Chapter 6: Space & Depth Perception

Lec 11

Jonathan Pillow, Sensation & Perception (PSY 345 / NEU 325)
Princeton University, Spring 2019

normal trichromat

protanope

deuteranope

tritanope

monochromat

scotopic light levels

Color Vision in Animals

- most mammals (dogs, cats, horses): dichromats
- old world primates (including us): trichromats
- marine mammals: monochromats
- bees: trichromats (but lack "L" cone; ultraviolet instead)
- some birds, reptiles & amphibians: tetrachromats!

Color vision doesn't work at low light levels!

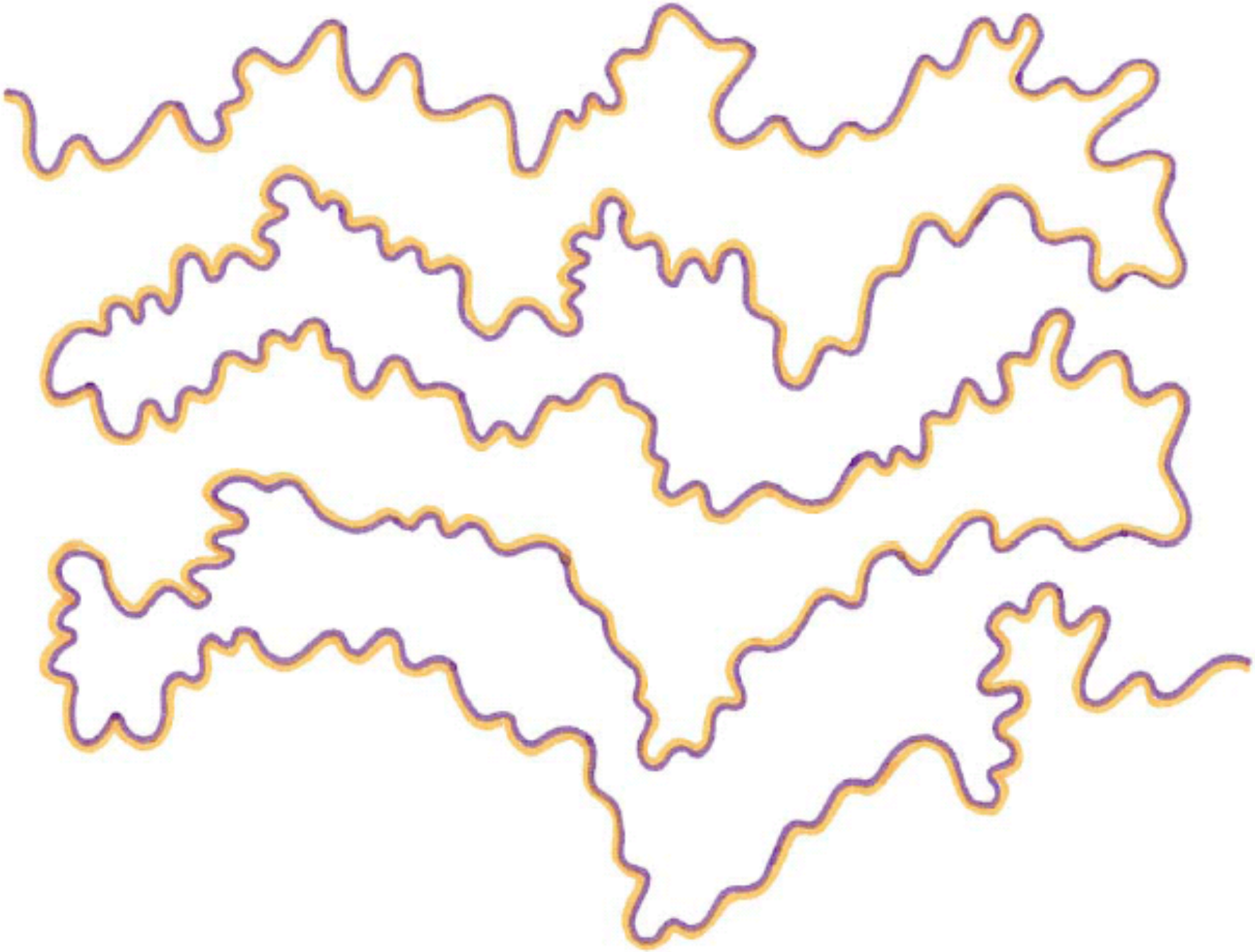
Two Regimes of Light Sensitivity

- **Photopic**: cones active, rods “saturated”
  - Sunlight and bright indoor lighting

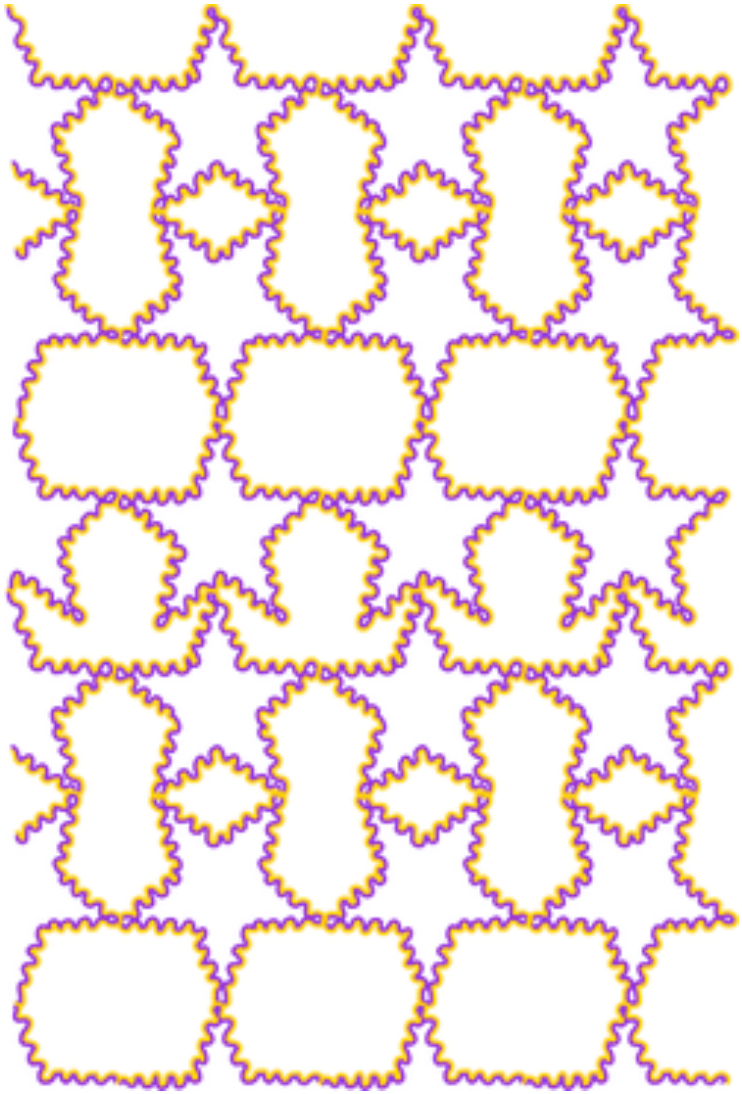
- **Scotopic**: rod vision, too dim to stimulate cones
  - Moonlight and extremely dim indoor lighting

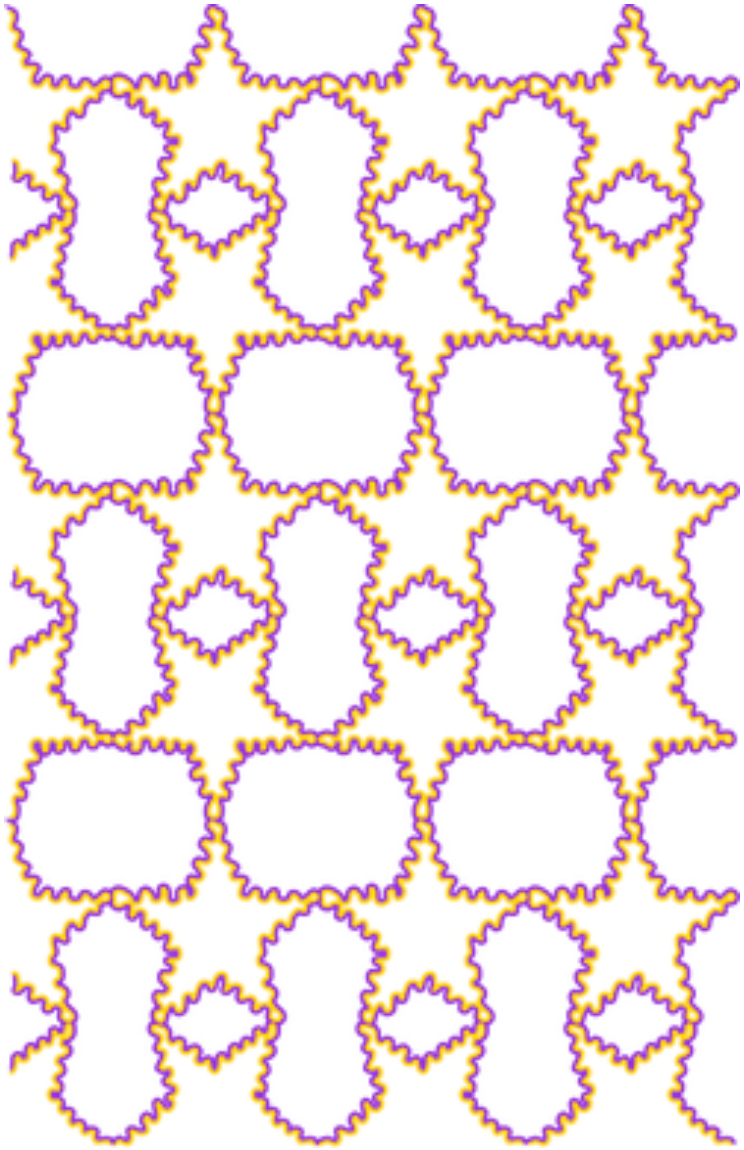
Other (unexplained) color phenomenon:

- watercolor illusion
- neon color spreading
- motion-induced color: *Benham's top*

