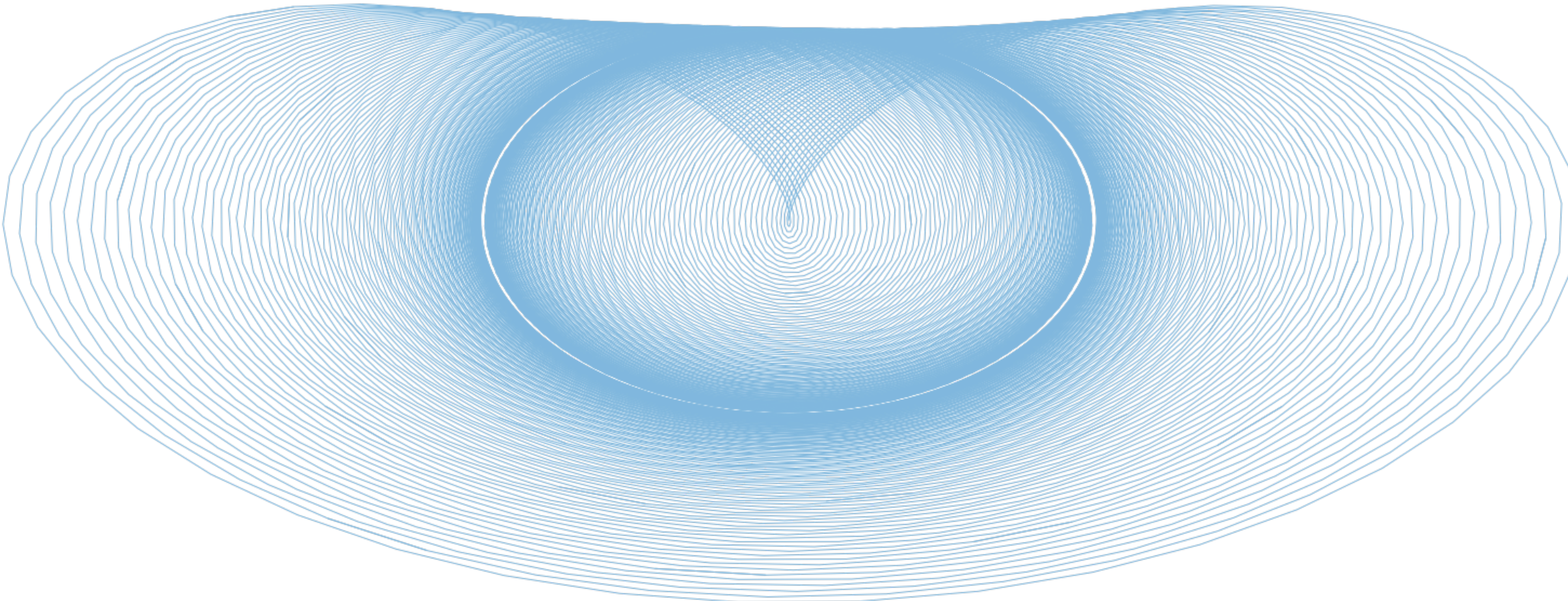
PHYS 1420 (F19)
Physics with Applications to Life Sciences



2019.09.04

Relevant reading:
Kesten & Tauck ch. 1.1-1.6 + Polya

Christopher Bergevin
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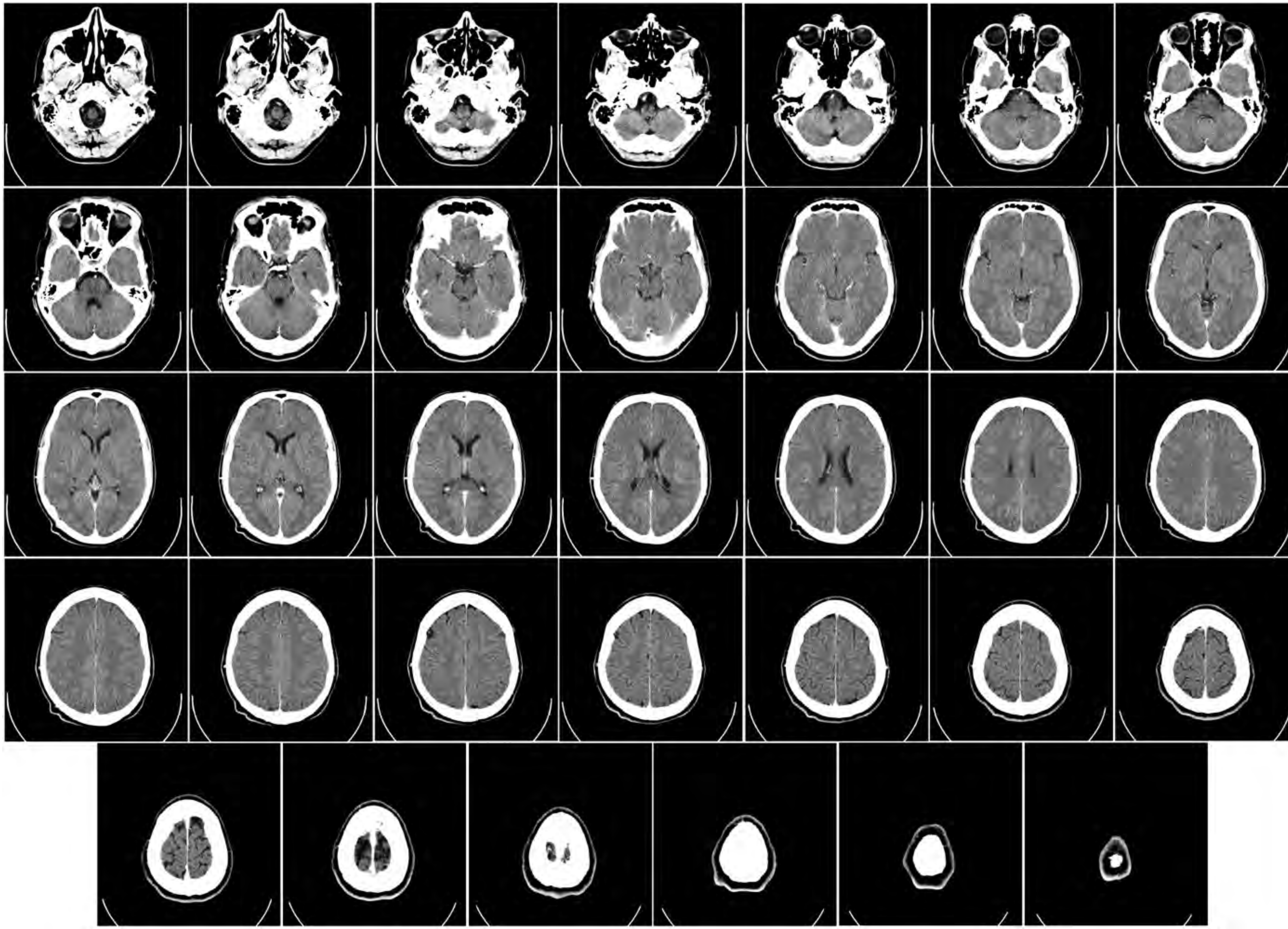
cberge@yorku.ca

