make up the string oscillate vertically. Electromagnetic waves are also transverse waves because the electromagnetic fields oscillate perpendicular to the direction in which the wave travels.

In a **longitudinal wave,** the particles in the medium move *parallel* to the direction in which the wave travels. Here we see a chain of masses connected by springs. If you give the first mass in the chain a sharp push, a disturbance travels down the chain by compressing and expanding the springs. Sound waves in gases and liquids are the most well known examples of longitudinal waves.

Question

→ What kind of waves are ocean waves?

Looking ahead: Standing Waves

- Consider that in 1-D, there can be two waves on a string: one going *forward* and one going *backward*

The superposition of two sinusoidal waves traveling in opposite directions.

- Their combination leads to interference (or *superposition*)

- Sometimes the waves interfere (i.e., add up) *constructively*, other times it is *destructively*

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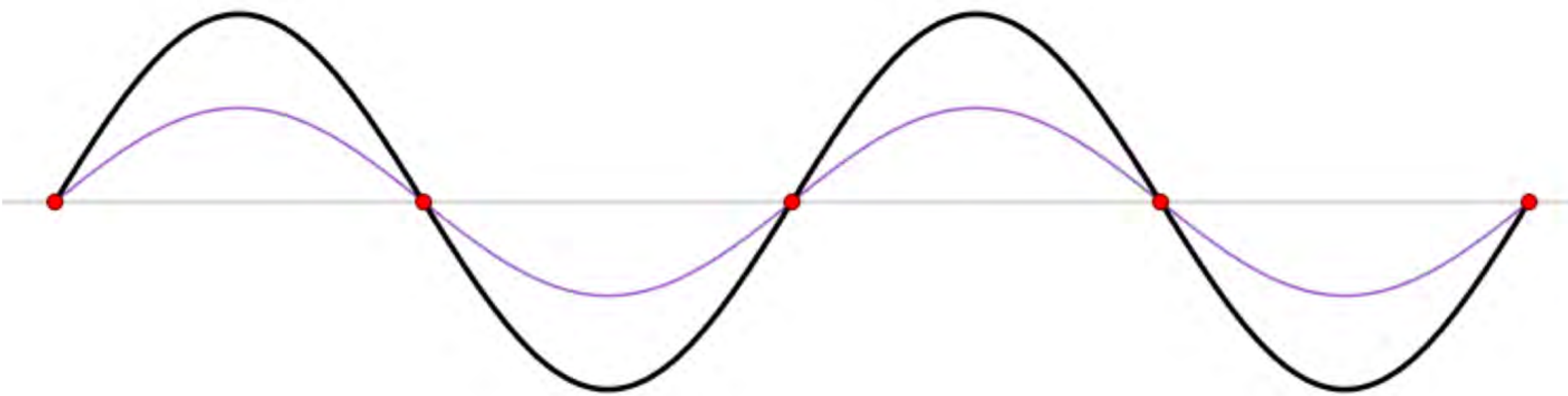
<u>Looking ahead</u>: Standing Waves

... but is much more readily apparent via a movie

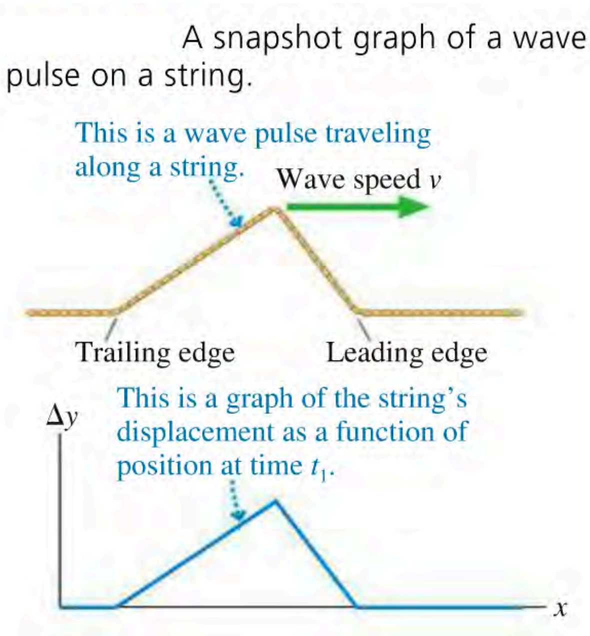


Blue is the left-going wave
Red is the right-going wave
Black is the sum of the two (i.e., the “standing” wave)

