

Office hours today: after class in Remo

Learning goals for today:

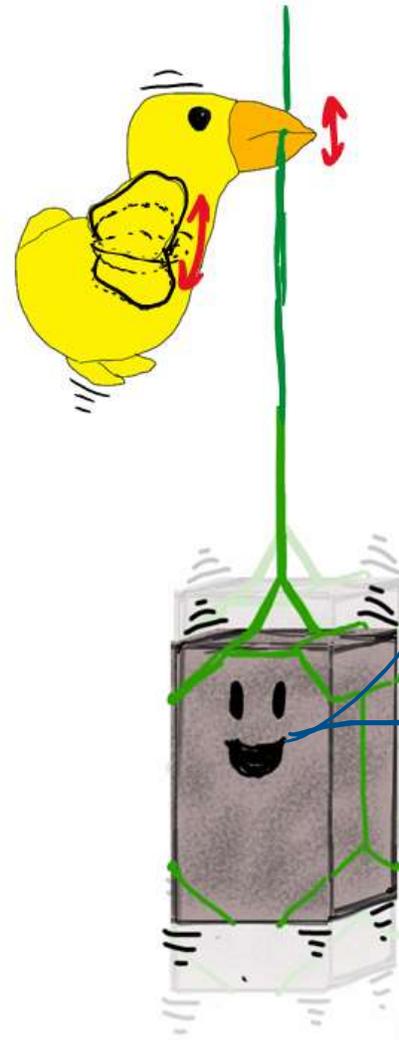
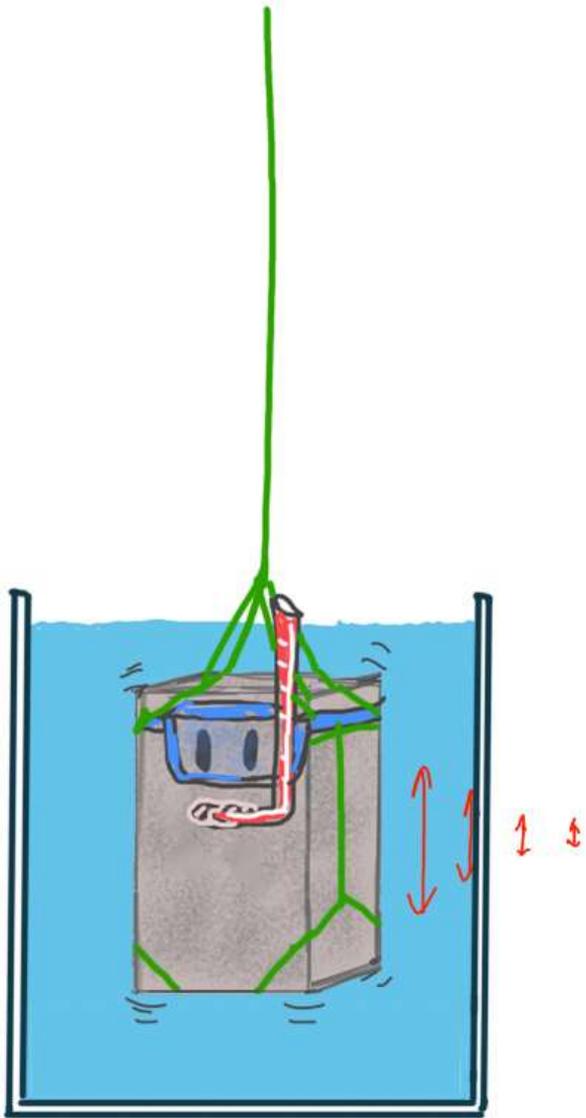
To explain how oscillators coupled together lead to travelling waves

To explain the difference between transverse and longitudinal waves

To describe the mathematical description of a one-dimensional travelling wave

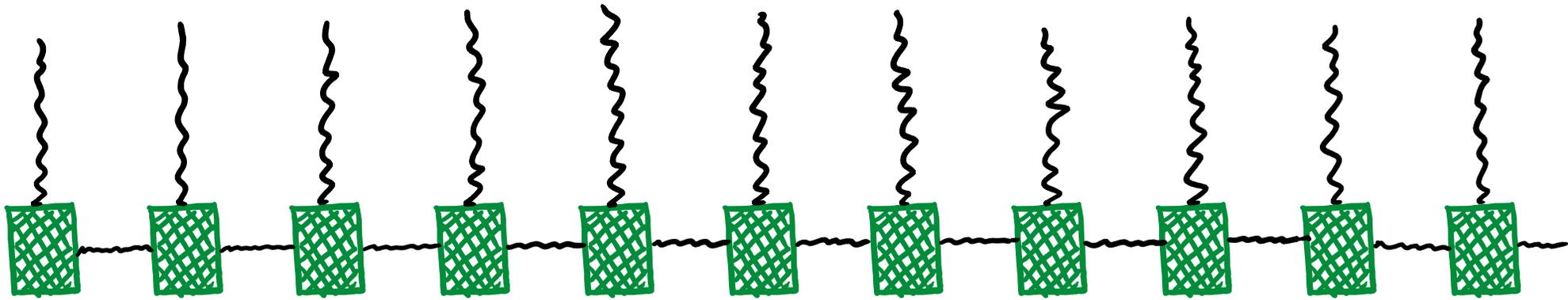
To relate the “snapshot” graph showing the shape of a wave at some time, to the “history” graph showing the displacement of one part of the medium as a function of time.

To describe qualitatively the nature of sound waves in a fluid.

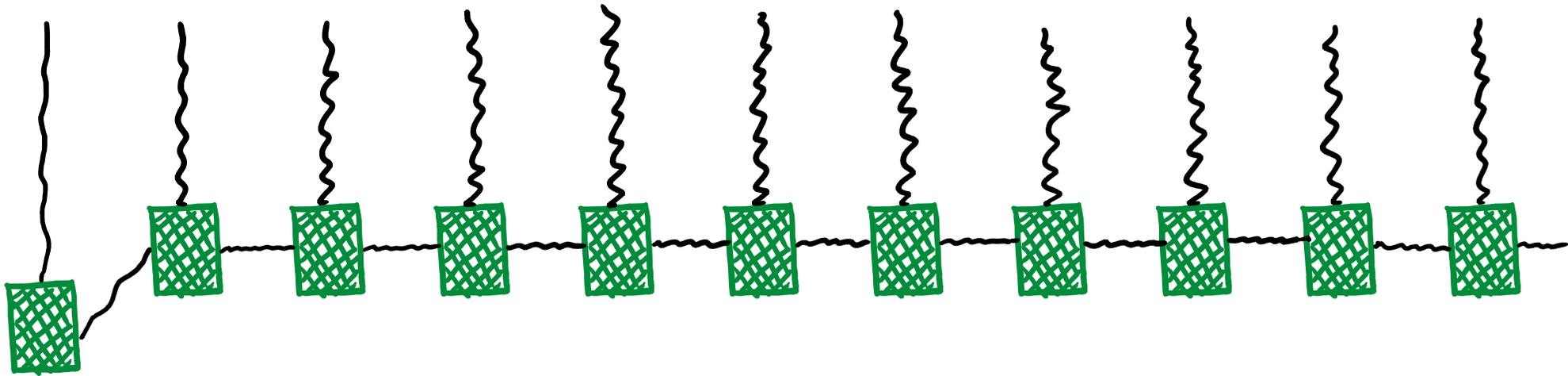


Last
time
in Physics
157

Coupled oscillators:

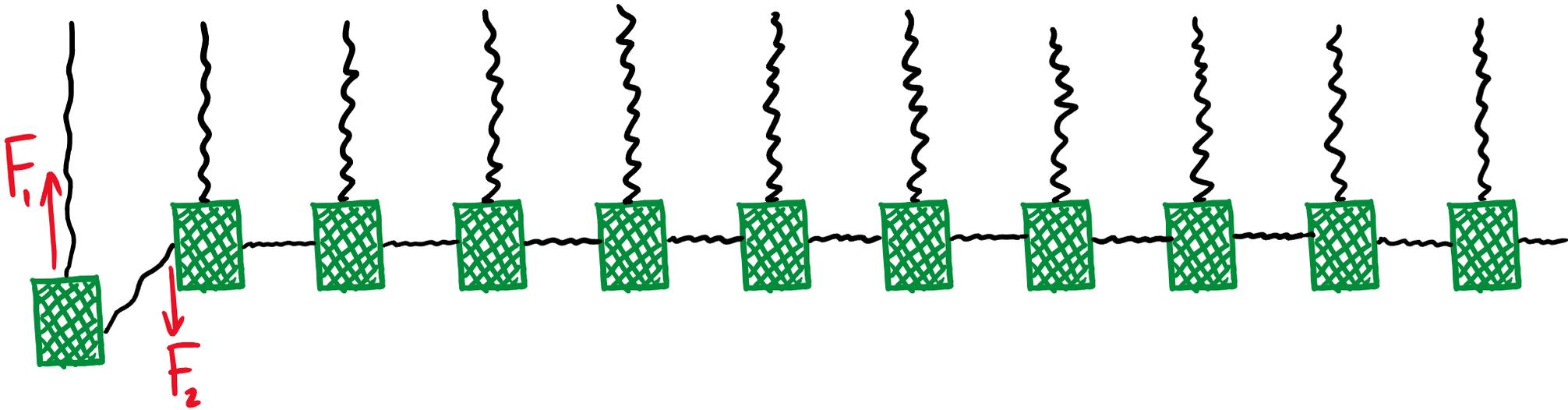


What happens if we pull the leftmost one down and release it?