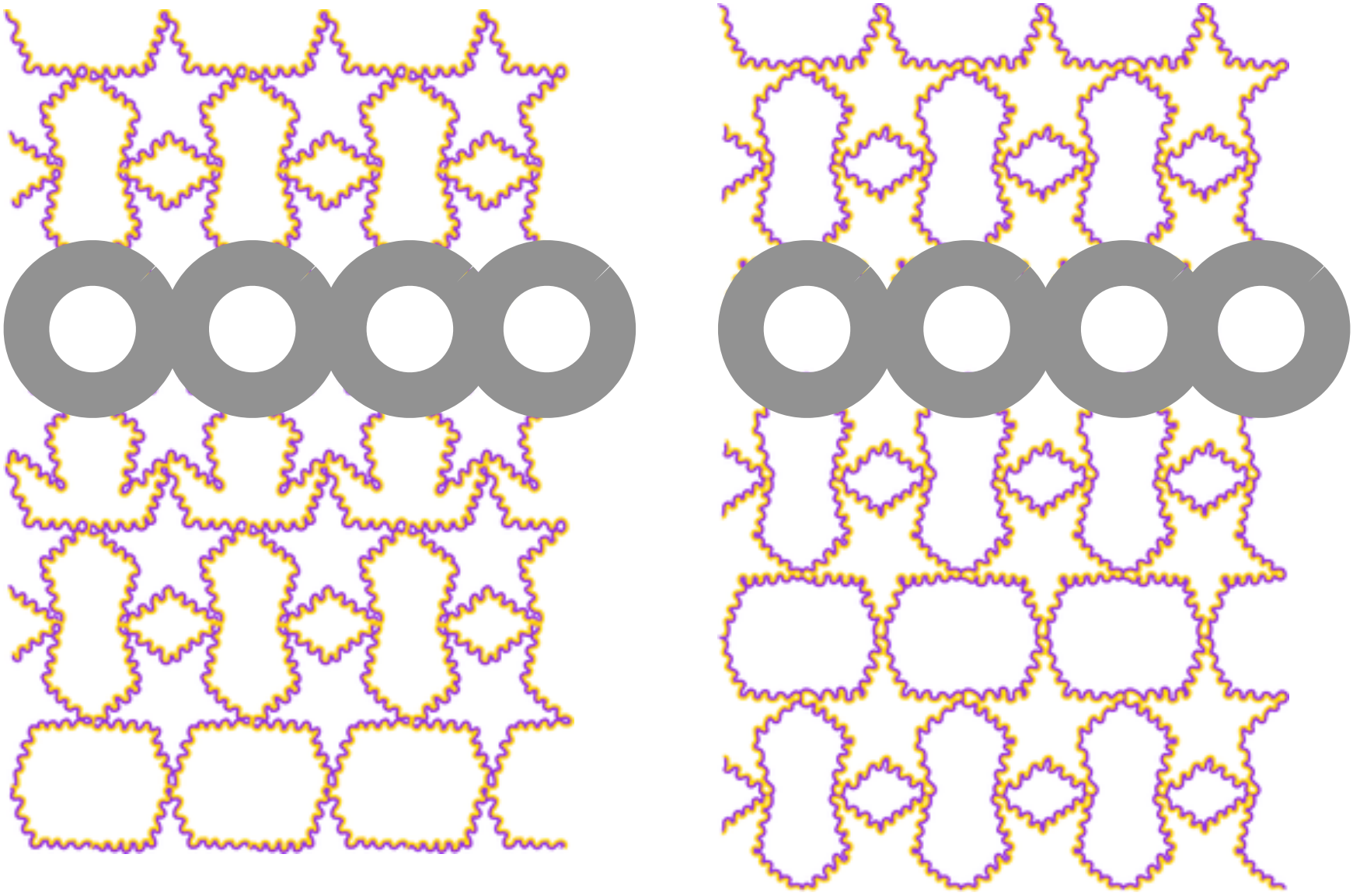


Watercolor illusion

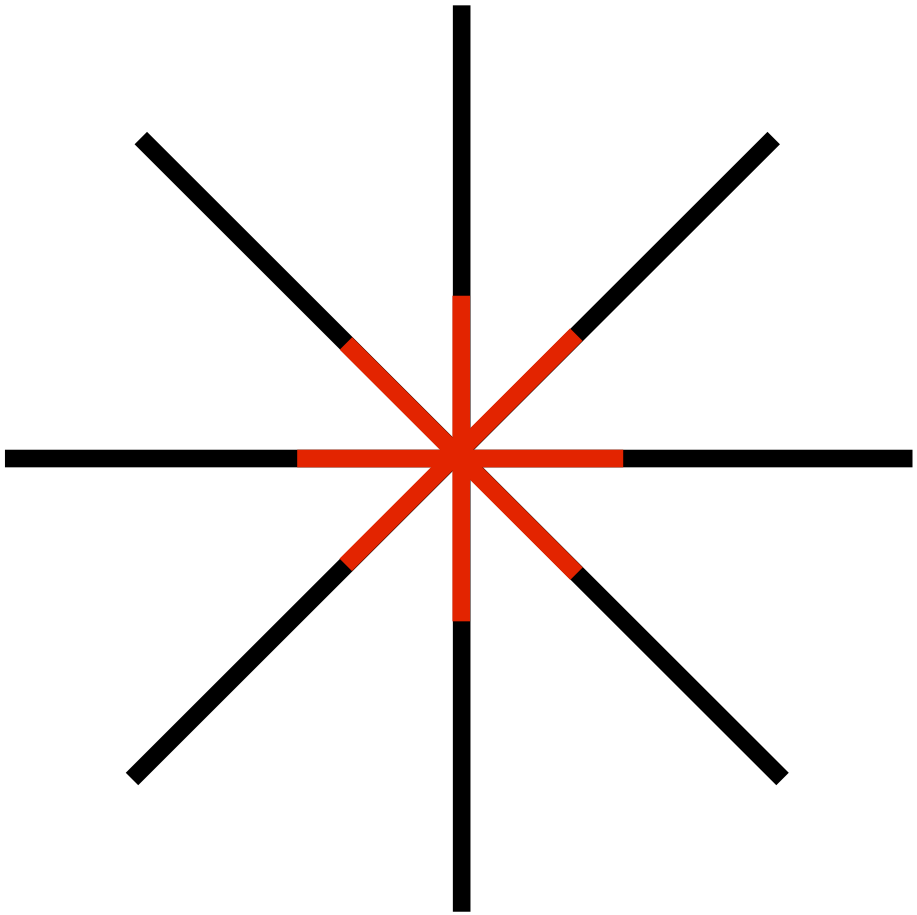




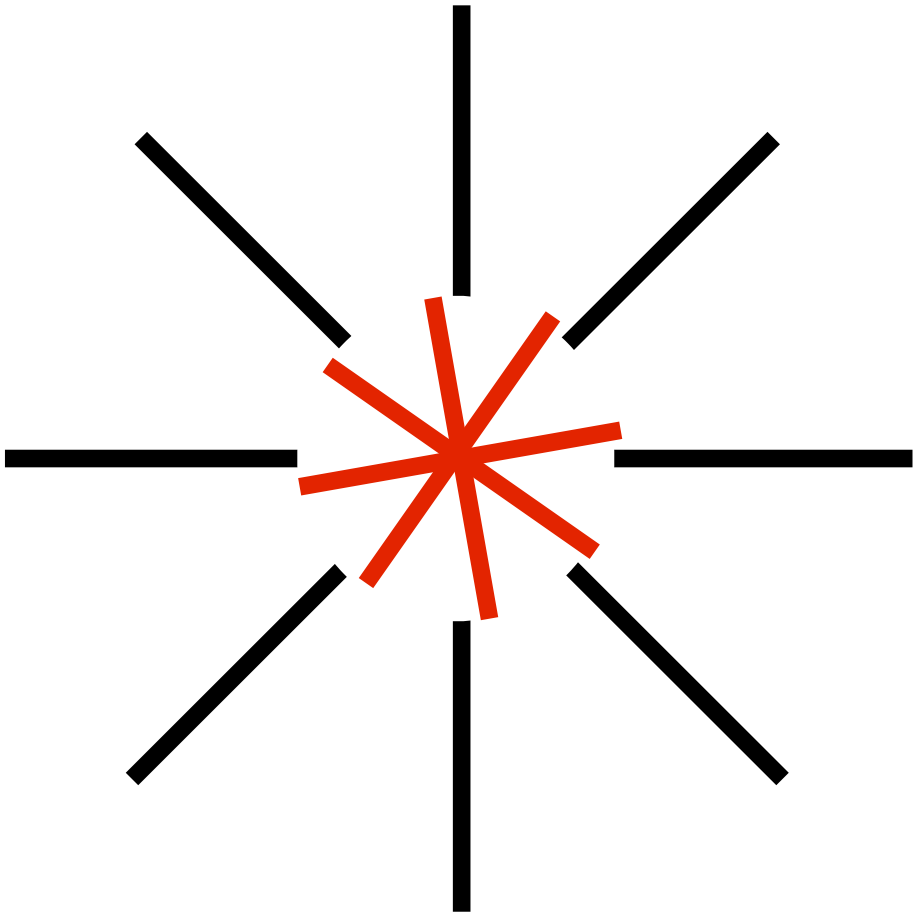
Watercolor illusion



Watercolor illusion



Neon Color-Spreading



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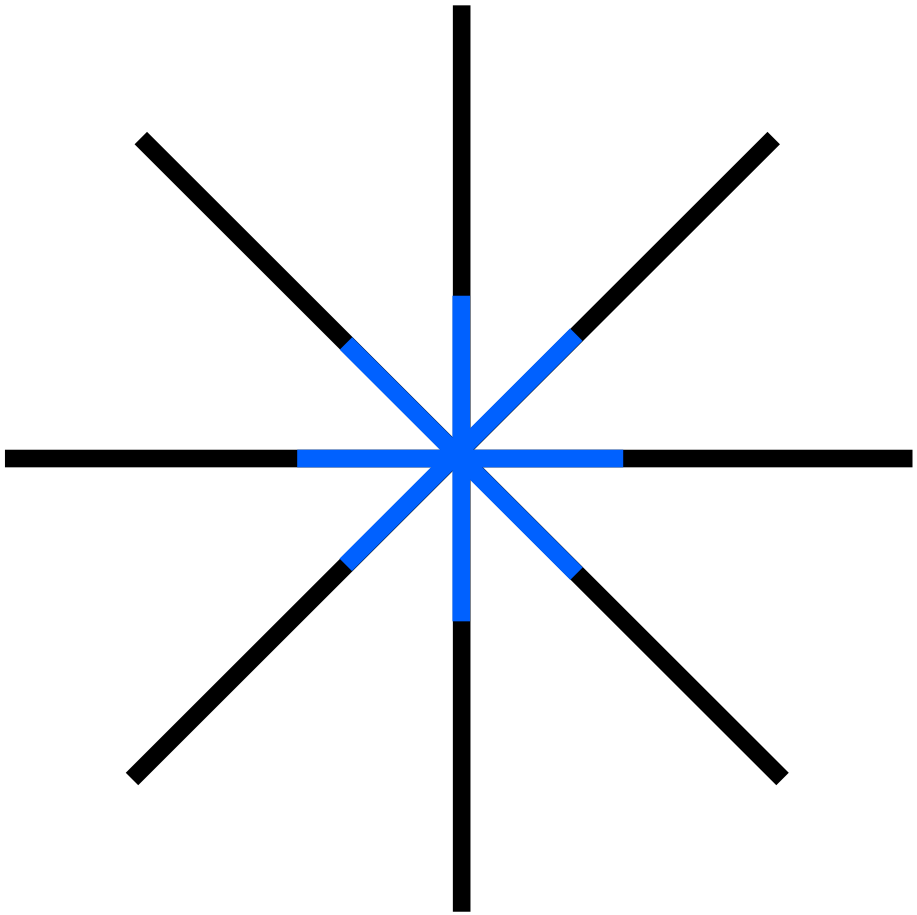
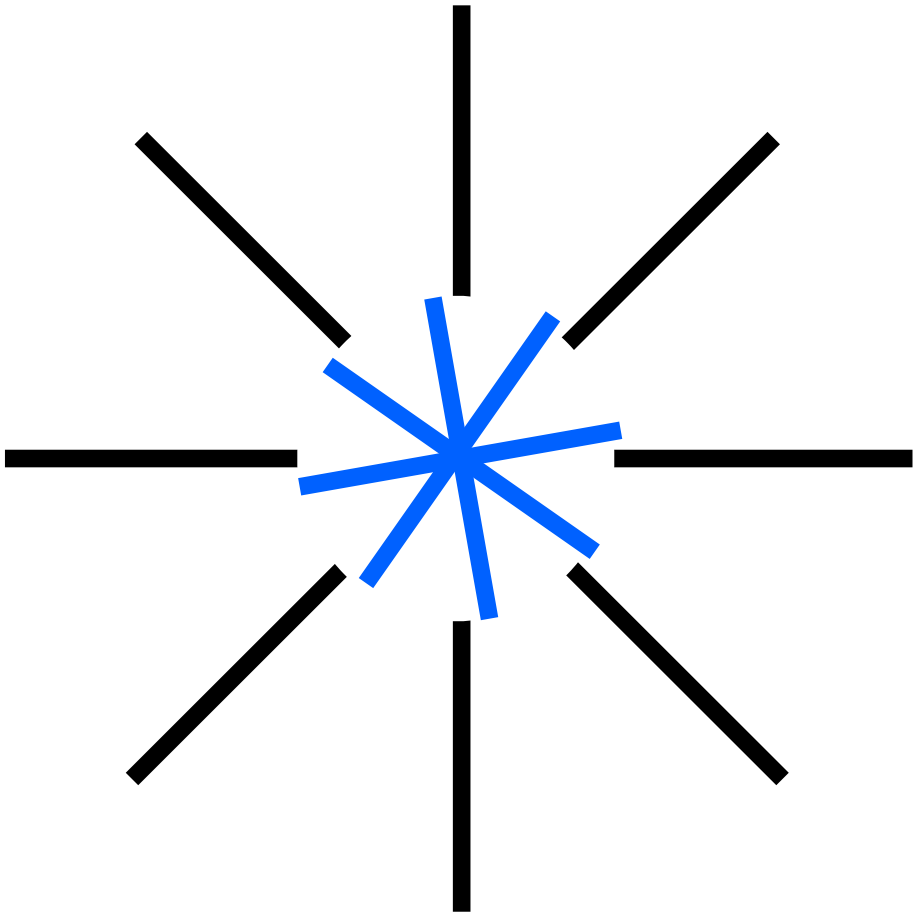