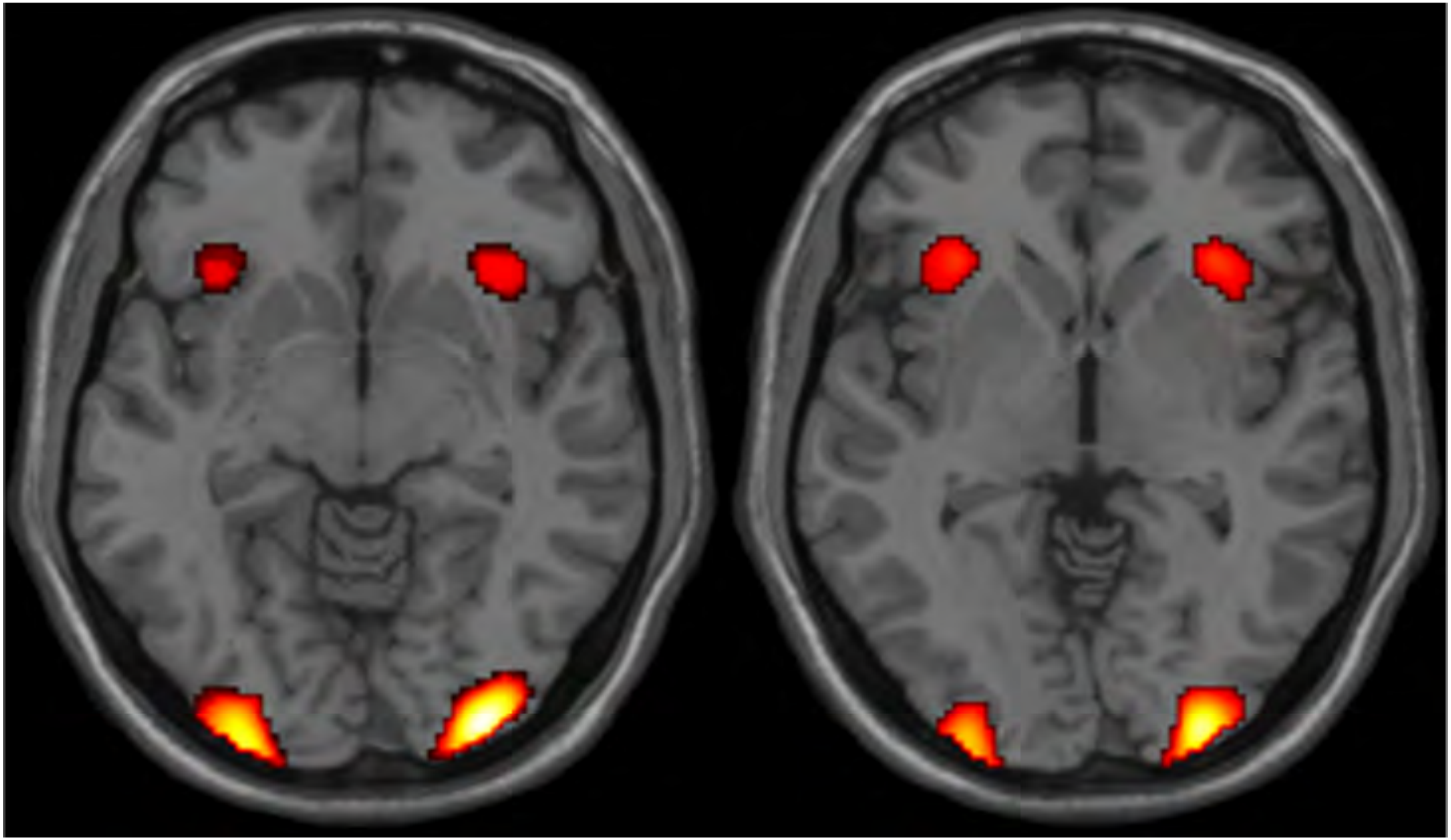


Wikipedia

https://nanomri.files.wordpress.com/2011/09/mri.jpg

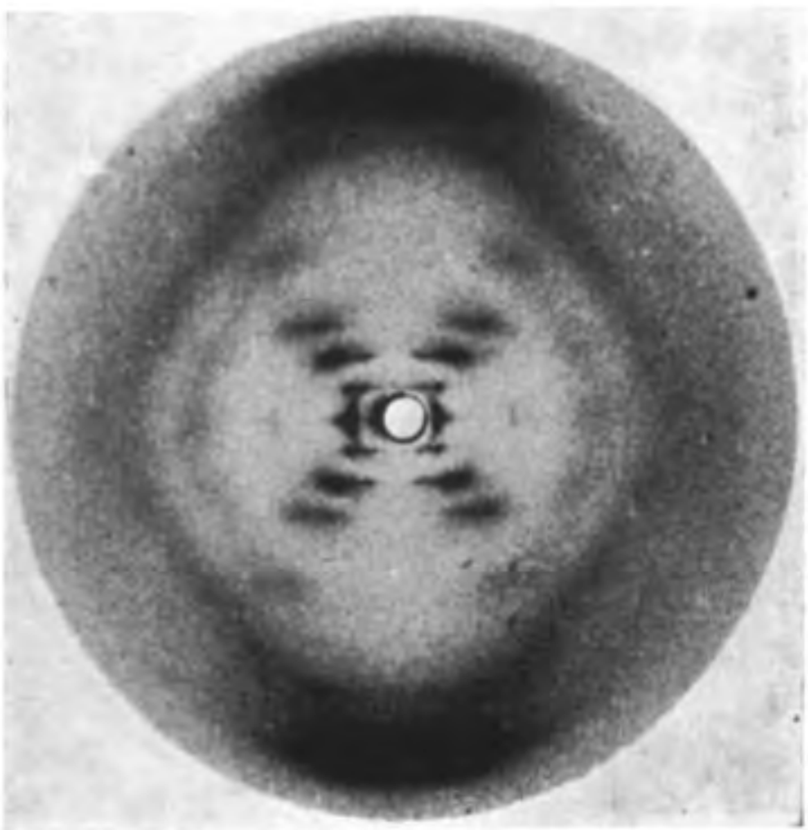
Question

How might we “see” brain? How it “functions”?



Question

How do we make a 3-D image of really small things (e.g., molecular structure)?



Sodium deoxyribose nucleate from calf thymus. Structure *B*

Franklin & Gosling (1953)

This figure is purely diagrammatic. The two ribbons symbolize the two phosphate—sugar