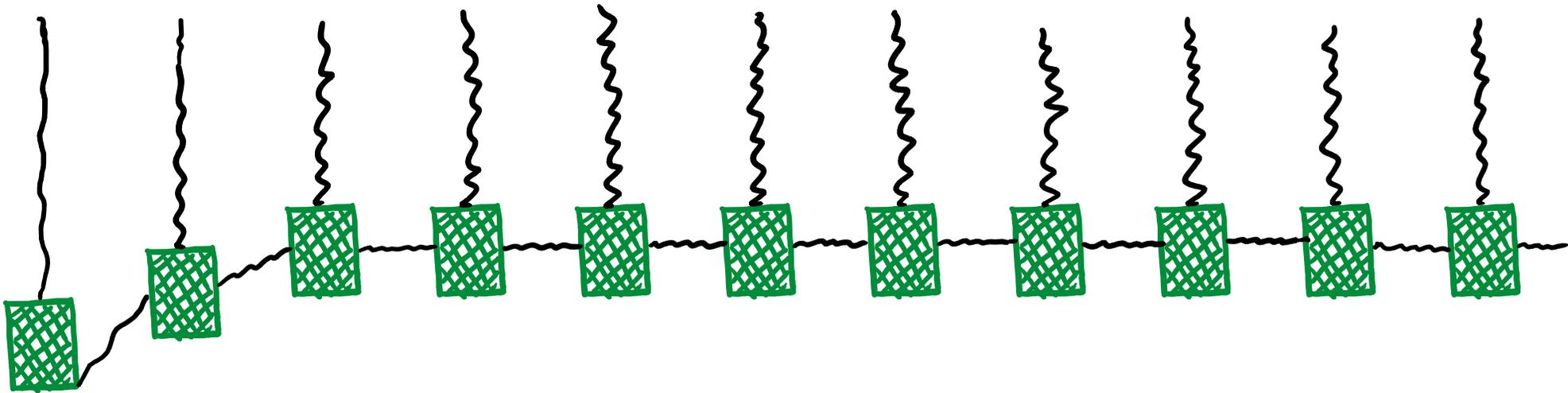
Coupled oscillators: Displacement of one oscillator leads to:

F_1 : restoring forces on that oscillator

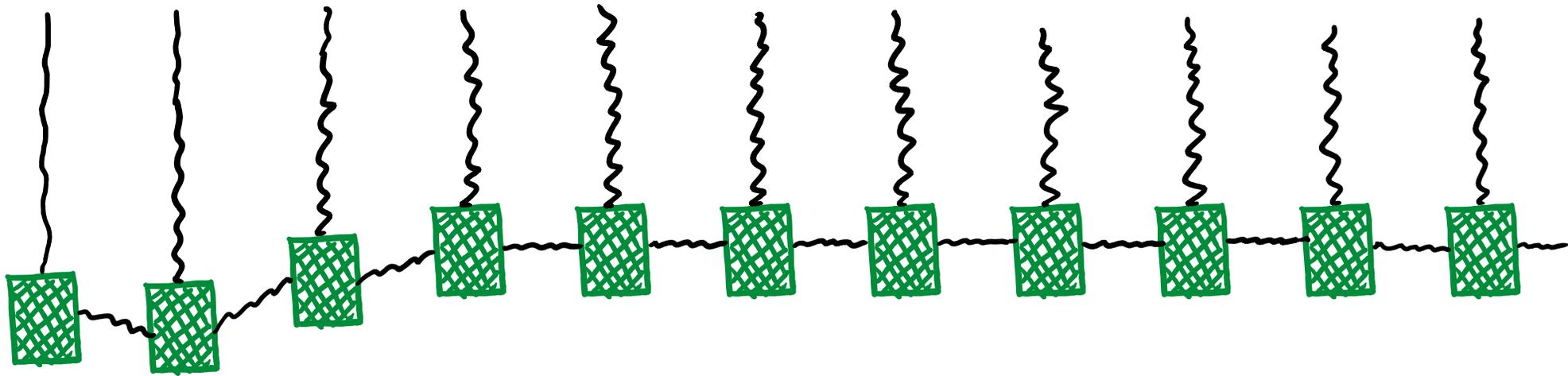


F_2 : forces to displace the nearby oscillators

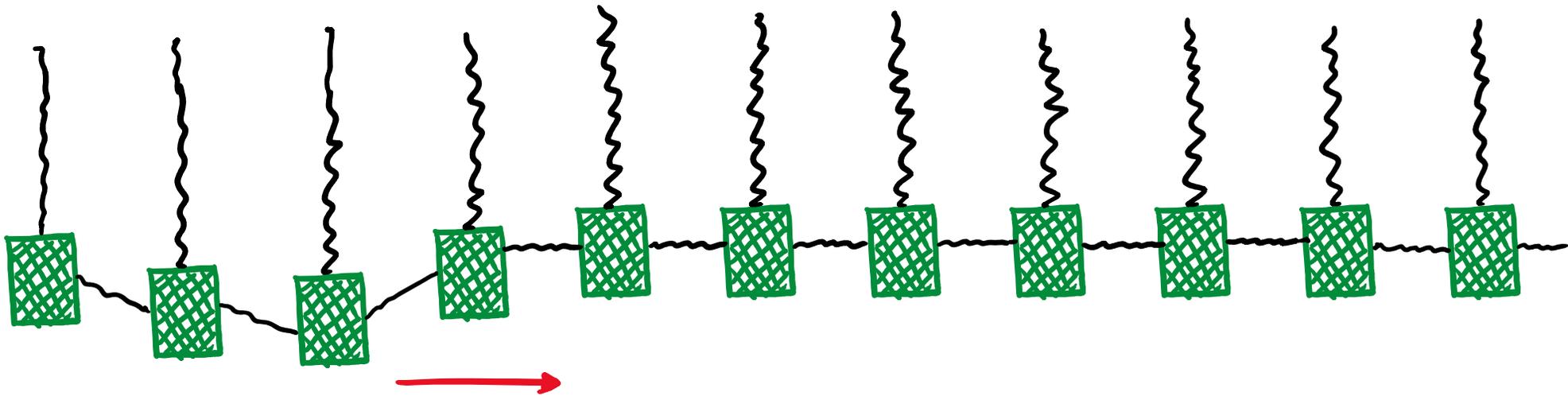
Coupled oscillators:



Coupled oscillators:

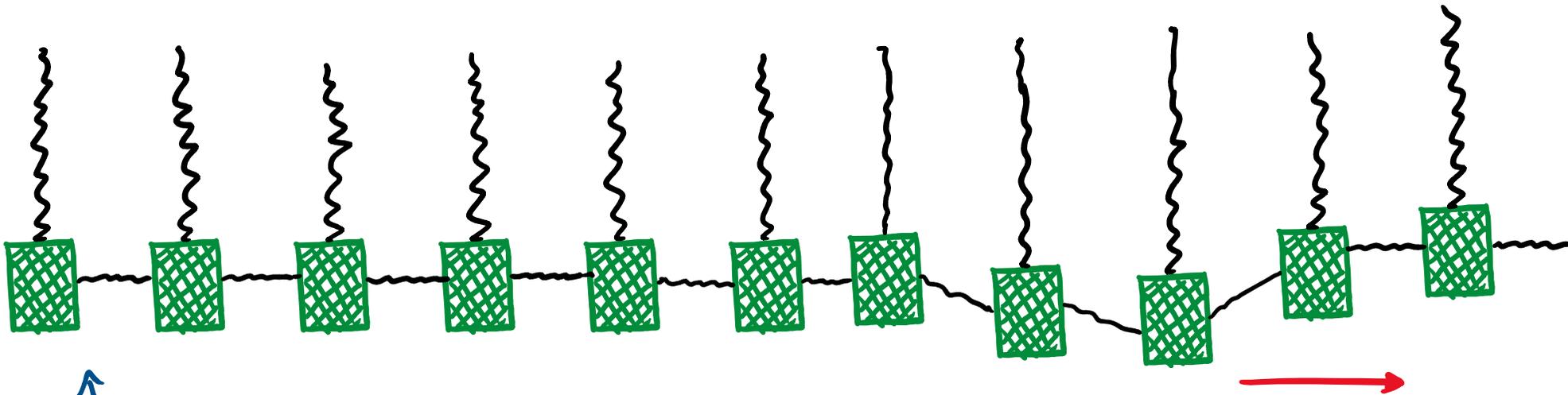


Coupled oscillators:



disturbance propagates along the chain

Coupled oscillators:



↑ these ones settle down to equilibrium since energy is transferred to the other oscillators

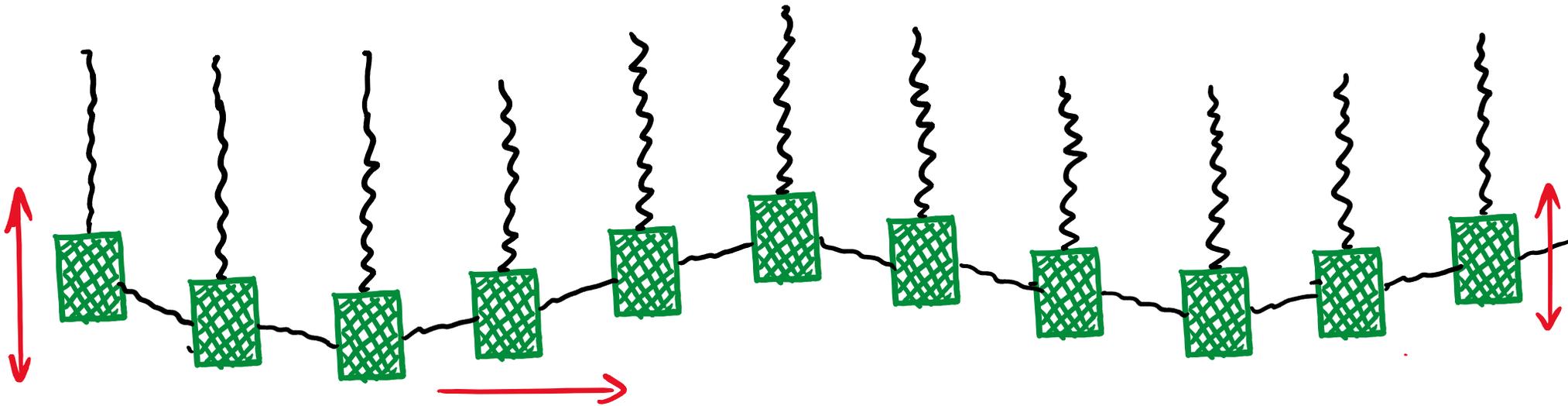
Coupled oscillator simulation: https://phet.colorado.edu/sims/normal-modes/normal-modes_en.html

Transverse Waves Demo:

<https://youtu.be/jSl14JjFnhY>

Coupled oscillators:

if we drive the leftmost oscillator...

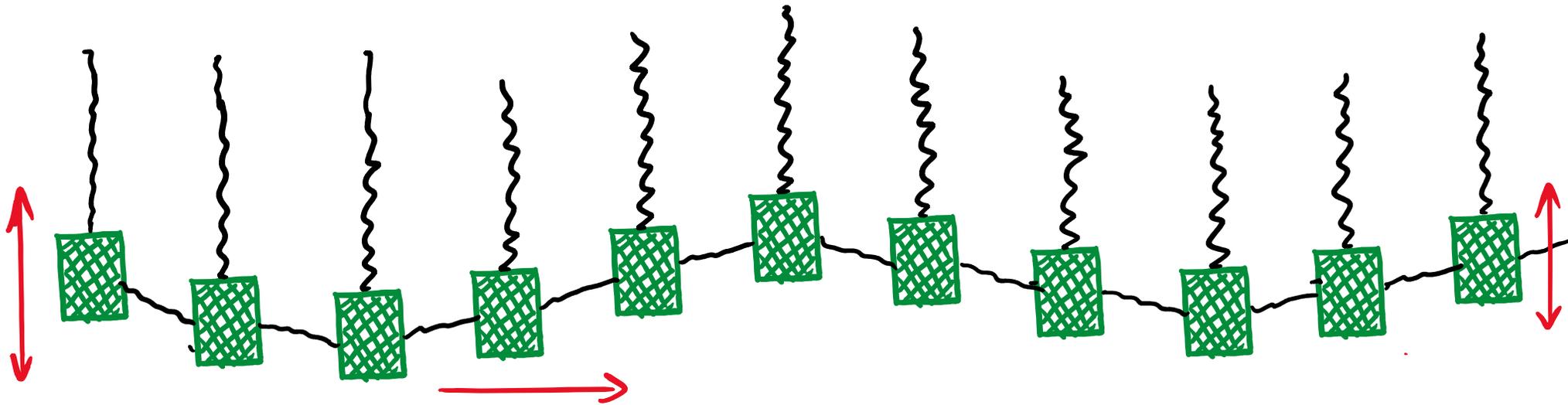


get traveling wave!

- continuously adding energy to system

Coupled oscillators:

if we drive the leftmost oscillator...



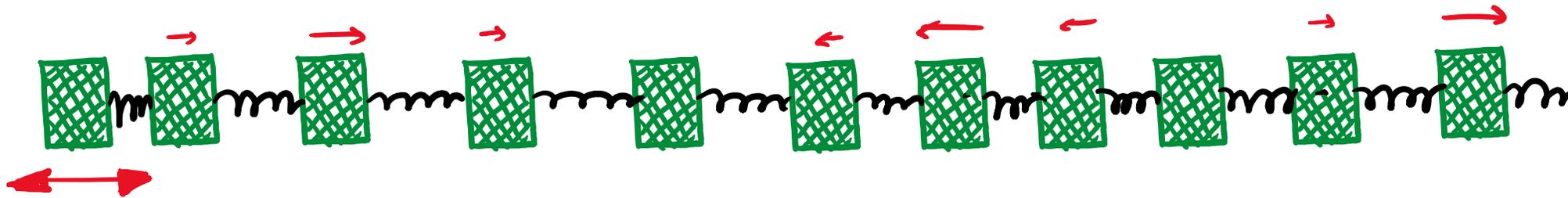
get traveling wave!

Transverse wave: oscillations perpendicular to direction wave travels

Coupled oscillators: longitudinal displacement

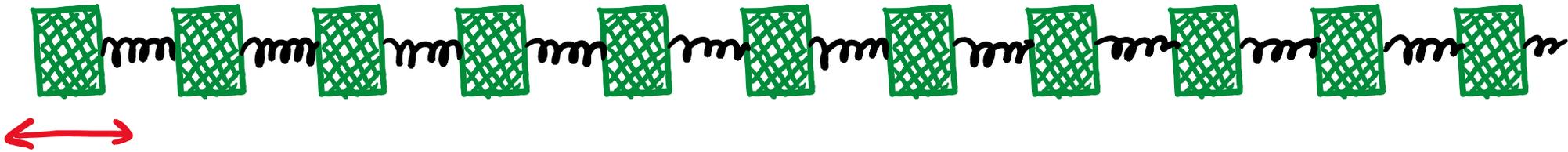


Coupled oscillators:

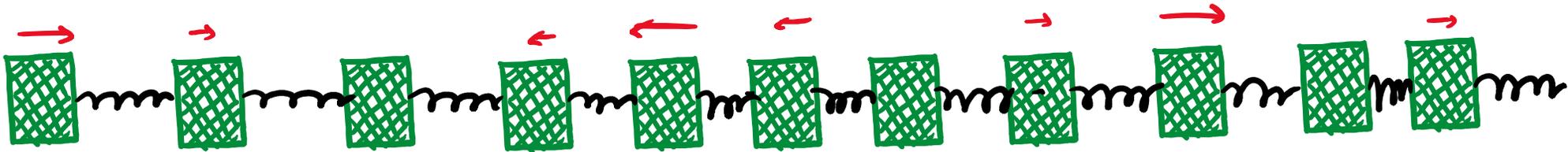


LONGITUDINAL WAVE

Coupled oscillators:



Coupled oscillators:

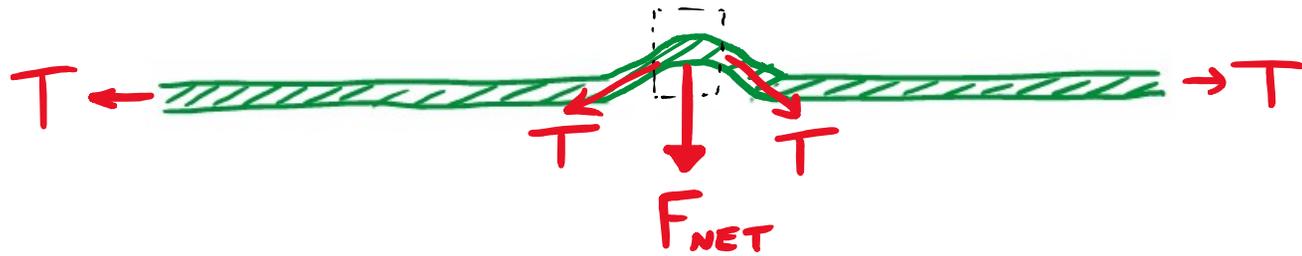


Longitudinal Waves Demo:

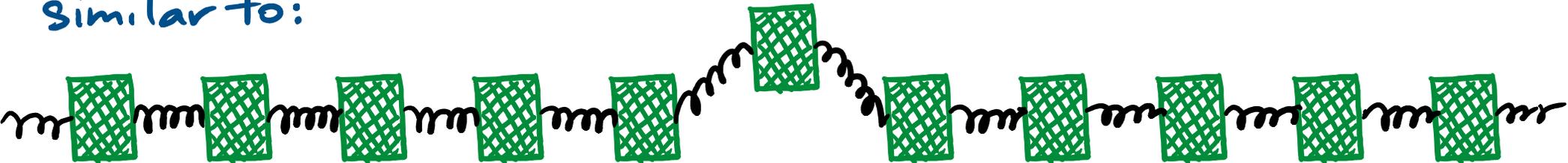
https://youtu.be/m7fXNV_S42M

Many (most?) physical systems act as
coupled oscillators...