Neon Color-Spreading



Neon Color-Spreading

Benham's top:

motion-induced color perception

http://www.michaelbach.de/ot/col_benham/index.html

- not well-understood; believed to arise from different color-opponent retinal ganglion cells having different temporal latencies.
- the flickering pattern stimulates the different color channels differently (although this is admittedly a crude theory)

Summary: color vision

- trichromacy: 3-dimensional color vision (vs. hyper-spectral cameras!)
- metamers
- color-matching experiment
- color space (RGB, HSB)
- non-spectral hues
- opponent channels, negatives & after-images
- color-opponent channels
- surface reflectance functions
- color constancy
- photopic / scotopic light levels
- additive / subtractive color mixing
- color blindness

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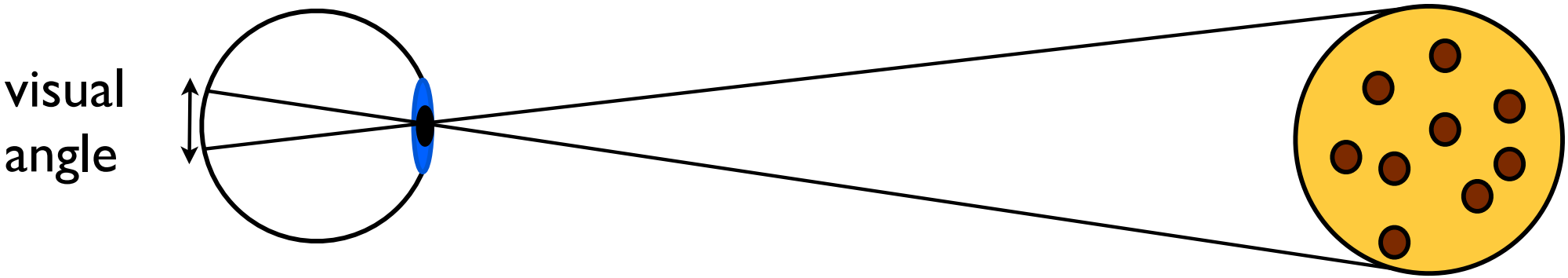
Depth Perception: figuring out how far away things are

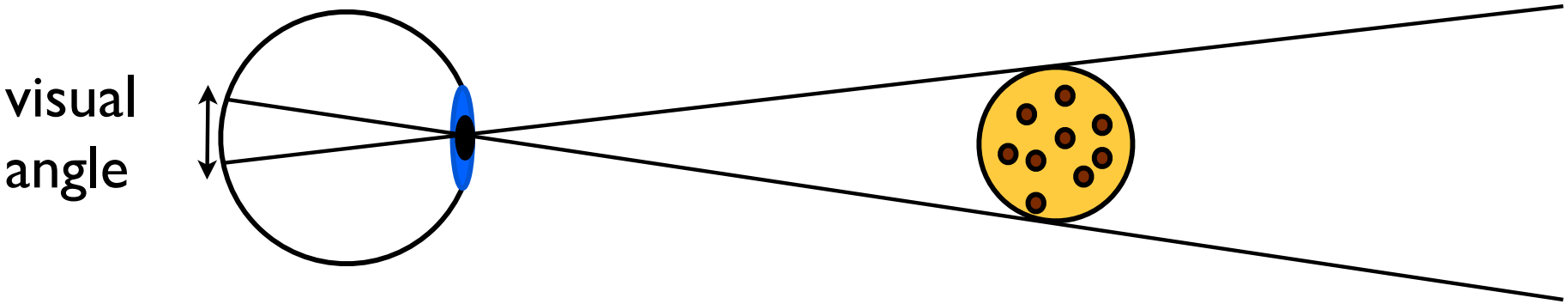
Problem: fundamental ambiguity between size and distance.



Large pizza, far away?

Depth Perception: figuring out how far away things are

Problem: fundamental ambiguity between size and distance.



… or small pizza, close by?

- Retinal signal is the same in both cases
- Have to use a variety of "cues" to decide distance to things

Study: People Far Away From You Not Actually Smaller

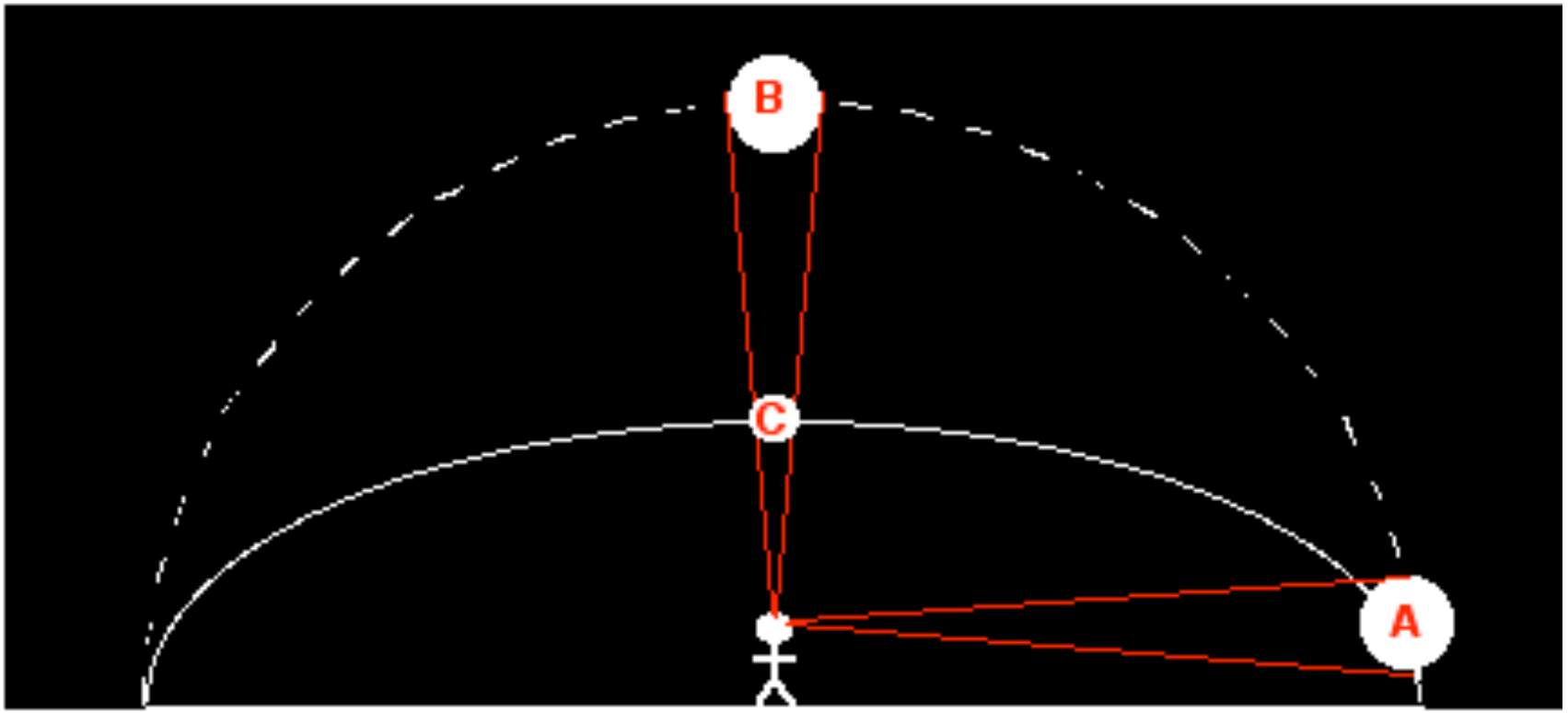
PRINCETON, NJ—According to a groundbreaking new study published Thursday in *The Journal Of Natural And Applied Sciences*, people who are far away from you are actually not, as once thought, physically smaller than you.

The five-year study, conducted by researchers at Princeton University, has shattered traditionally accepted theories that people standing some distance away from you are very small, and people close-by are very big.

http://www.theonion.com/articles/study-people-far-away-from-you-not-actually-smalle,33594/?ref=auto

Moon illusion: moon looks bigger at horizon than at its zenith

One explanation:



- moon subtends same visual angle at horizon as at zenith (0.52 deg = a thumb's width an arm's length)
- if sky overhead perceived as being closer than sky at horizon, you'd infer that the moon overhead must be smaller

Motivating questions:

1. Why do we have two eyes?

2. How does the brain combine information from the two eyes to get a percept of depth?

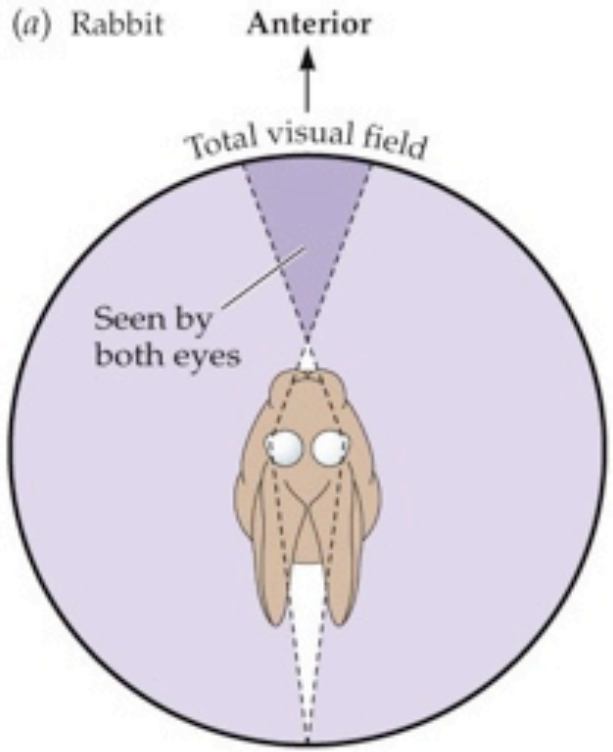
3. How can information from just one eye provide a percept of depth?