chains, and the horizontal rods the pairs of bases holding the chains together. The vertical line marks the fibre axis

Watson & Crick (1953)

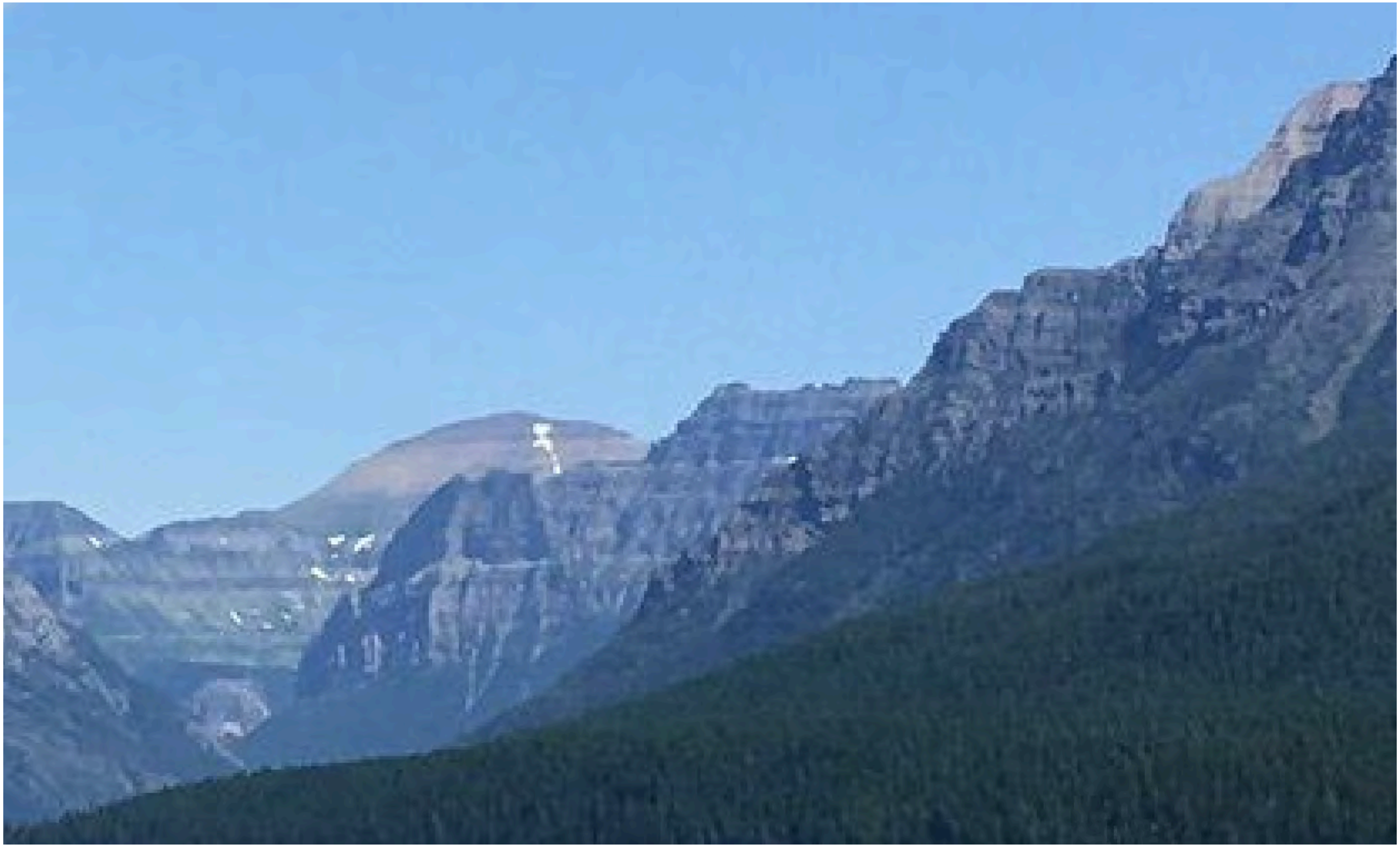
→ How did Watson and Crick actually figure out a "double helix" for DNA?

Caveat

Even “simple” questions can be hard…

e.g., How many mountain *peaks* are there in this image?

e.g., How many mountain *peaks* are there in this image?



Etymology

- What does “physics” even mean?