Stretched string: tension provides restoring force for displaced section



similar to:



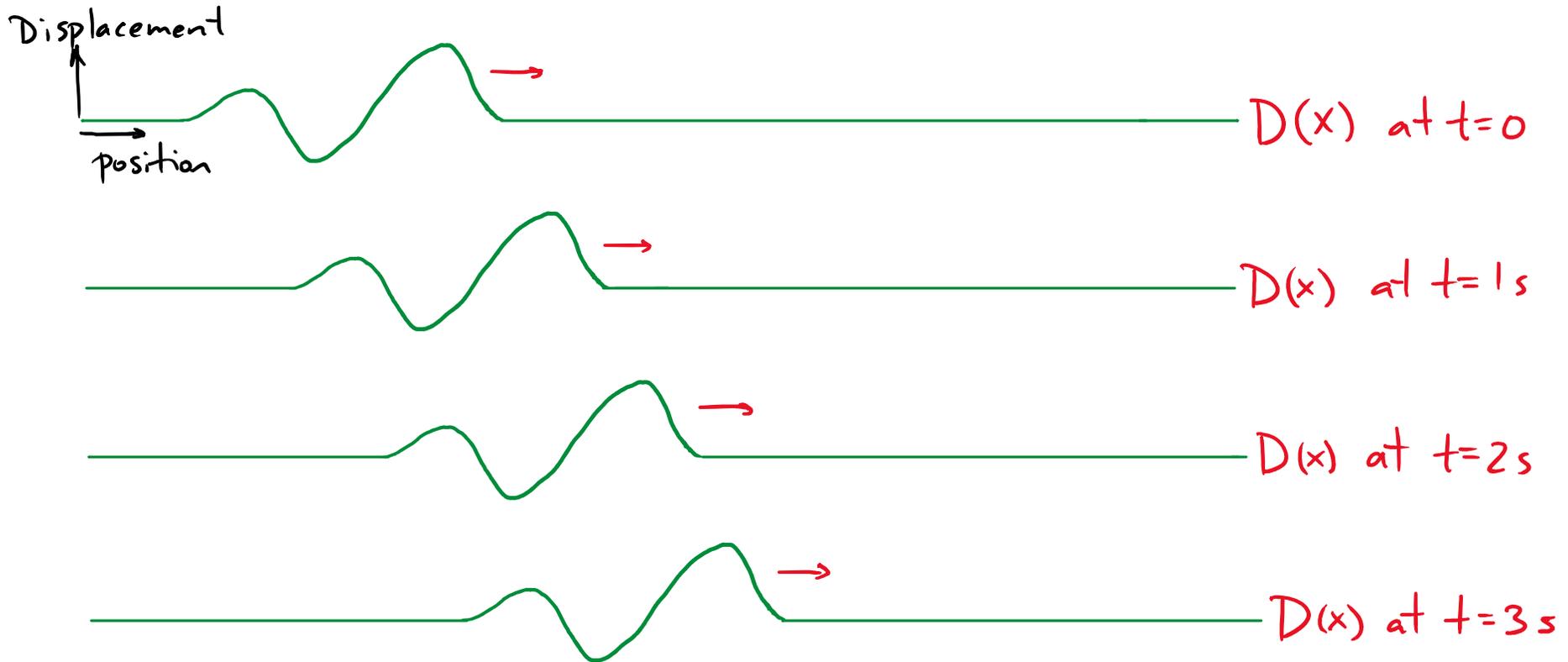
PHET Demo: waves on a string:

<https://youtu.be/j7ovJMKHrWY>

https://phet.colorado.edu/sims/html/wave-on-a-string/latest/wave-on-a-string_en.html

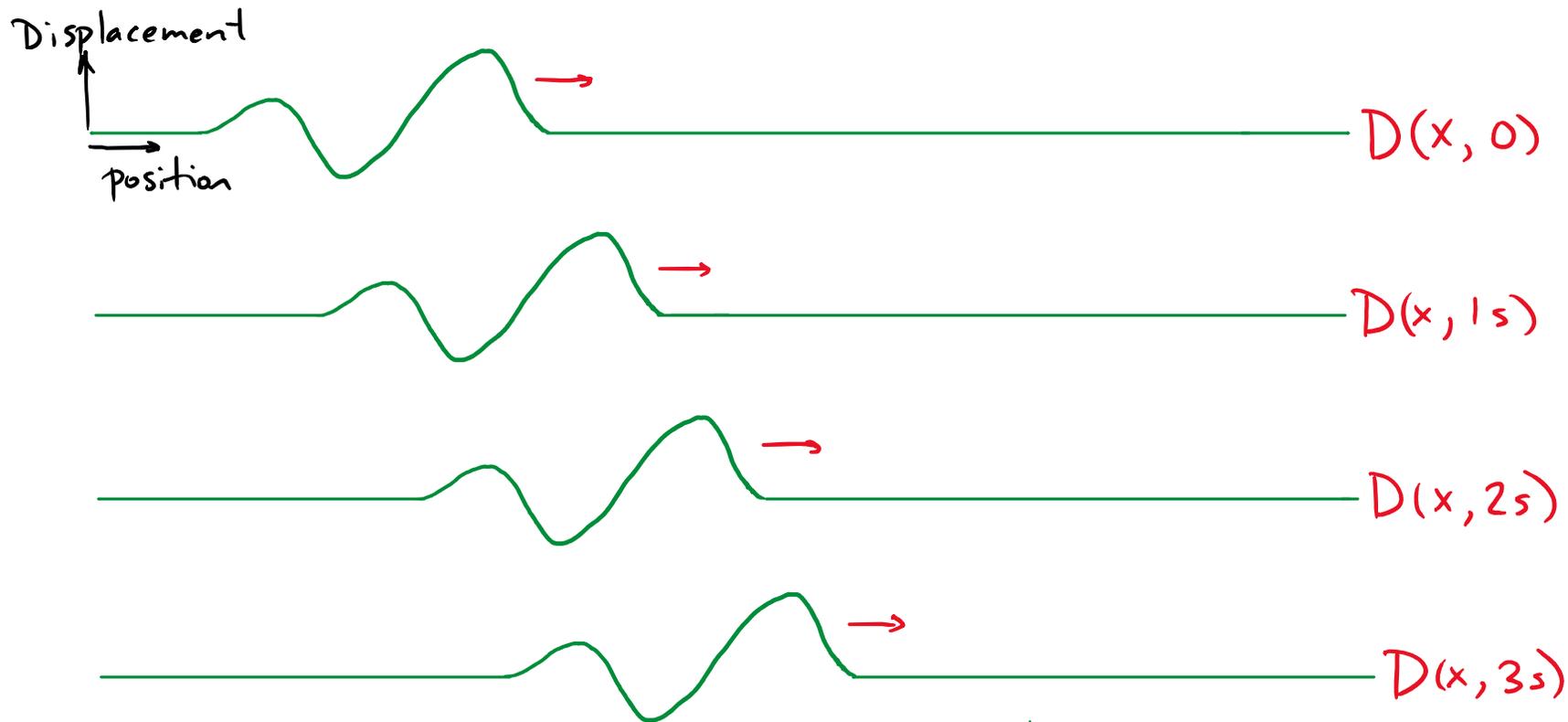
Mathematical description of waves:

At each time, we have a function that describes a "snapshot" of the wave at that time:



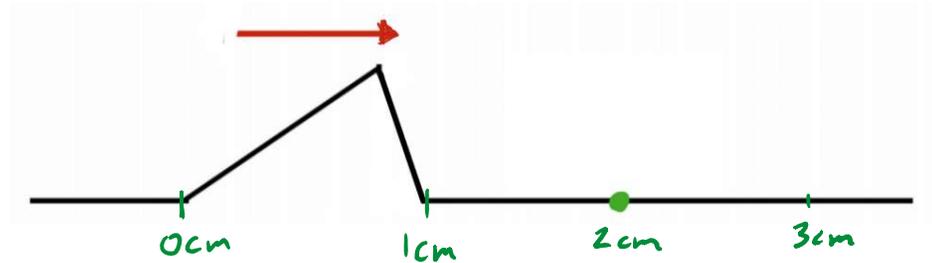
Mathematical description of waves:

define $D(x,t)$: displacement at position x at time t .