Why have two eyes?

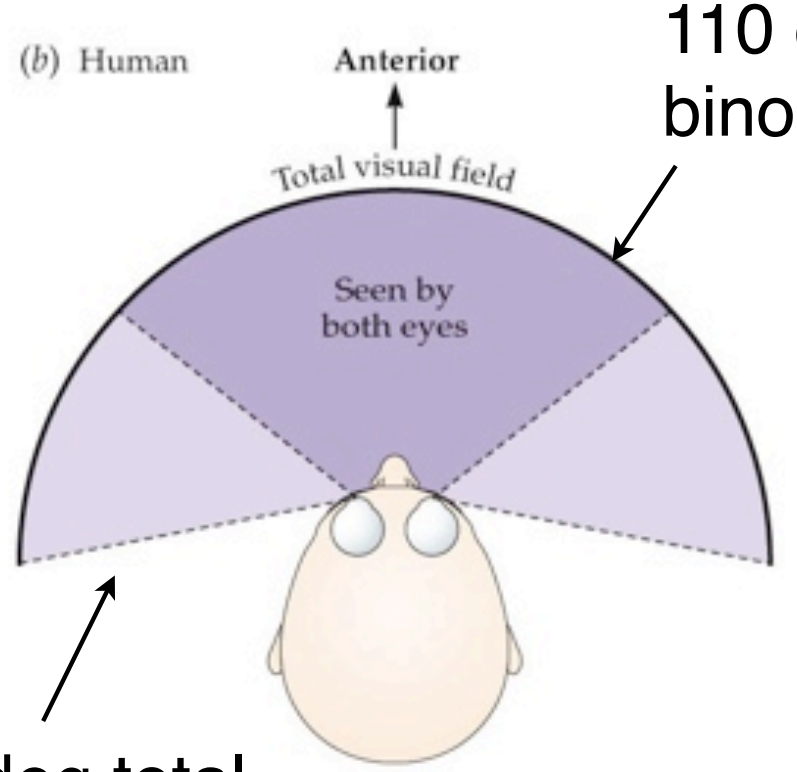
1. Binocular summation: pool twice as much light.

– (Eye chart is easier to read with both eyes than with one, for example)

2. Increase field of view (prey, more than predators)



360 deg vision!



110 deg binocular

190 deg total

Why have two eyes?

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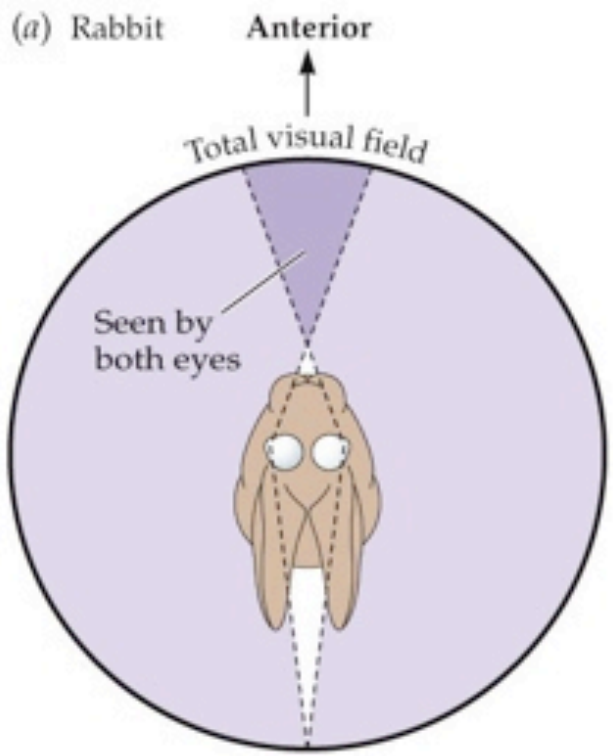
2. Increase field of view (prey, more than predators)



360 deg vision!

"This explains why it is so hard to sneak up on a rabbit."

Why have two eyes?

1. Binocular summation: pool twice as much light.

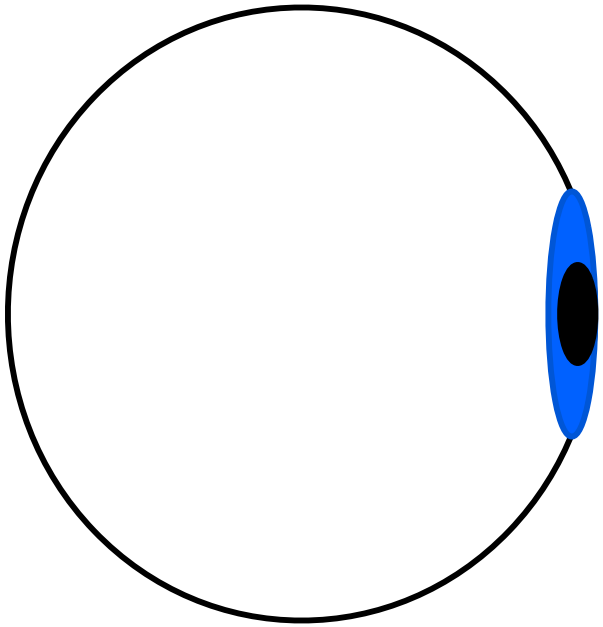
– (Eye chart is easier to read with both eyes than with one, for example)

2. Increase field of view (prey, more than predators)

3. Depth perception: can tell how far away things are by comparing the images captured by two eyes

But first…

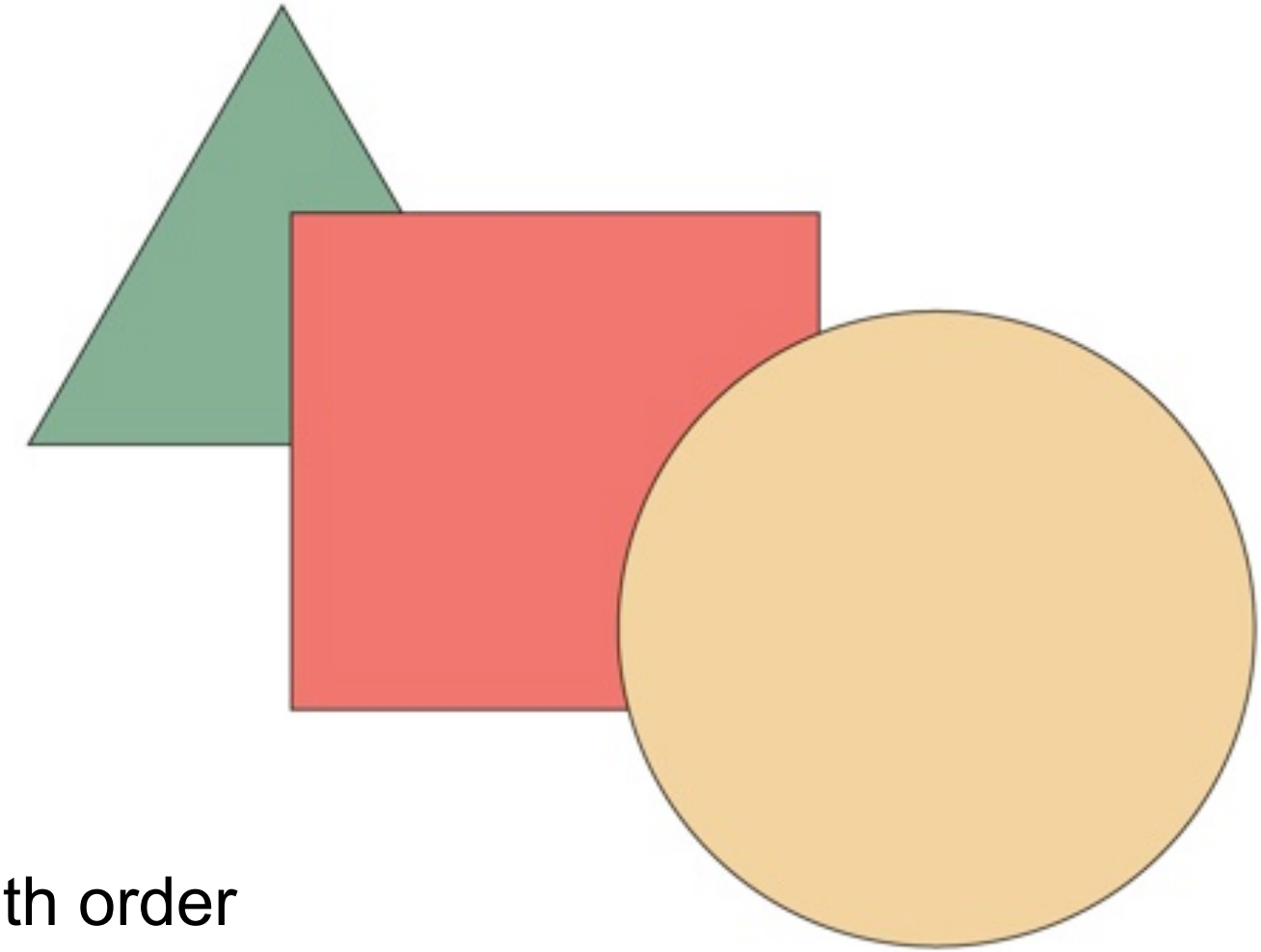
- **Monocular depth cue**: cue that is available even when the world is viewed with one eye alone



Surprisingly, you can get a lot of info about depth from a single eye!

Monocular Cues to Three-Dimensional Space

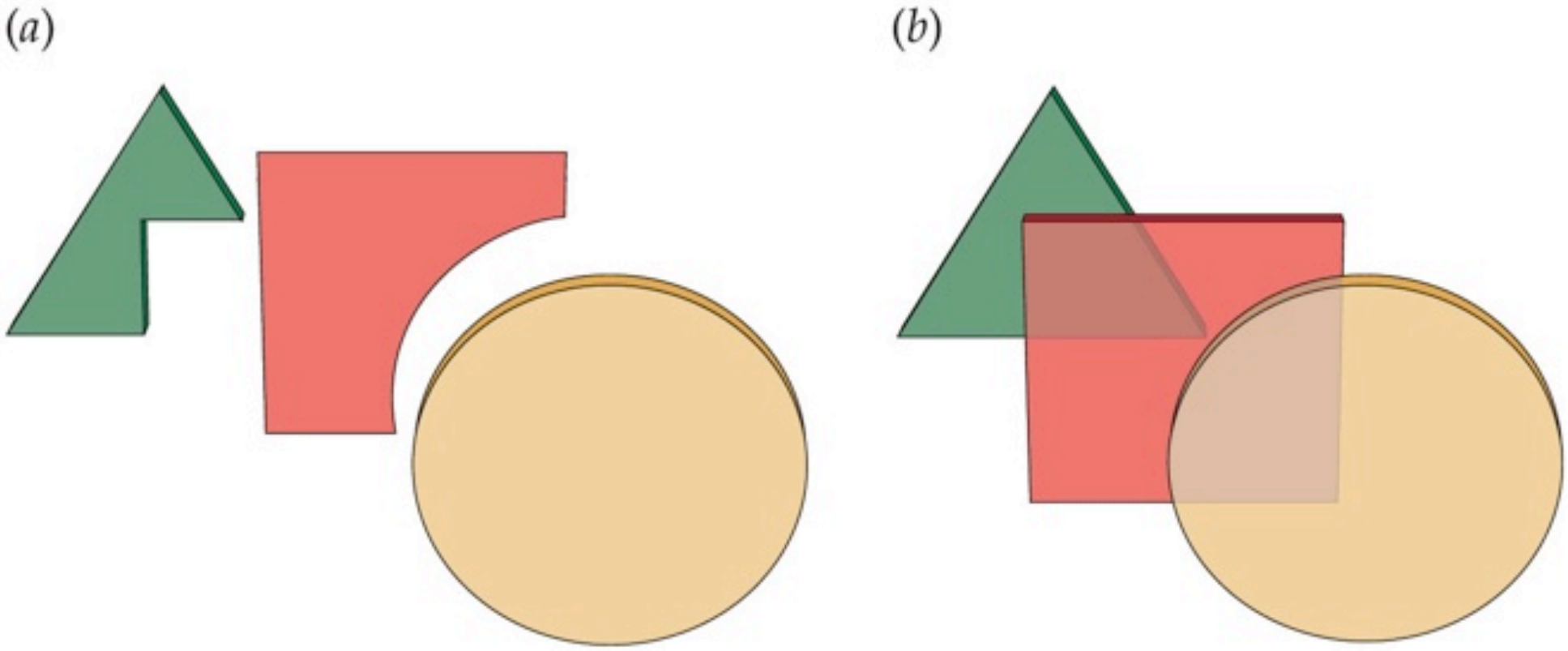
Occlusion: one object obstructs the view of part of another object