(from wikipedia)
“Physics (from Ancient Greek: φυσική (ἐπιστήμη) *phusikḗ (epistḗmē)* *’knowledge of nature’*, from φύσις *phúsis* "nature)….

… is the natural science that involves the study of matter and its motion and behavior through space and time, along with related concepts such as energy and force. One of the most fundamental scientific disciplines, the main goal of physics is to understand how the universe behaves.”

(from Merriam-Webster)
“A science that deals with matter and energy and their interactions”

(Kahn Academy)
“To be honest, it’s really difficult to define exactly what physics is. For one, physics keeps changing as we progress and make new discoveries.”

(our working PHYS 1420 definition) → **Problem solving**

PHYS 1420 Logistics

York University
PHYS 1420: Physics with Applications to Life Sciences
(6 credits; two-semester course)
Fall 2019 Syllabus

Time & Location
Lecture: MWF 12:30-1:30 (ACE 102)
Tutorial: T 1:30-2:30 (ACE 102)
Labs: Scheduled individually via course registration

Instructor: Christopher Bergevin
Email: cberge [at] yorku.ca
Office: Petrie 240
Office Hours: T 2:30(ish)–4:00 and/or by appointment (email to set up)

TAs/Graders:

- TBD (TBD@yorku.ca)

Graders:

- TBD (TBD@yorku.ca)

Course Website – `http://www.yorku.ca/cberge/1420F2019.html`

Prerequisites: A survey of physics in which many fundamental concepts are emphasized through applications to the life sciences. Topics include kinematics, dynamics, momentum and energy for linear and rotational motion; elementary kinetic theory and thermodynamics; static and current electricity; waves and physical and geometrical optics; elements of modern physics. This is a calculus-based course recommended for students unlikely to take 2000-level Physics courses. Prerequisites: 12U Physics or OAC Physics or SC/PHYS 1510 4.00; MHF4U Advanced Functions and MCV4U Calculus and Vectors, or 12U Advanced Functions and Introductory Calculus, or OAC Algebra and OAC Calculus, or SC/MATH 1505 6.00, or SC/MATH 1520 3.00. Course Credit Exclusions: SC/PHYS 1010 6.00; SC/PHYS 1410 6.00; SC/PHYS 1800 3.00 and SC/PHYS 1801 3.00; SC/ISCI 1310 6.0.

Two-semester Sequence: Note that PHYS 1420 is a two-semester course. C. Bergevin will be teaching the Fall 2019 (F19) term, while Prof. Cody Storry will be teaching the Winter 2020 term. This syllabus applies to the fall term. For F19, we are aiming to cover chapters 1–9 & 11–13 of the text. Not all material in these chapters will be covered, and there will be material covered in class not explicitly covered from the textbook.

Learning Objectives: By the end of the course (F19), students should be able to

- Understand the foundations of the areas of physics with application in life sciences. More specifically, topics include: kinematics (1-D and 2-D); momentum; work and energy for linear and rotational motion; fluid statics and dynamics; diffusion; oscillations; waves.

PHYS 1420 Logistics

PHYS 1420 (Fall 2019)

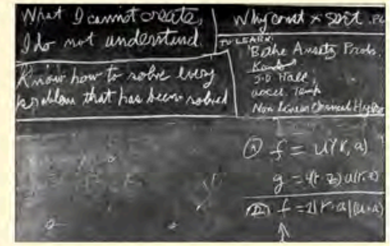
https://www.yorku.ca/cberge/1420F2019.html

Google Maps | Google Scholar | Dropbox | Thesaurus | Geocaching | York | Other | JASA-EL EM | NSERC DG | Sapling | PHYS 1420 (F19)

Physics with Applications to Life Sciences (PHYS 1420)

York University

Fall 2019 - Course Website



Basic Information

- A survey of physics in which many fundamental concepts are emphasized through applications to the life sciences. Topics include kinematics, dynamics, momentum and energy for linear and rotational motion; elementary kinetic theory and thermodynamics; static and current electricity; waves and physical and geometrical optics; elements of modern physics. This is a calculus-based course recommended for students unlikely to take 2000-level Physics courses. Prerequisites: 12U Physics or OAC Physics or SC/PHYS 1510 4.00; MHF4U Advanced Functions and MCV4U Calculus and Vectors, or 12U Advanced Functions and Introductory Calculus, or OAC Algebra and OAC Calculus, or SC/MATH 1505 6.00, or SC/MATH 1520 3.00. Course Credit Exclusions: SC/PHYS 1010 6.00; SC/PHYS 1410 6.00; SC/PHYS 1800 3.00 and SC/PHYS 1801 3.00; SC/ISCI 1310 6.0.

- **Location & Time:** MWF 12:30-1:30 (ACE 102) AND Tutorial T 1:30-2:30 (ACE 102)

- **Course Syllabus** (includes course logistics): here (pdf; tentative draft prior to 2019.09.04)

- **Instructor:** Christopher Bergevin
  Office: Petrie 240
  Email: cberge [AT] yorku.ca
  Office Hours: T 2:30ish-4:00 and/or by appointment
  Phone: 416-736-2100 ext.33730
- **TAs:** See syllabus
- **Text** *University Physics for the Physical and Life Sciences vols. 1 & 2* by Kesten PR and Tauck DL (W H Freeman & Co, 2012). You will also need a copy of the lab manual, available only from the university bookstore. Lastly, you will need the Sapling Online Homework license, which comes packaged w/ the hard copy of the course text as sold by the bookstore. You will not need a "clicker" for F19.