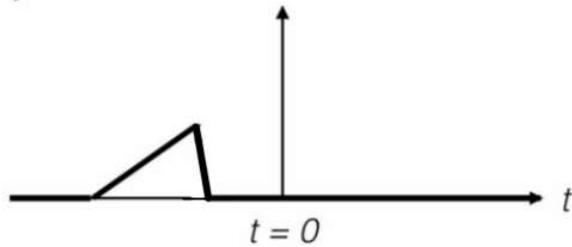


note: some waves change shape over time

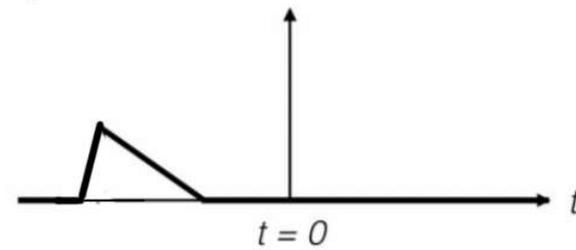
The graph to the right shows $D(x, 0)$, the snapshot of a right-moving wave pulse at time $t=0$. Which of the graphs below could represent $D(2\text{cm}, t)$?



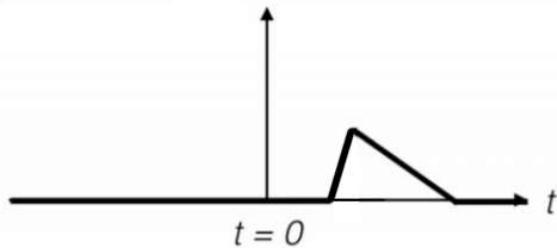
A)



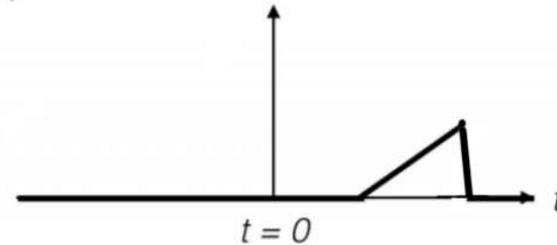
B)



C)



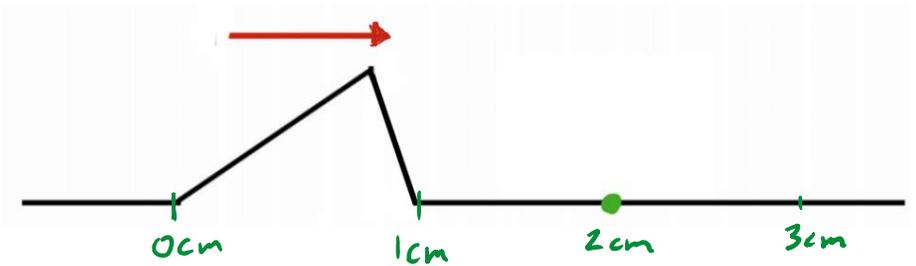
D)



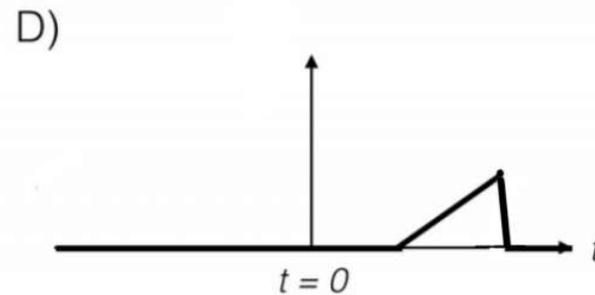
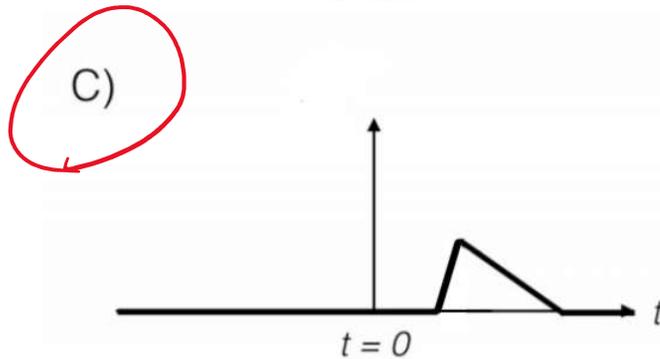
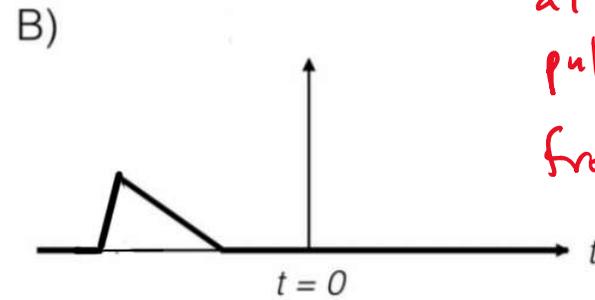
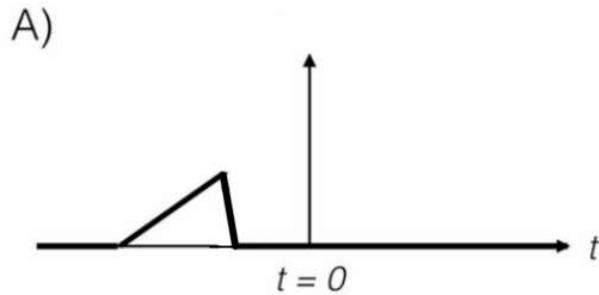
DEMO:

<https://youtu.be/GErNfz7toNQ>

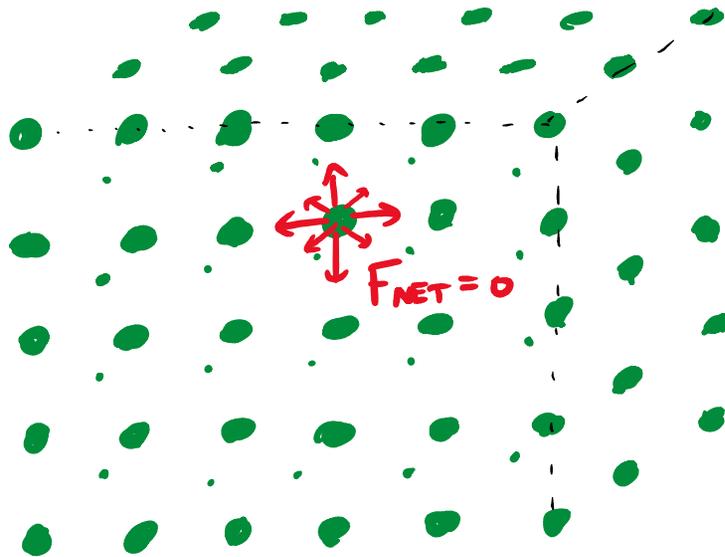
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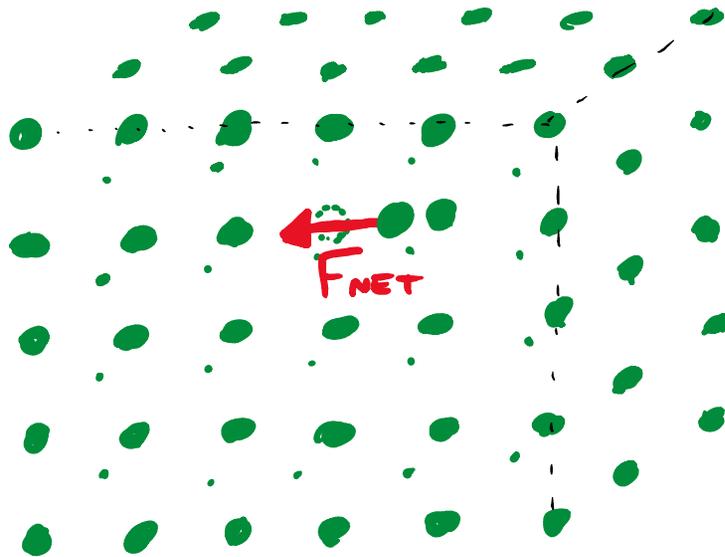
no motion before $t=0$
 at some time after $t=0$
 pulse reaches green dot,
 front of pulse is
 steeper, so
 displacement
 increases quickly
 then decreases
 slowly.