- cue to relative depth order
- **non-metrical depth cue** - provides order information only, no measure of distance in depth

Monocular Cues to Three-Dimensional Space

Occlusion: one object obstructs the view of part of another object

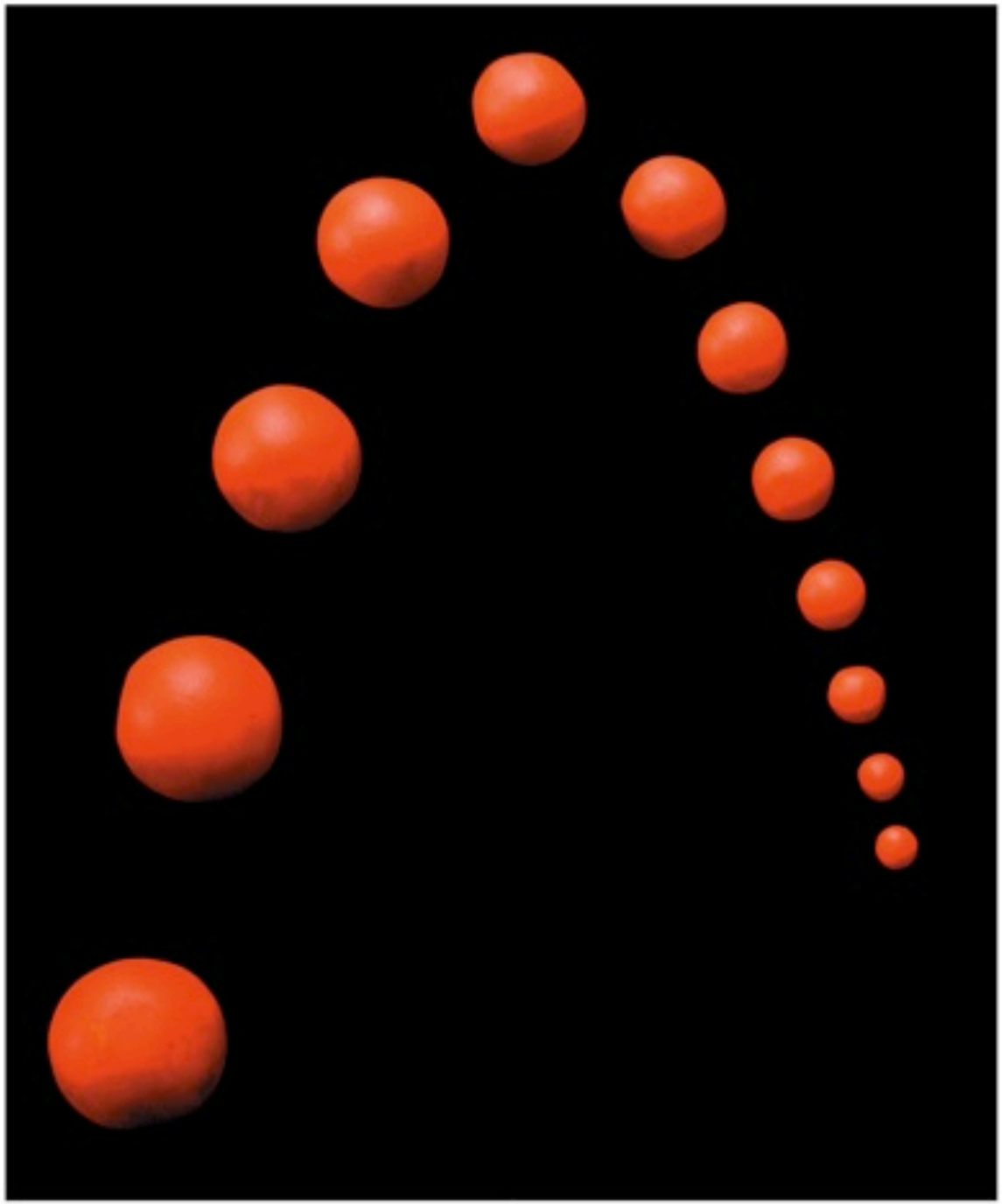


could be accidental view of this

more likely scene

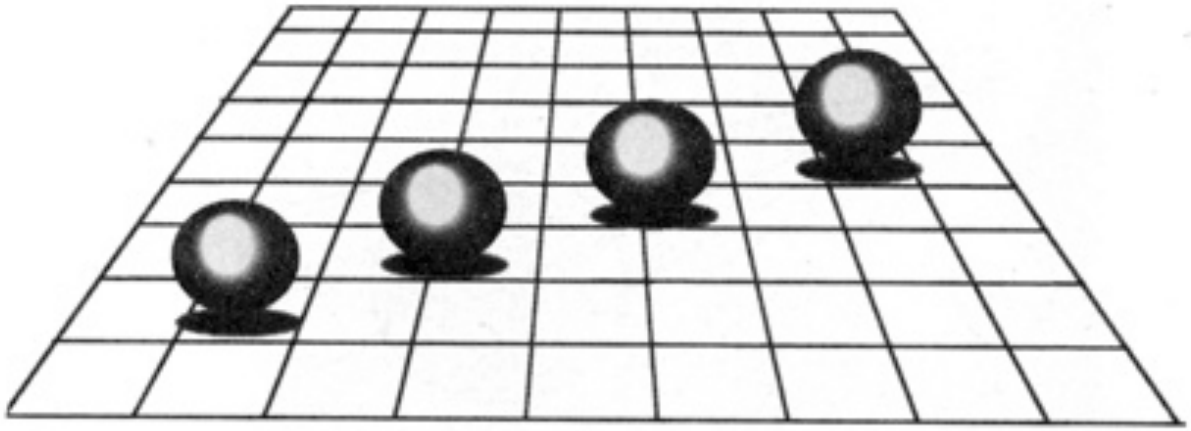
Relative Size

Metrical depth cue:
A depth cue that provides quantitative information about distance in the third dimension

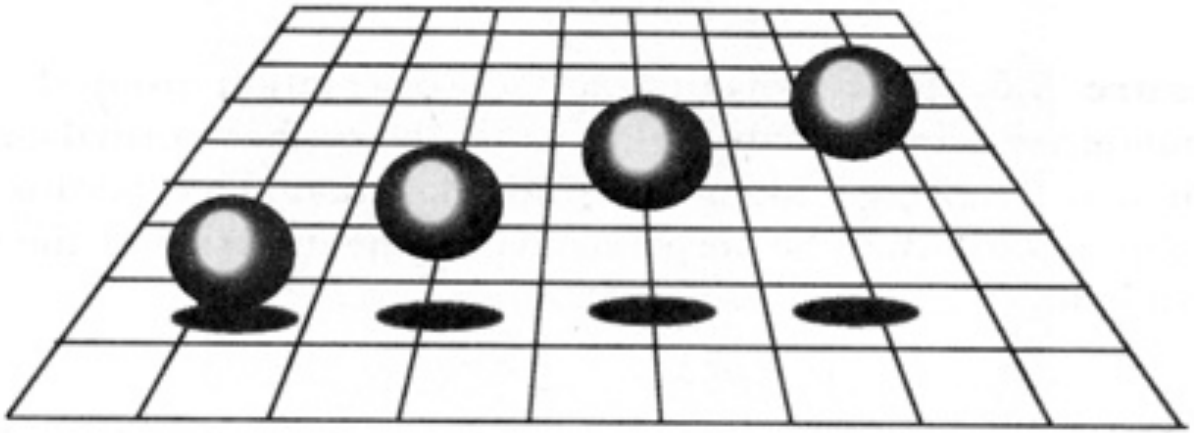


If all beads are all the same size, then a bead twice as small is twice as far away