Updates and useful bits

https://www.yorku.ca/cberge/1420F2019.html

PHYS 1420 Logistics

Important Dates (2019)

First Day of Class	Sept. 4
Add Deadline	Sept. 17
Fall Reading Week	Oct. 14–18 (**no classes**)
Midterm Exam	Oct. 21
Drop Deadline	Nov. 8
Last Day of Class	Dec. 2
Final Exam	TBD

PHYS 1420 Course "Philosophy" (WOT version)

1. Learn the basics of 1st year physics and some applications to the life sciences

→ "Physics" is generally equated w/ a branch of critical inquiry trying to track down the "universal rules" that govern how the universe works

2. Develop/refine "quantitative problem solving" skills

→ Ultimately an issue of "***attitude***" such that you feel comfortable tacking the unknown (as these sorts of skills are invaluable and will open doors for you downstream). by and large, this involves refining/developing your mathematical-based reasoning skills

PHYS 1420 Course "Philosophy" (WOT version cont)

- Areas such as biophysics are two-way streets in that such can be simultaneously viewed as both "physics-applied-to-biology" and "biology-motivating/informing-physics". So physics & biology can be seen as naturally going together hand-in-hand

- By and large, we follow a well-established curricular path, covering: Newtonian mechanics, concept of energy, circular motion, oscillations, etc….

- … BUT also weave in some novel directions (e.g., diffusion)

- A handful of associated mathematical topics naturally fall out of this (to varying degrees of depth): vectors, calculus (i.e., how things "change"), polar coordinates, geometry, sinusoids, etc….

PHYS 1420 Logistics

- Course website: http://www.yorku.ca/cberge/PHYS1420F19.html

- Read the book & come to class (& get a scratch pad and notebook)

- Do the HW (both written & online) → purpose is to practice problem-solving & develop confidence!

- Come to tutorials and engage w/ one another

- All the above will help you get properly prepared for the tests

→ Let’s take a step back for a moment and look at some of the broader “themes” that we aim to (interdisciplinarily) weave into the course.....

Etymology

- What does “physics” even mean?

(from wikipedia)
“Physics (from Ancient Greek: φυσική (ἐπιστήμη) *phusikḗ (epistḗmē) ’knowledge of nature’*, from φύσις *phúsis* "nature)….

… is the natural science that involves the study of matter and its motion and behavior through space and time, along with related concepts such as energy and force. One of the most fundamental scientific disciplines, the main goal of physics is to understand how the universe behaves.”

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(Kahn Academy)
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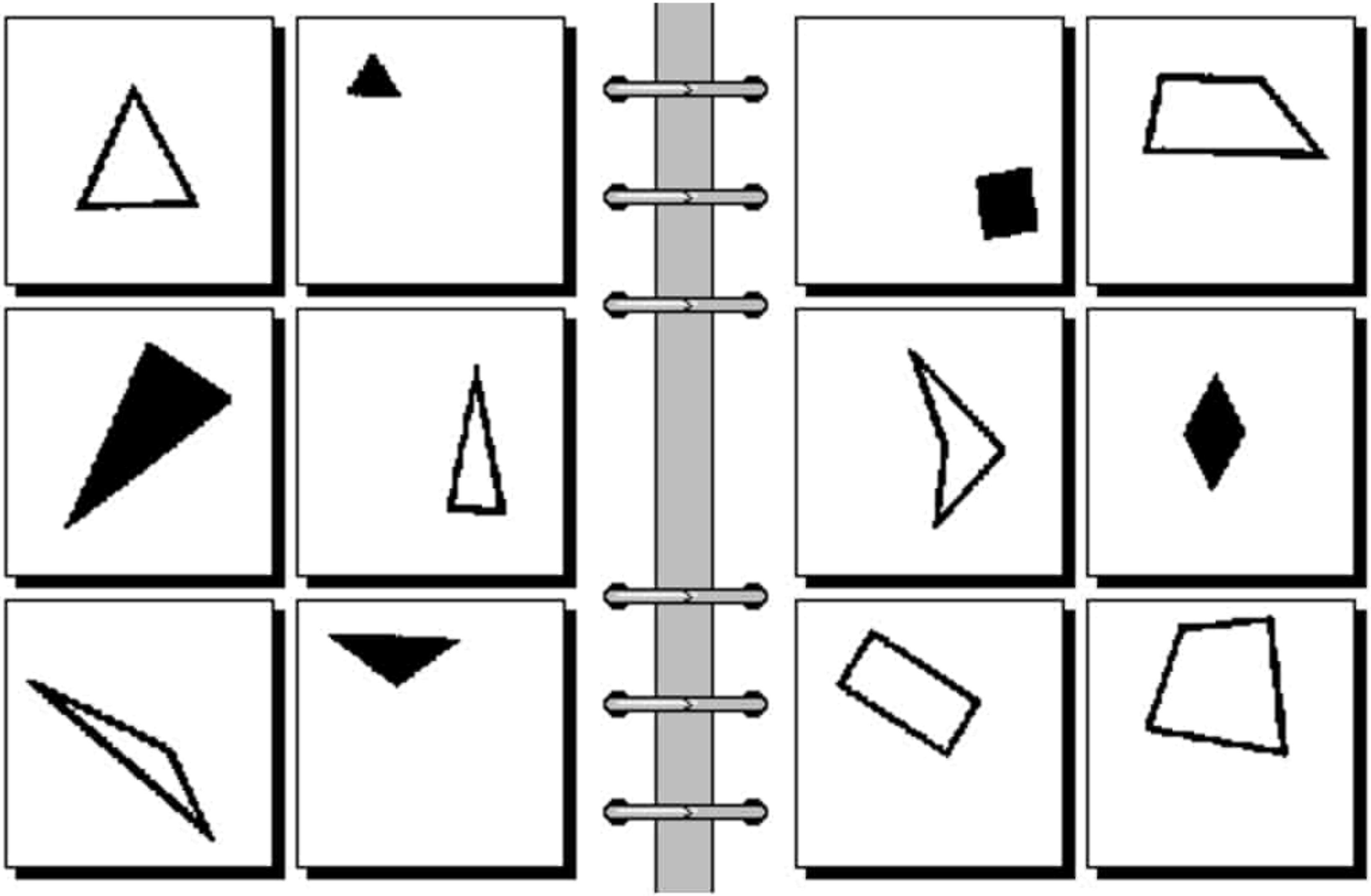
(our working PHYS 1420 definition) → **Problem solving**