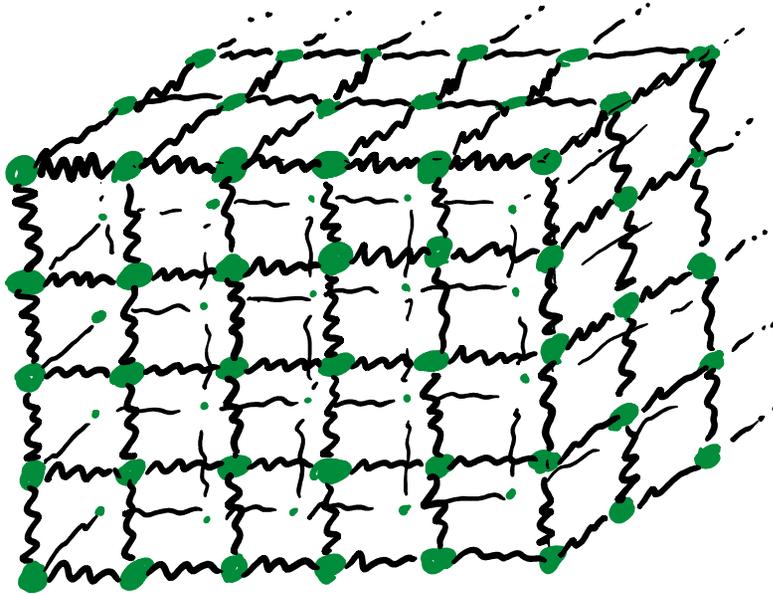
Solid: each atom is in an equilibrium position



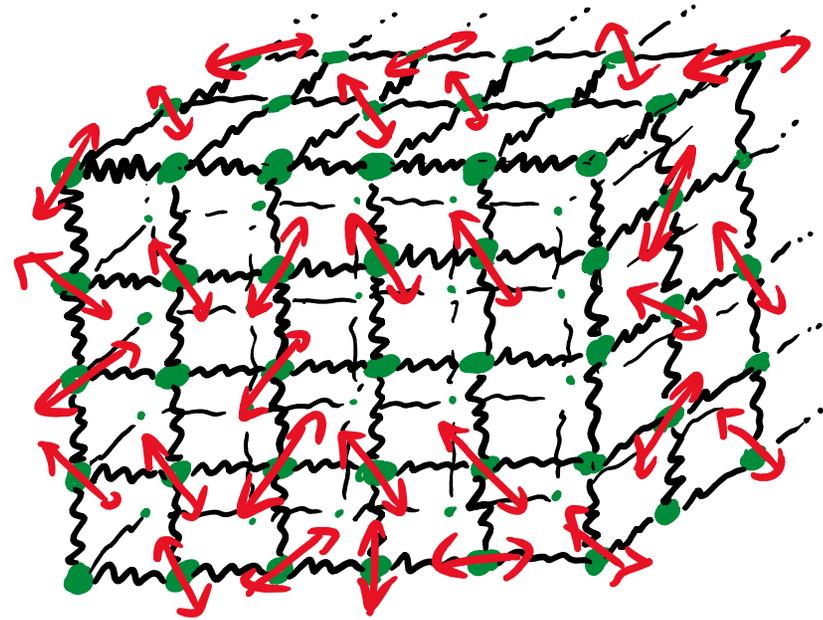
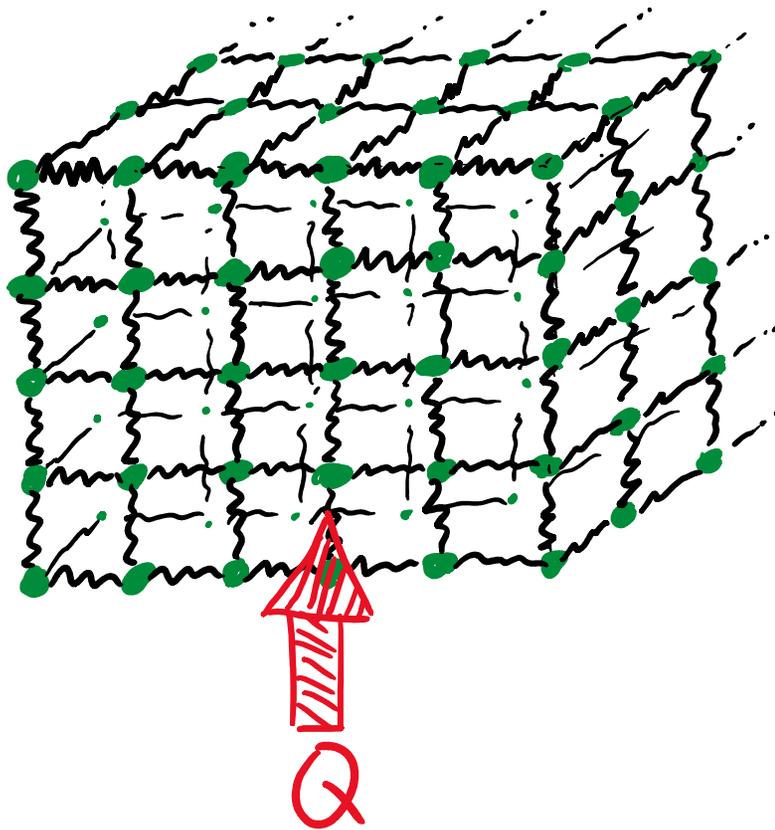
Solid: each atom is in an equilibrium position
- displaced atoms feel restoring force



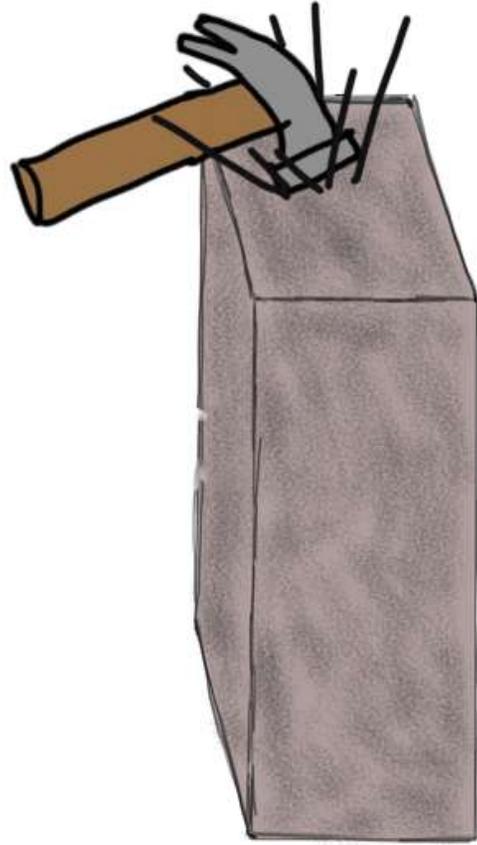
Solid: each atom is in an equilibrium position
Similar to a lot of coupled oscillators:



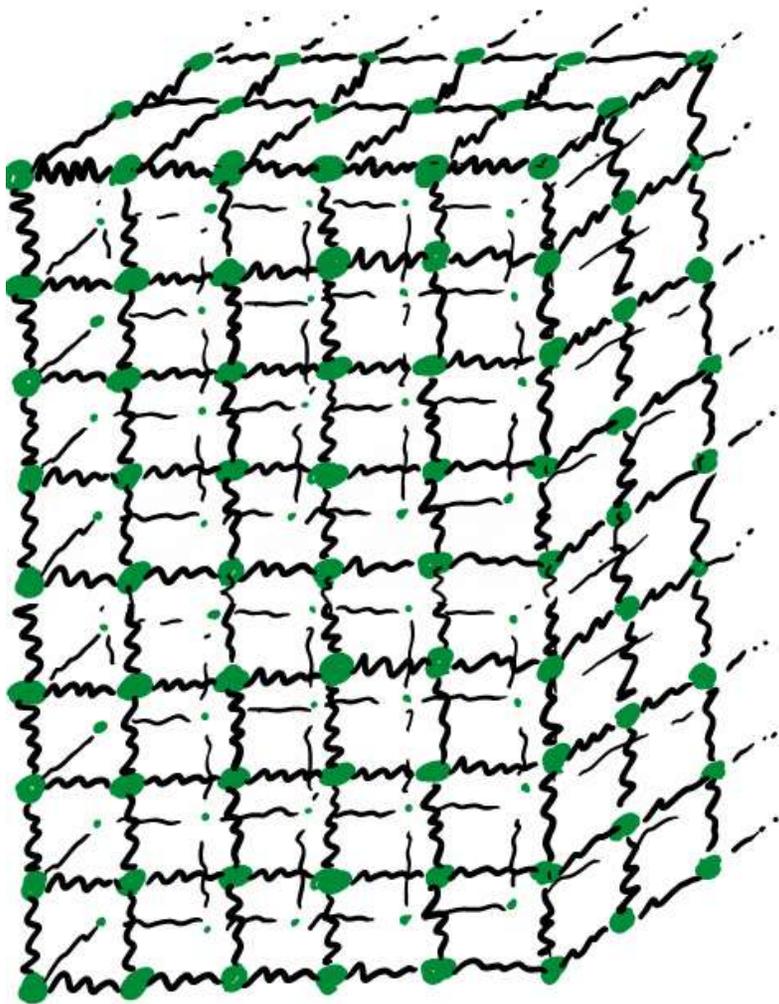
Warm solid: these oscillators have small random oscillations about equilibrium