Depth from Shadows

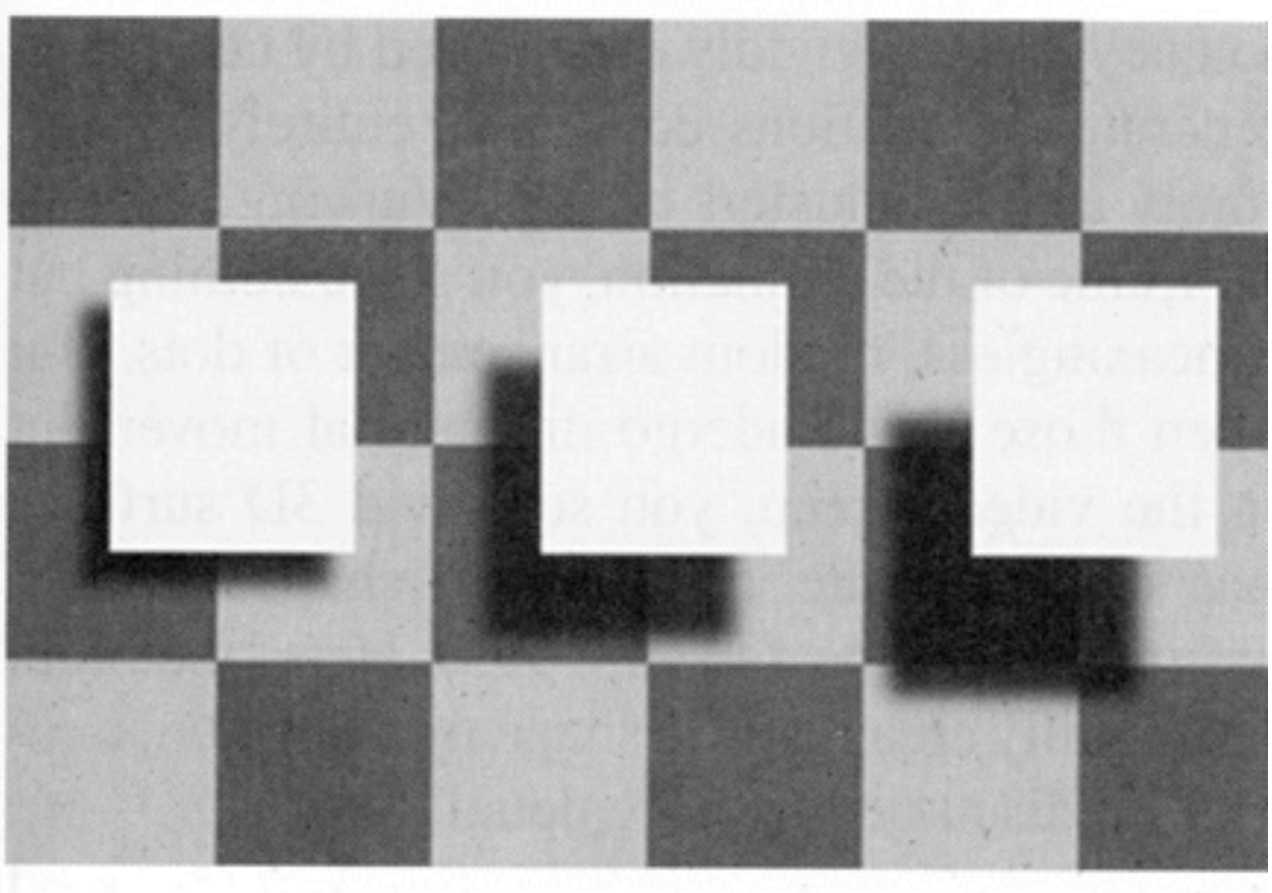


A

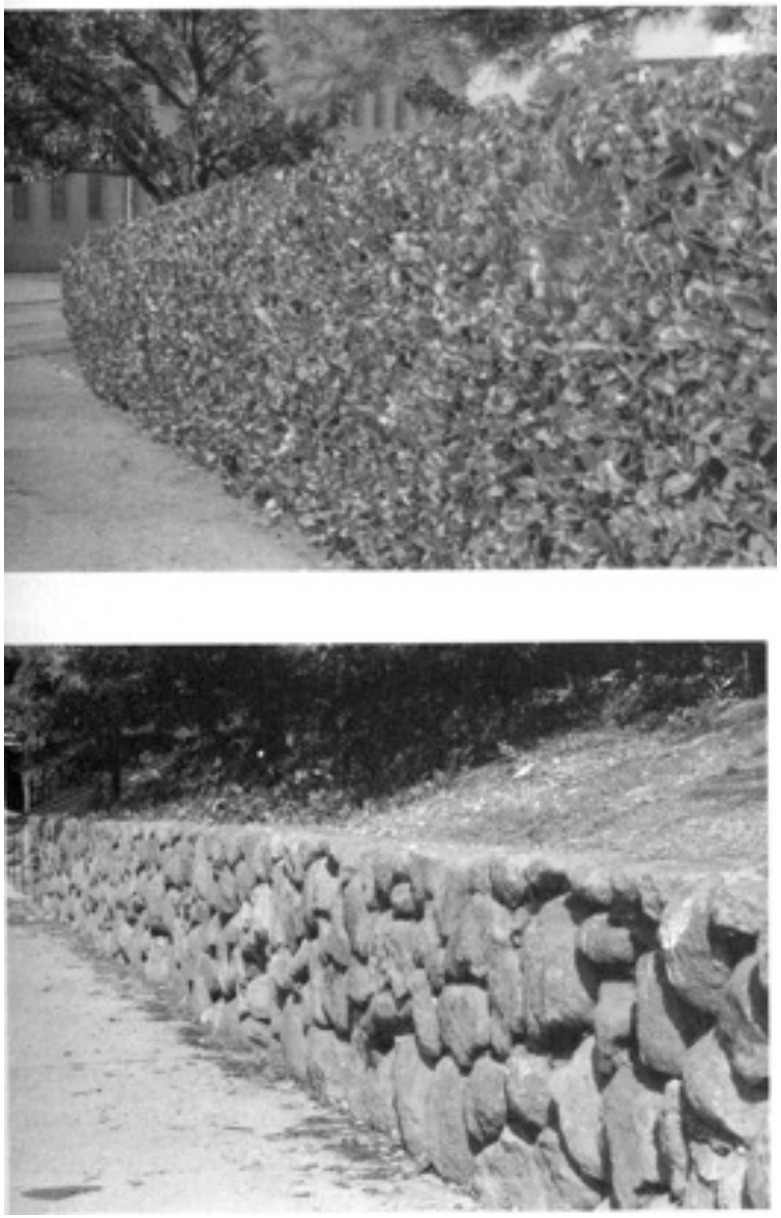


B

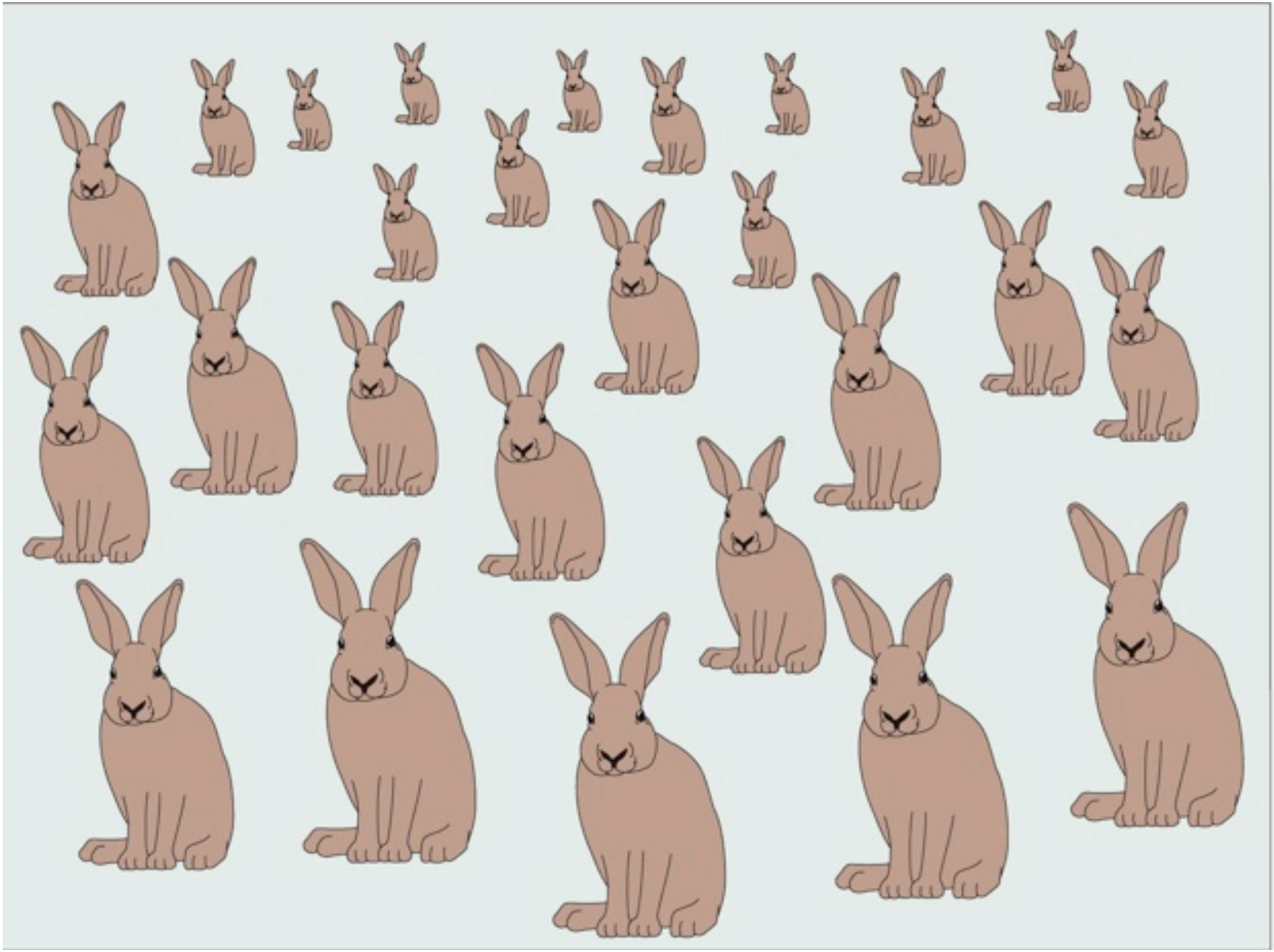
Depth from Shadows



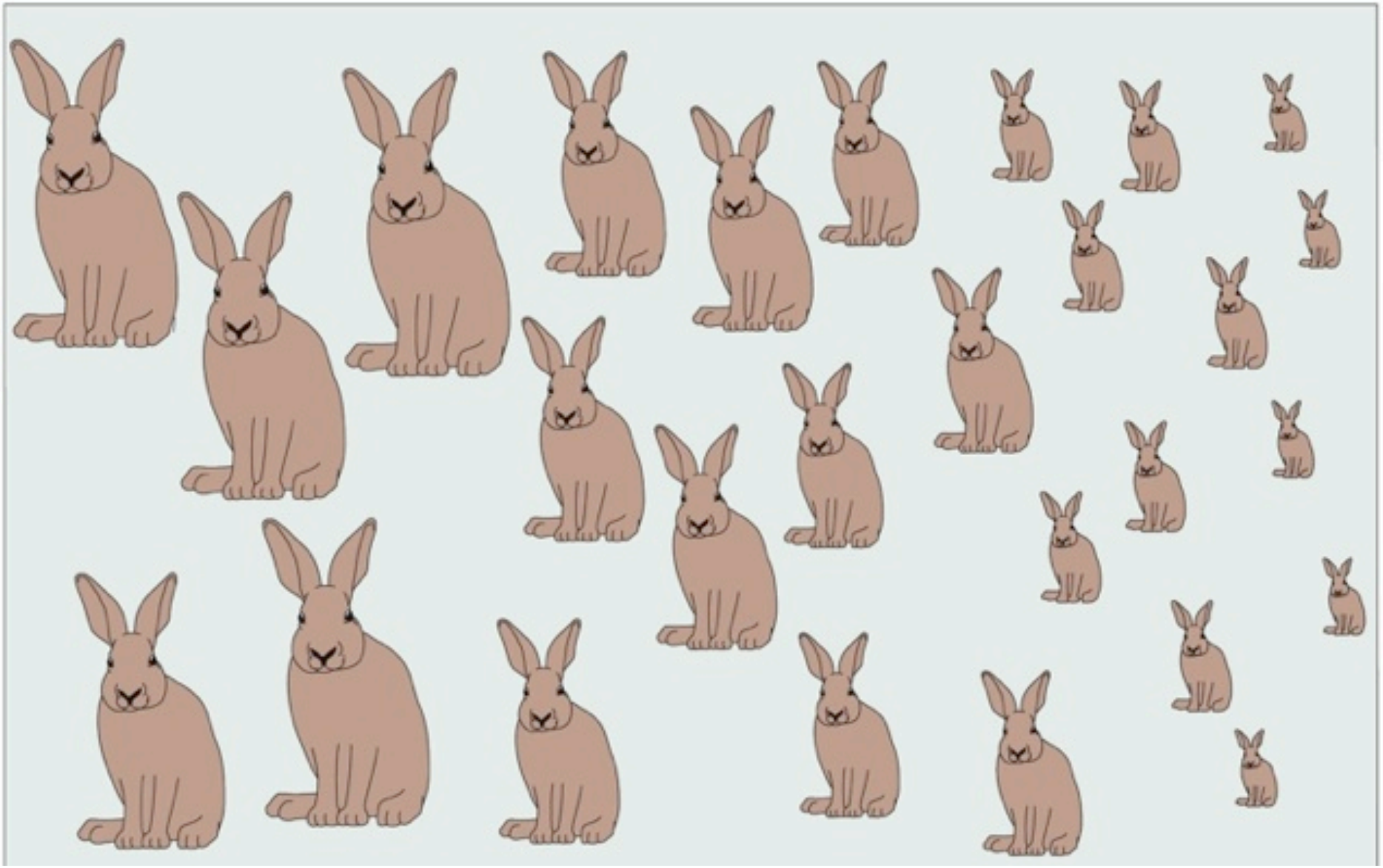
Texture Gradient



Size, Texture Gradient, & Height in Plane

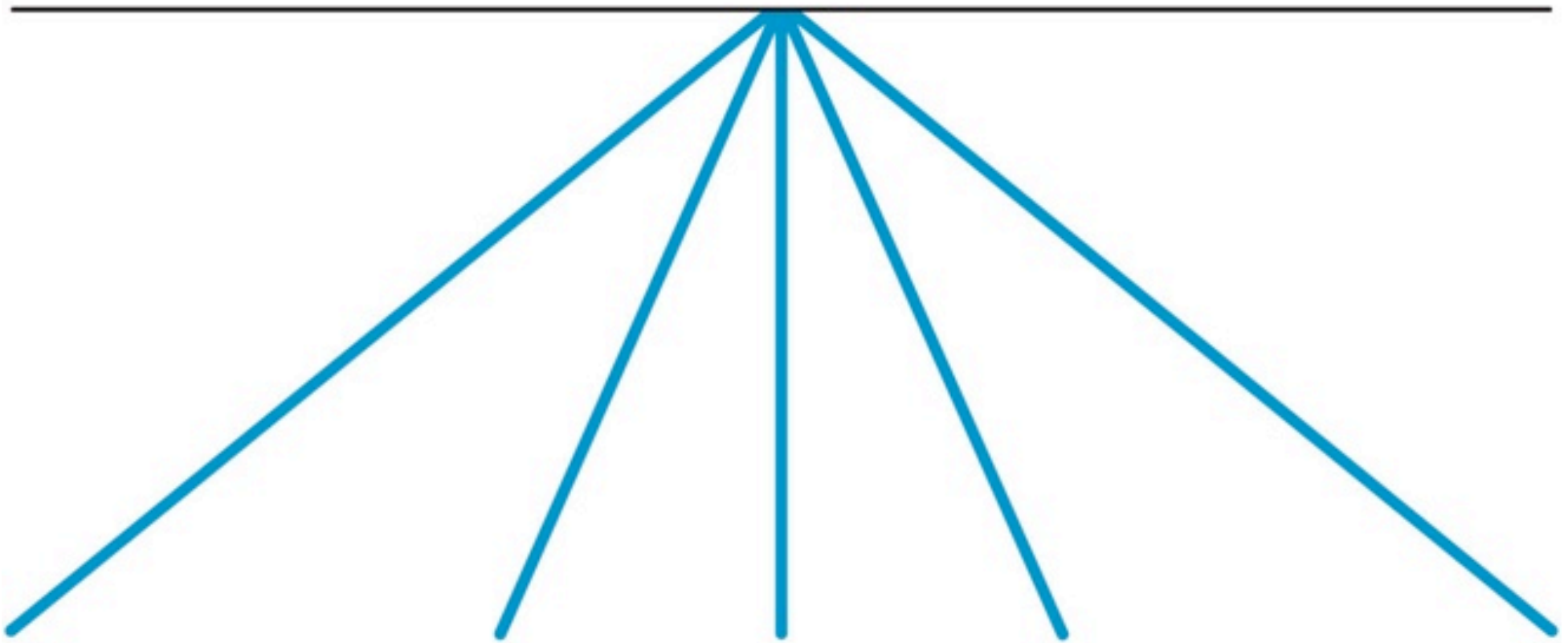


Size & Texture = less influential if not paired with Height in Plane



Rabbits on a wall?

Linear perspective



- parallel lines converge if moving away in depth
- this is due to *perspective projection*

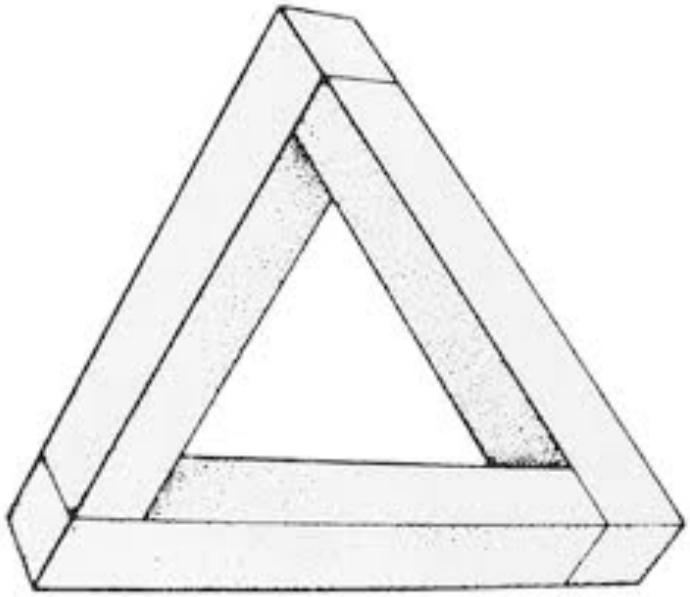