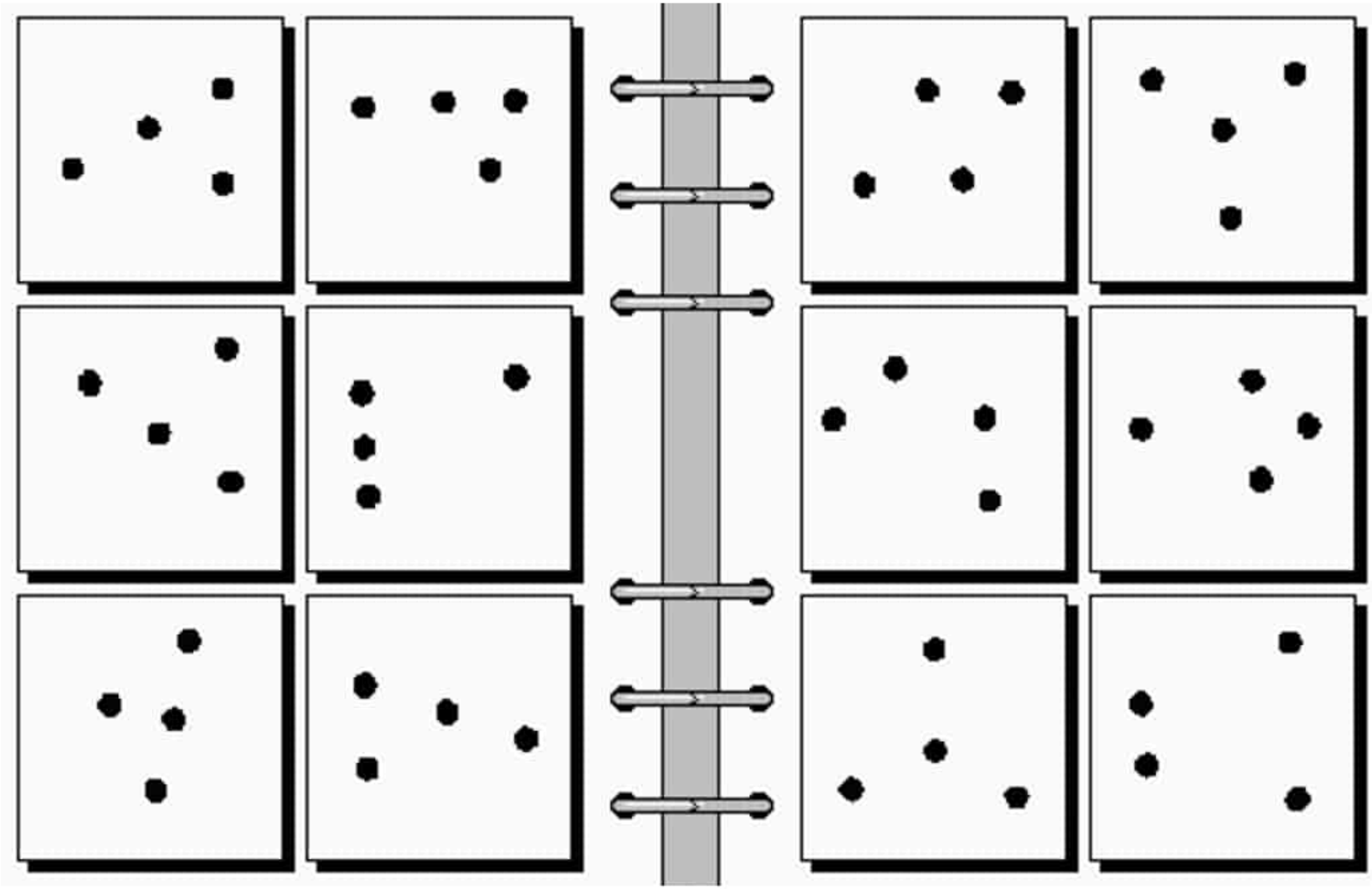
<u>"Puzzles"</u> – Bongard problems

Determine the "rule" that is different between the two sides (each of six)