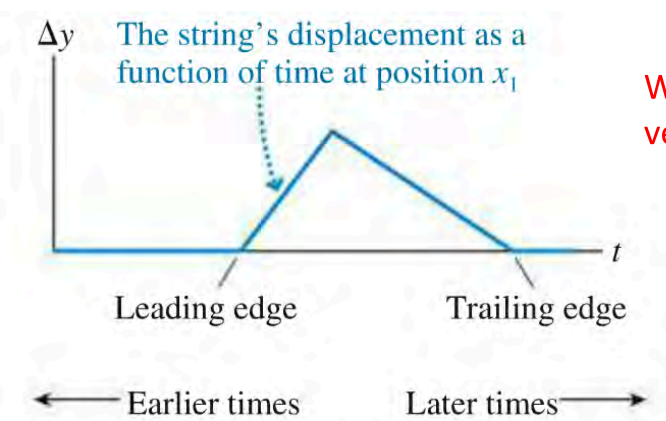
<u>Note</u>: Locations where the amplitude stays zero are called ***nodes***

https://en.wikipedia.org/wiki/Standing_wave

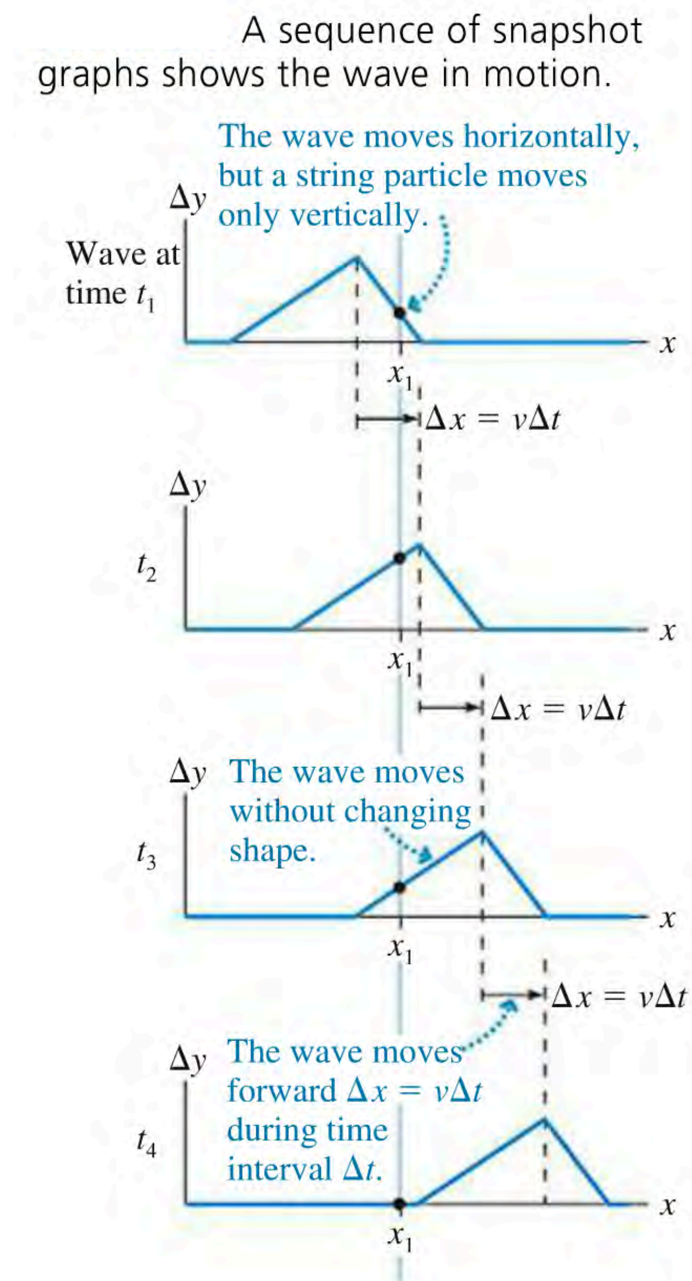
How to describe a wave?



Wave height versus position



Wave height versus time



Note: Wave shape appears “flipped” between the two....

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