Medieval (pre-renaissance) art

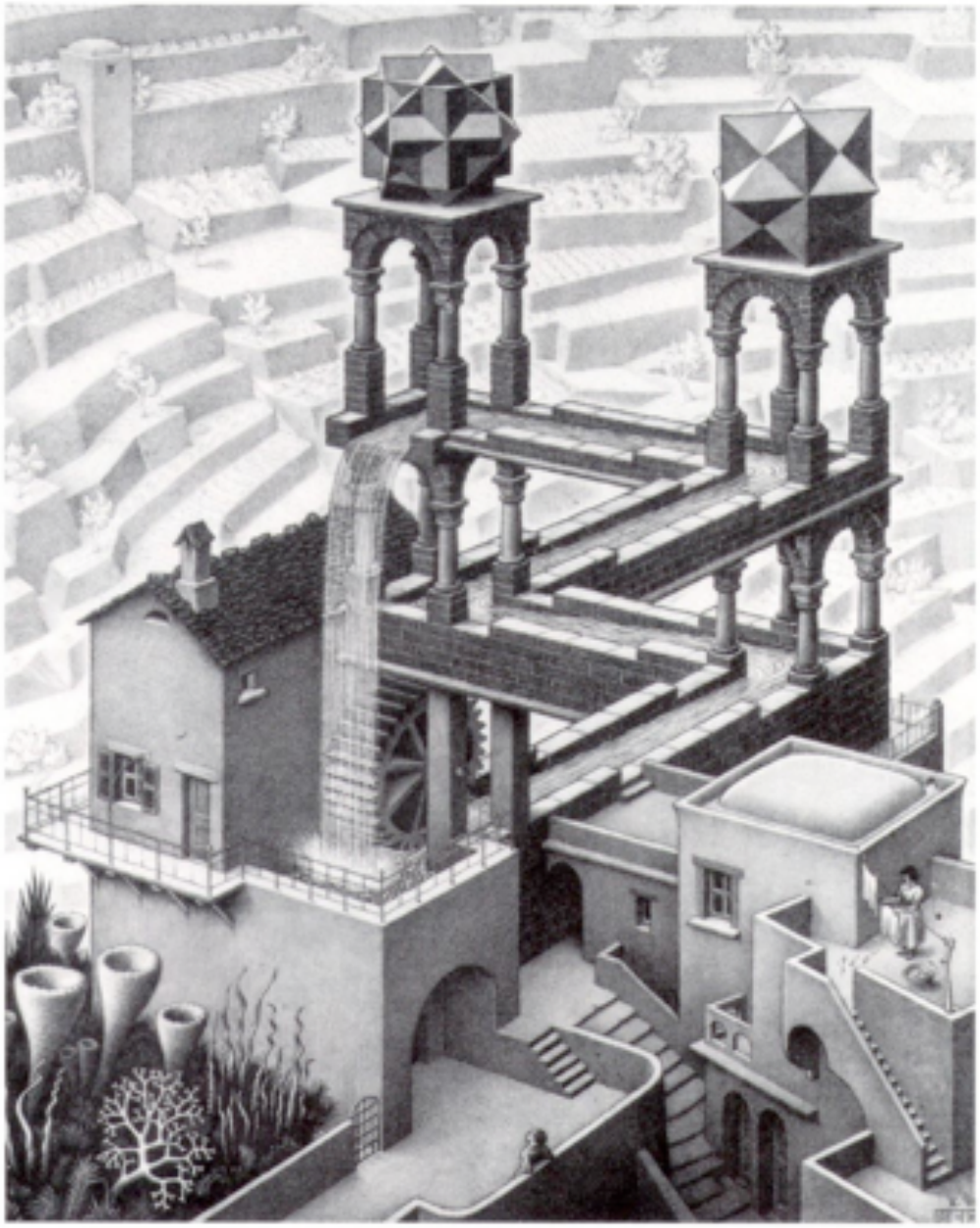
renaissance art

- parallel lines in a single depth plane remain parallel
- other parallel lines converge as they recede in distance

impossible figures: rely on rules of linear perspective

(provide local information about depth that is globally inconsistent)





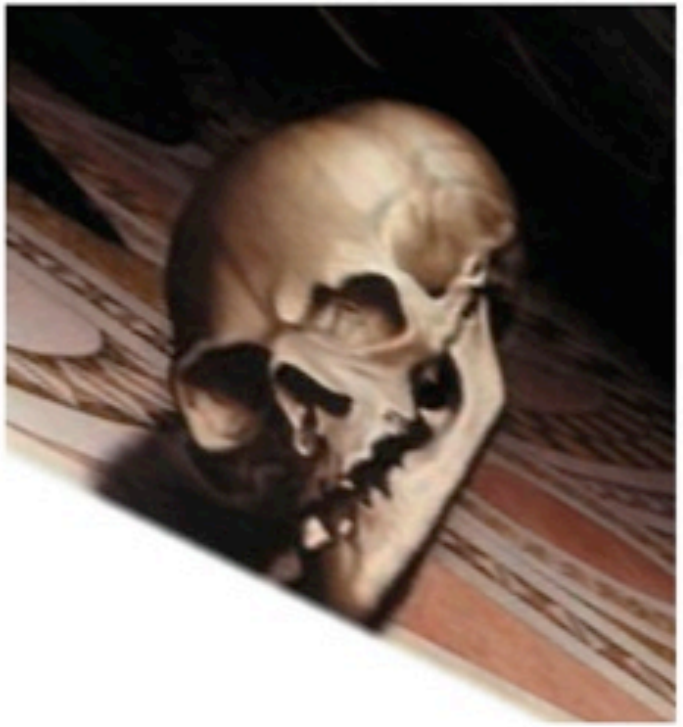
Hans Holbein: The Ambassadors (1533)

anamorphosis

"A distorted projection or perspective requiring the viewer to use special devices or occupy a specific vantage point to reconstitute the image."