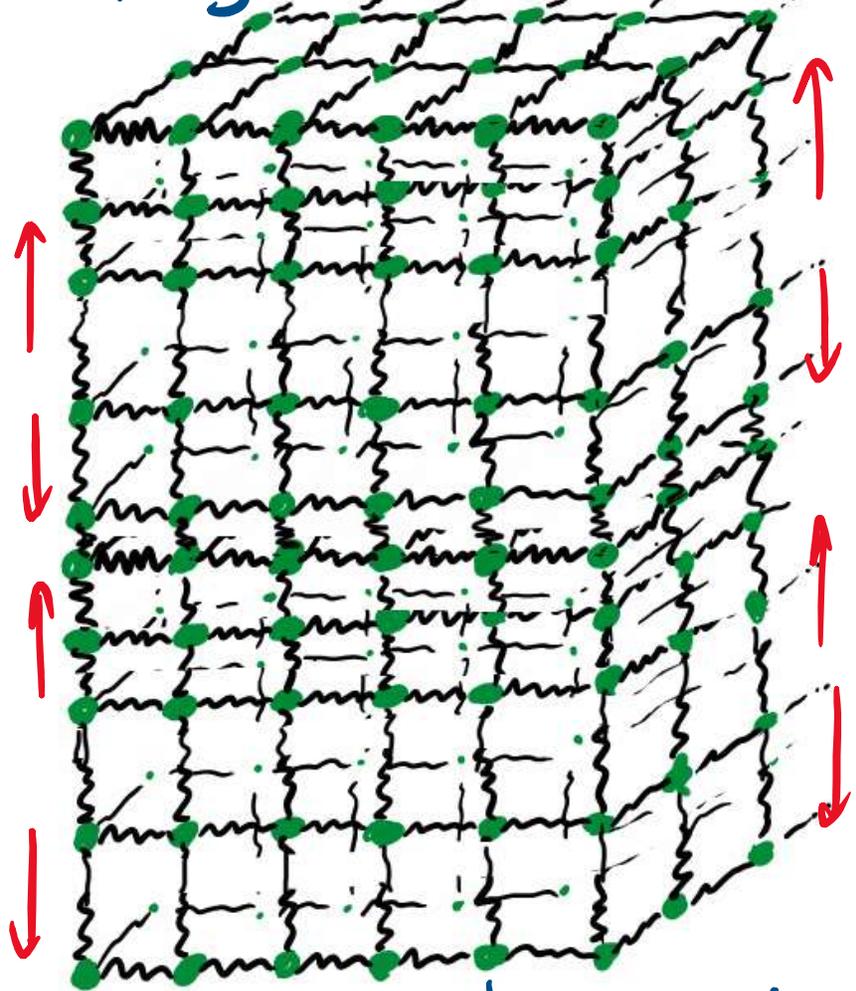
But: can also have coordinated oscillations
due to macroscopic external forces



equilibrium:

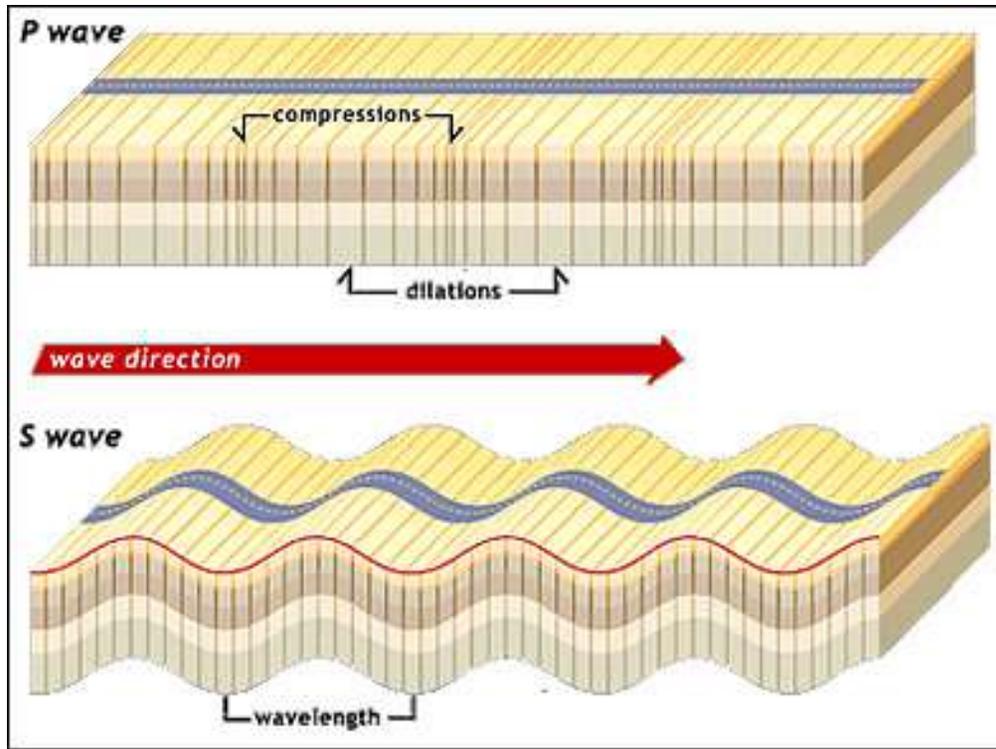


longitudinal vertical wave



= sound wave in solid.

Can also have transverse waves in solids: e.g. S waves in earthquakes



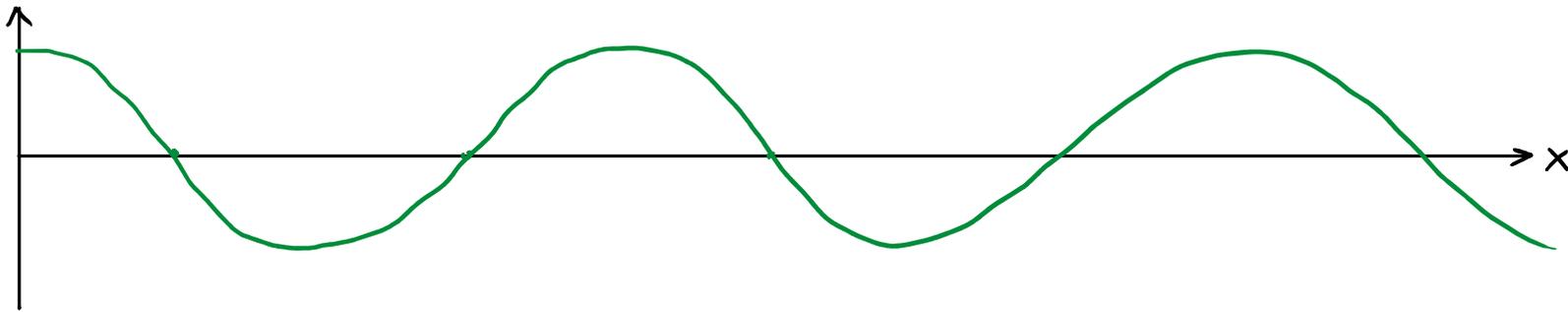
longitudinal
faster "primary"

transverse
slower "secondary"

also: surface waves

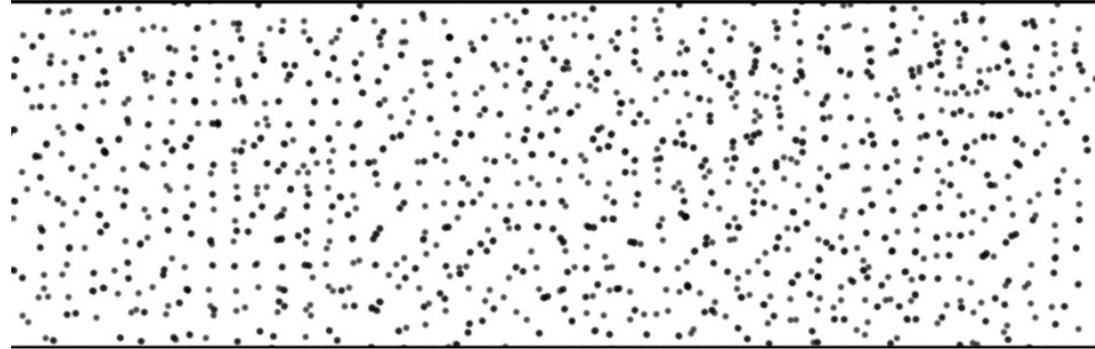
from www.sms-tsunami-warning.com

Discussion question:

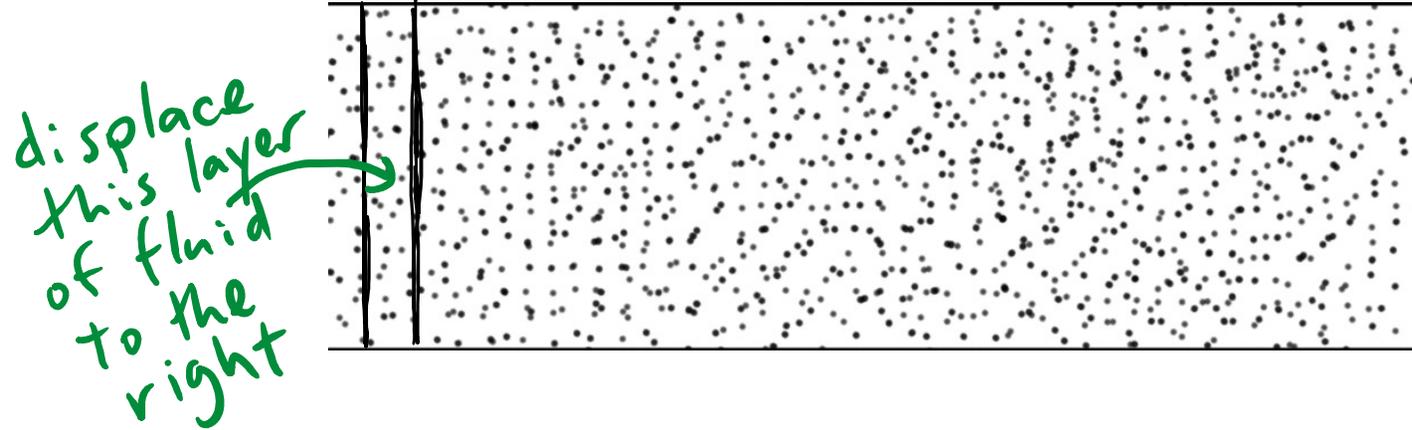


What is "waving" in a sound wave? What does the vertical axis represent if this describes a sound wave at some time?

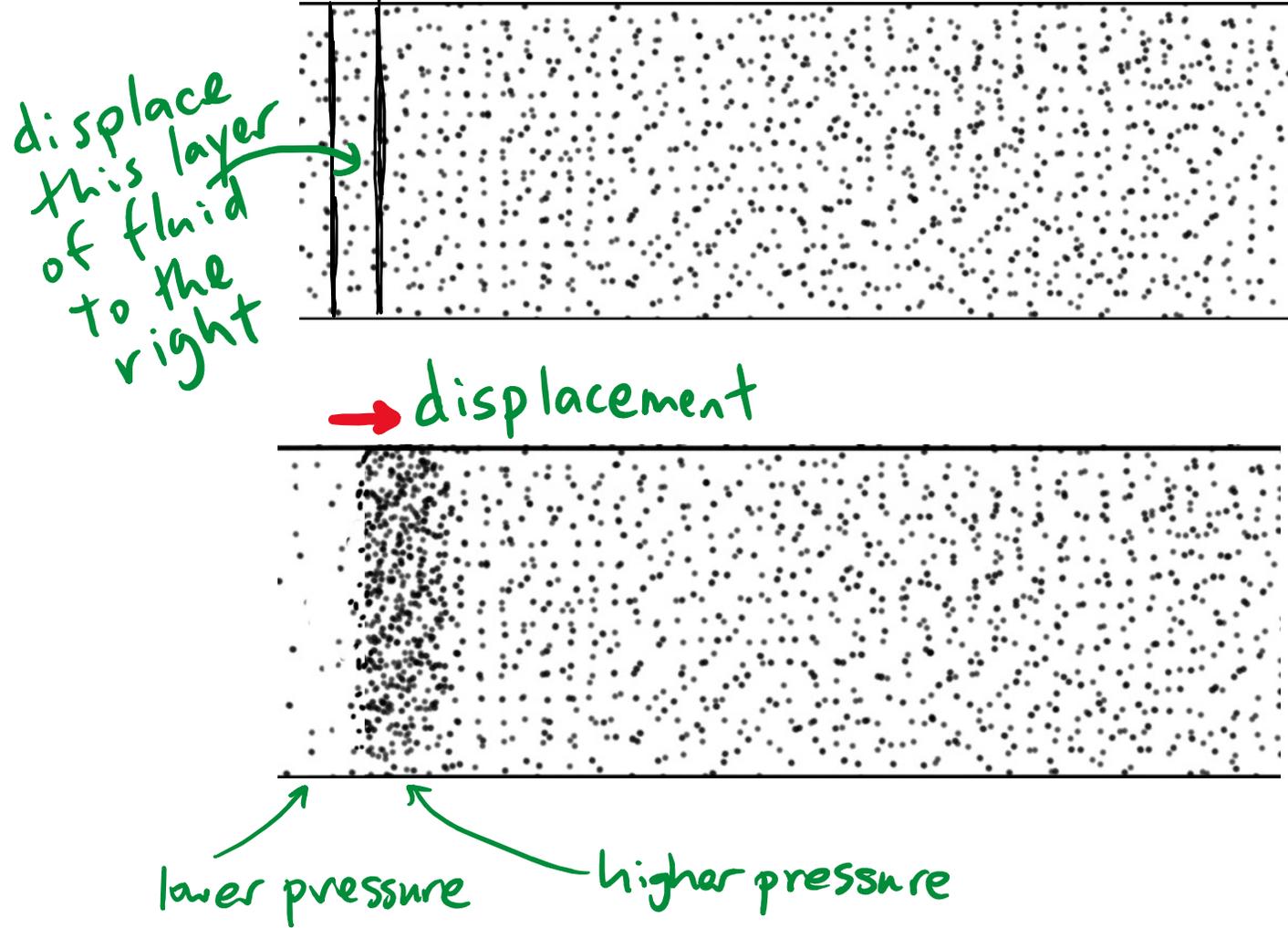
Fluid in equilibrium: uniform density/pressure



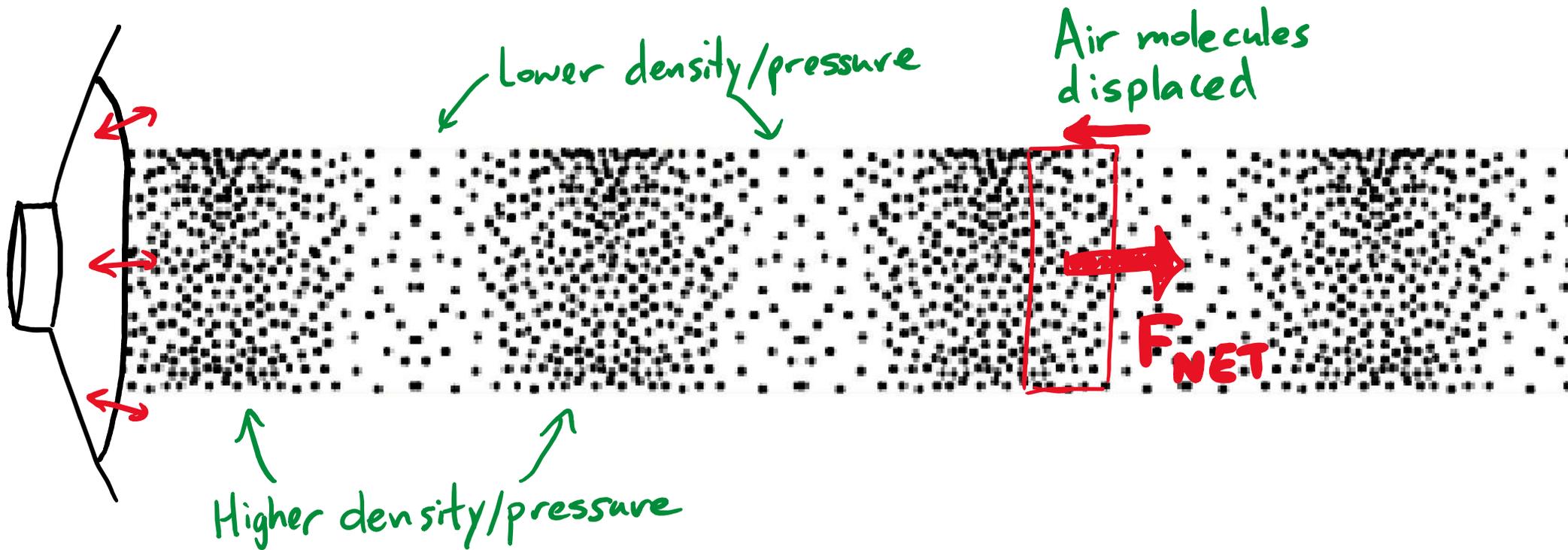
Fluid in equilibrium: uniform density/pressure



Fluid in equilibrium: uniform density/pressure



Sound in a fluid: longitudinal waves



<https://www.youtube.com/watch?v=px3oVGXr4mo&t=1m46s>