Hans Holbein, *The Ambassadors* (1533)

(*b*)



modern day anamorphic art

same idea: use rules of linear perspective to create images that look 3D only from a particular vantage point (i.e., an "accidental" one)

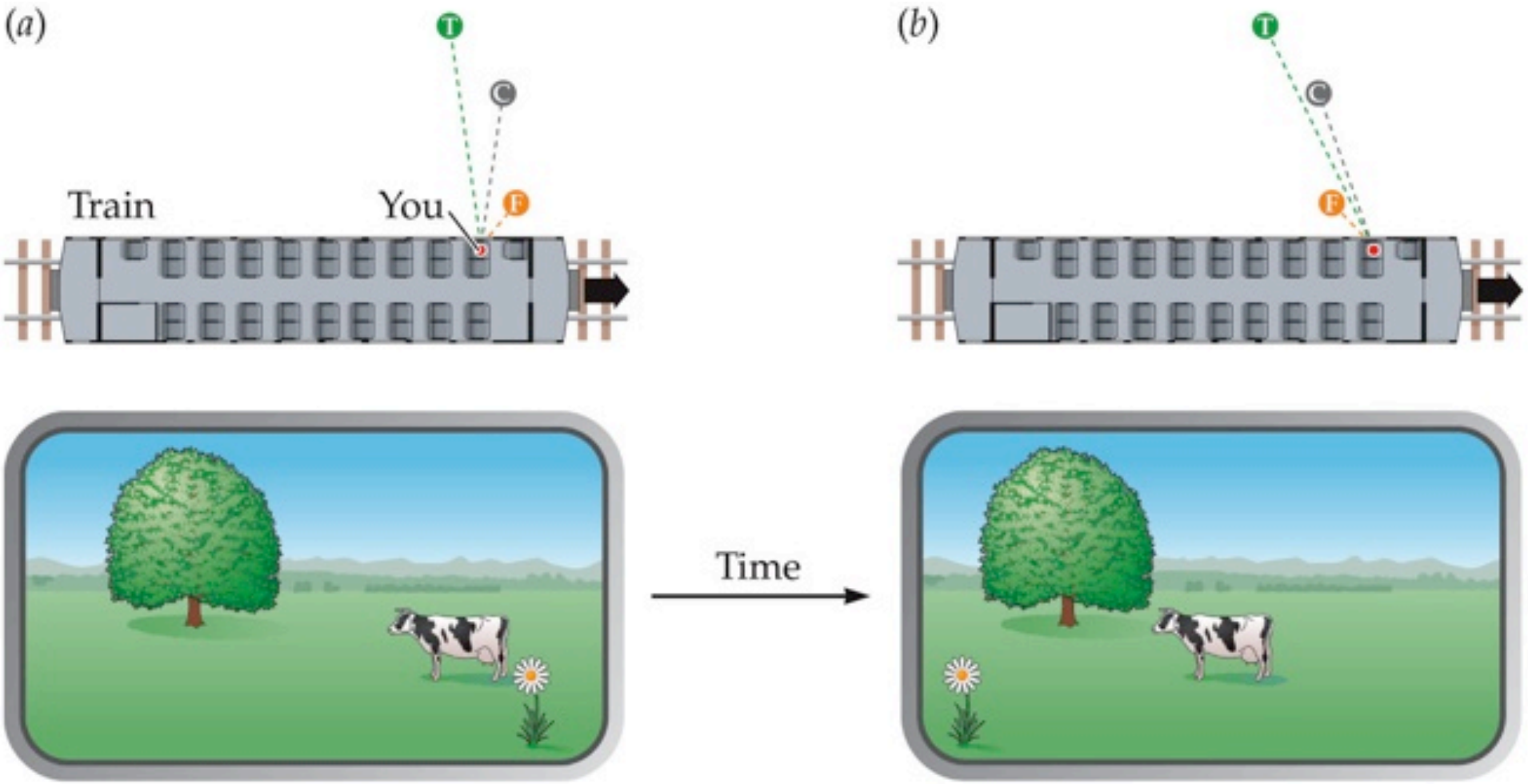
modern day anamorphic art

modern day anamorphic art

István Orosz. “Mirror Anamorphosis”

Motion Parallax

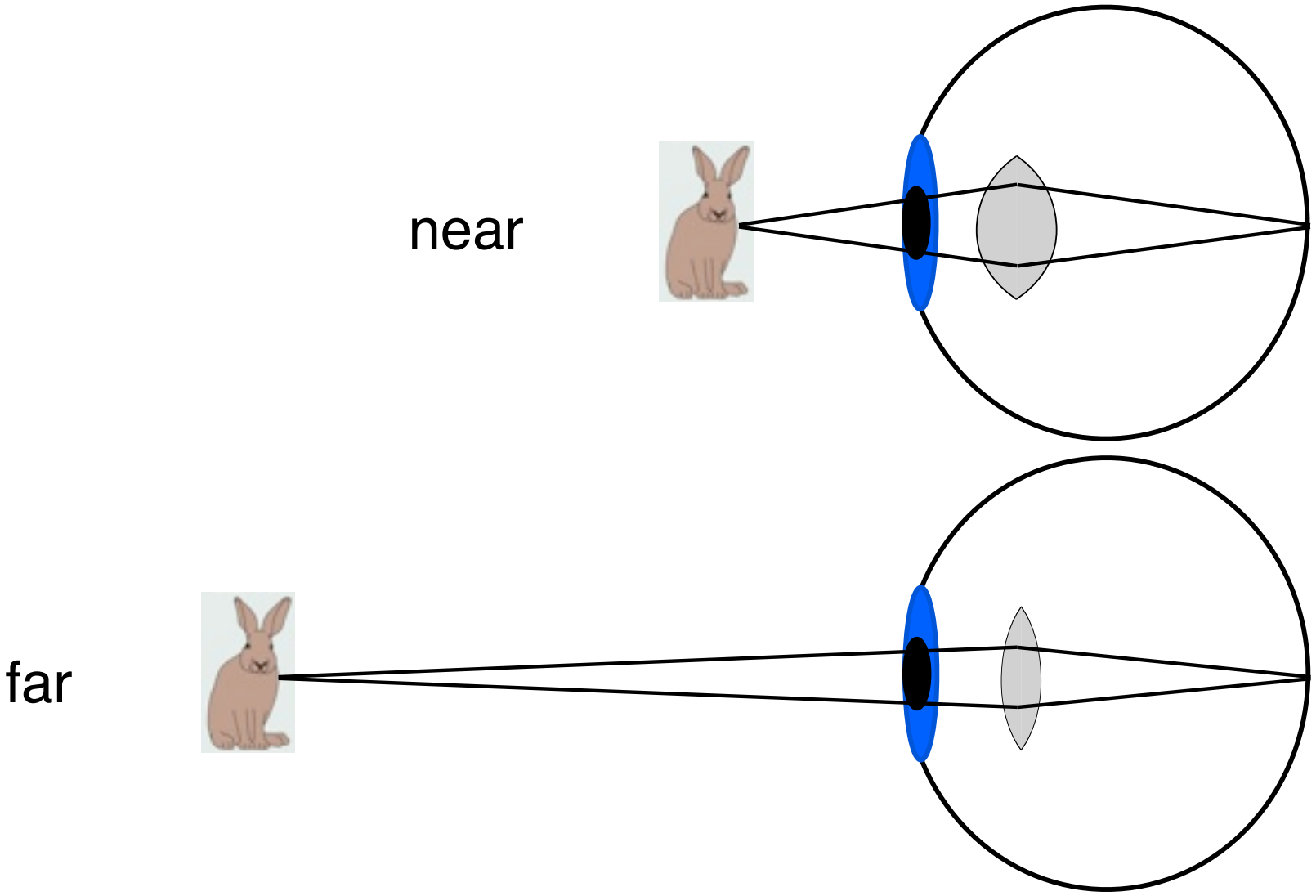
- Nearby objects move by more quickly than far away objects



Depth cues from motion parallax with wii-mote

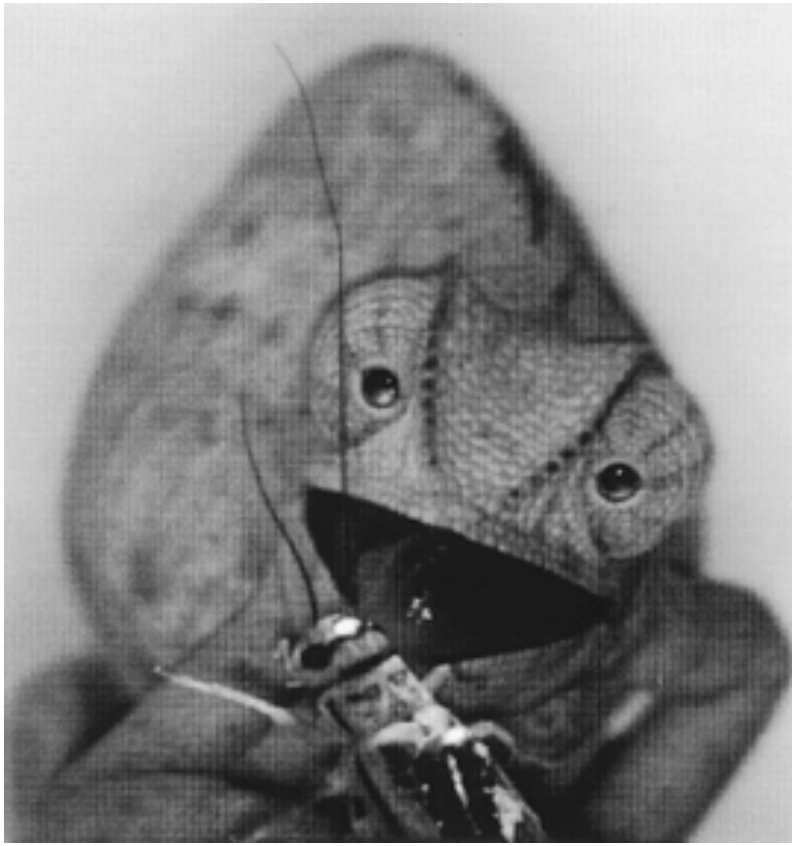
http://www.youtube.com/watch?v=Jd3-eiid-Uw

Accommodation - “depth from focus”

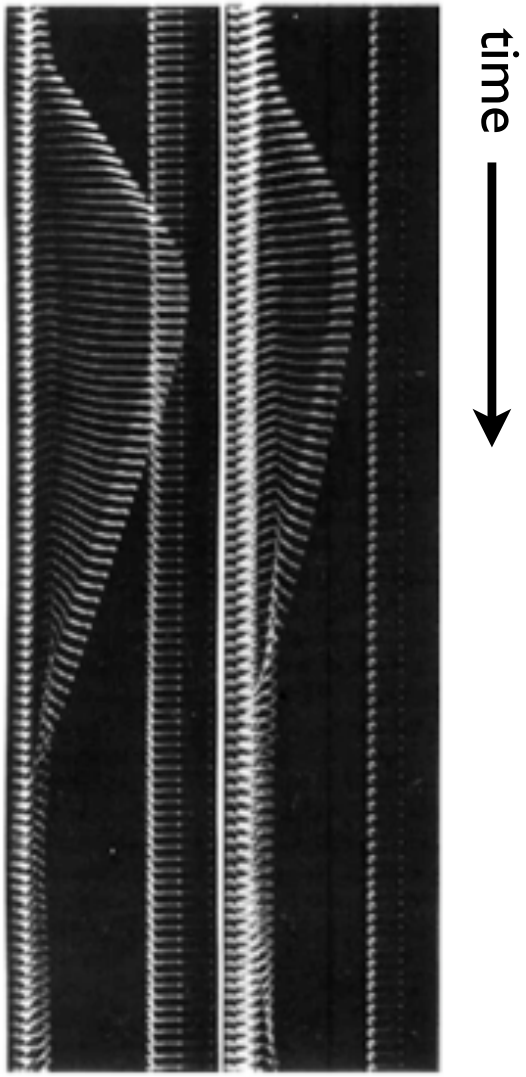


- Lens needs more accommodation to focus nearby objects
- Blur: cue that an object is in a different depth plane

Predatory behavior



chameleon



Harkness 1977