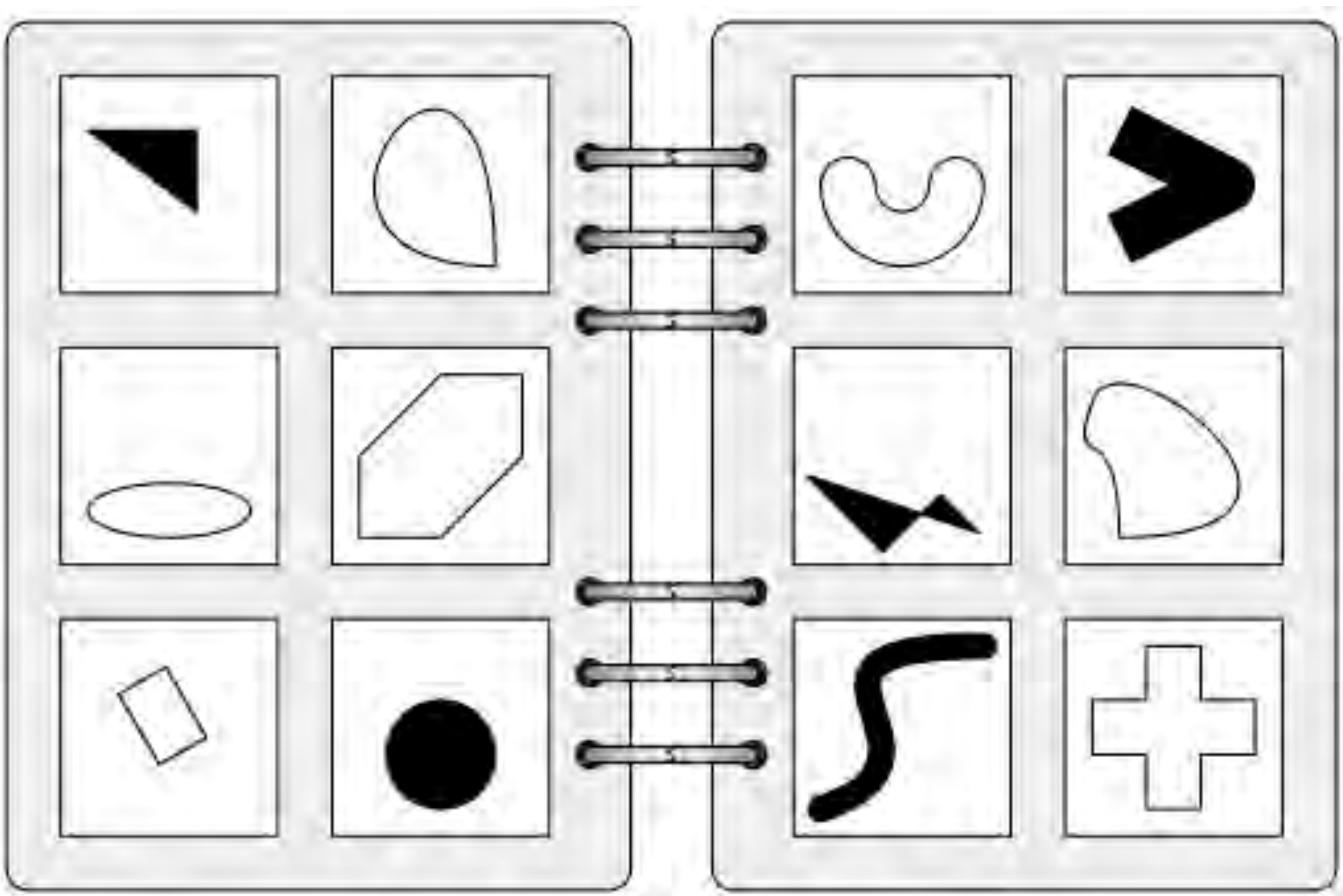


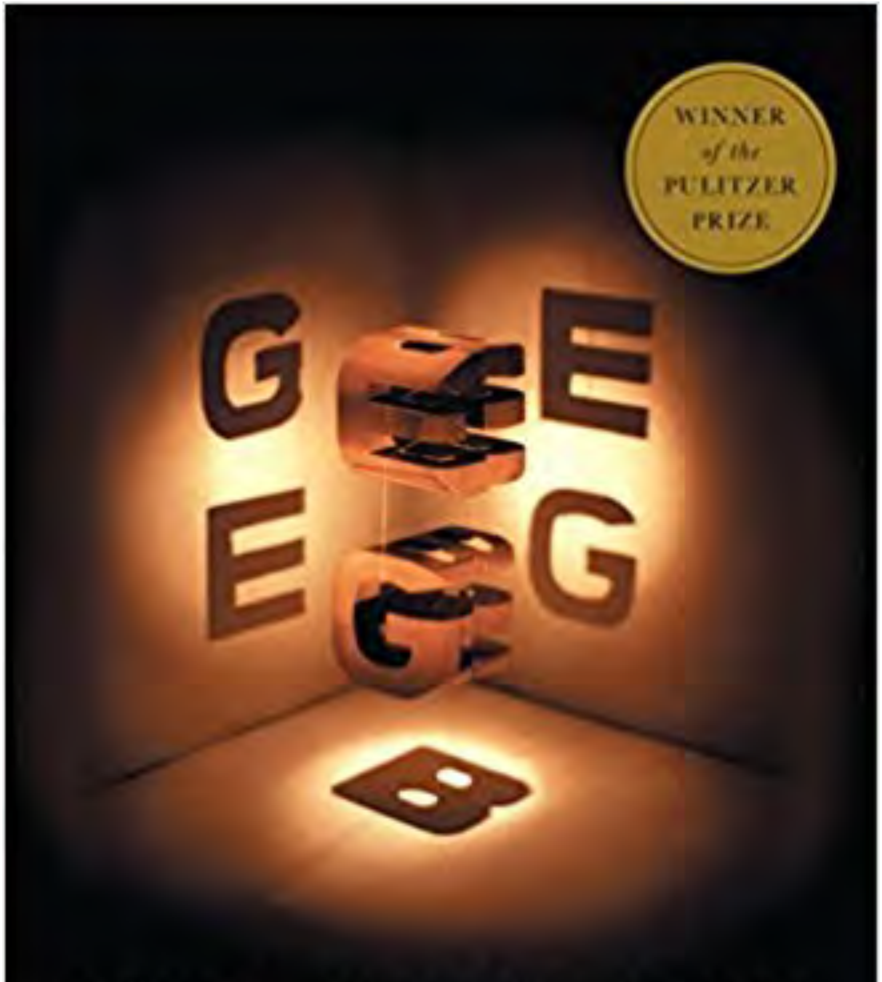
e.g., http://www.foundalis.com/res/bps/bpidx.htm

<u>“Puzzles”</u> – Bongard problems



“Puzzles” – Bongard problems





GÖDEL, ESCHER, BACH:

an Eternal Golden Braid

DOUGLAS R. HOFSTADTER

A metaphorical fugue on minds and machines in the spirit of Lewis Carroll

Polya

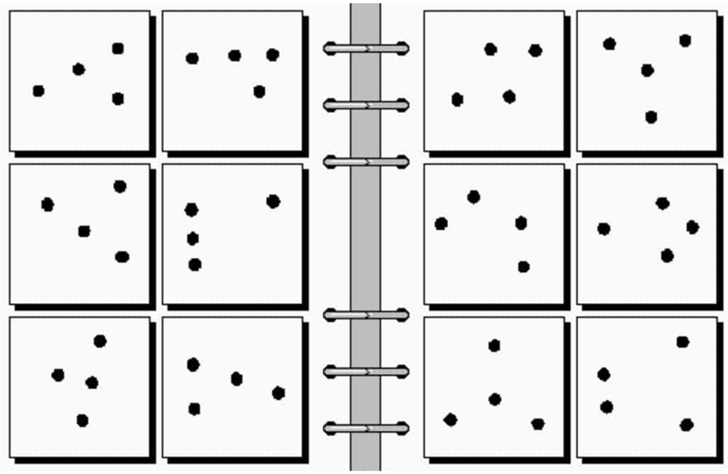
How To Solve It

A New Aspect of Mathematical Method

G. POLYA

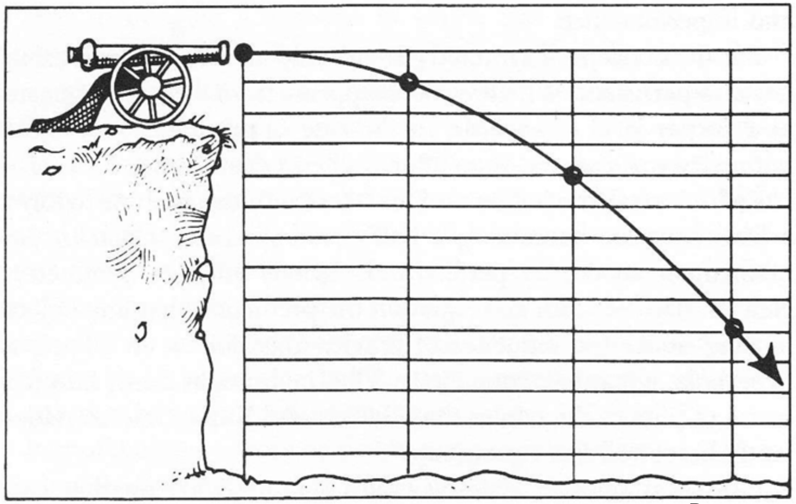
Stanford University

How To Solve It was originally published by Princeton University Press in 1945. The Anchor Books edition is published by arrangement with Princeton University Press.



<u>Theme</u>: Problem-solving......

A man lives on the tenth floor of a building. Every day he takes the elevator to go down to the ground floor to go to work or to go shopping. When he returns he takes the elevator to the seventh floor and walks up the stairs to reach his apartment on the tenth floor. Why does he do this?



von Baeyer

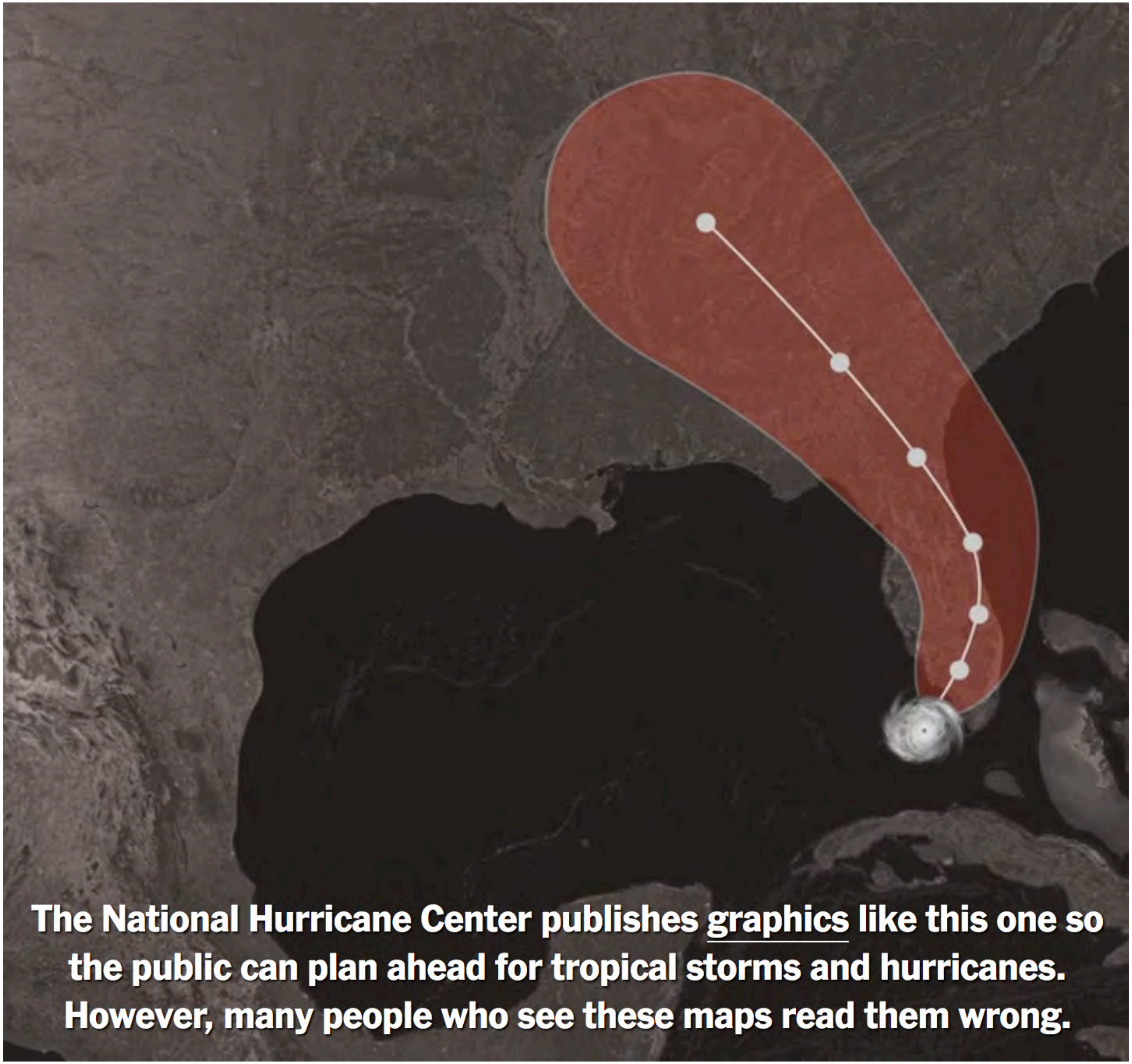
e.g., “classical mechanics”

<u>Theme</u>: What is Life?

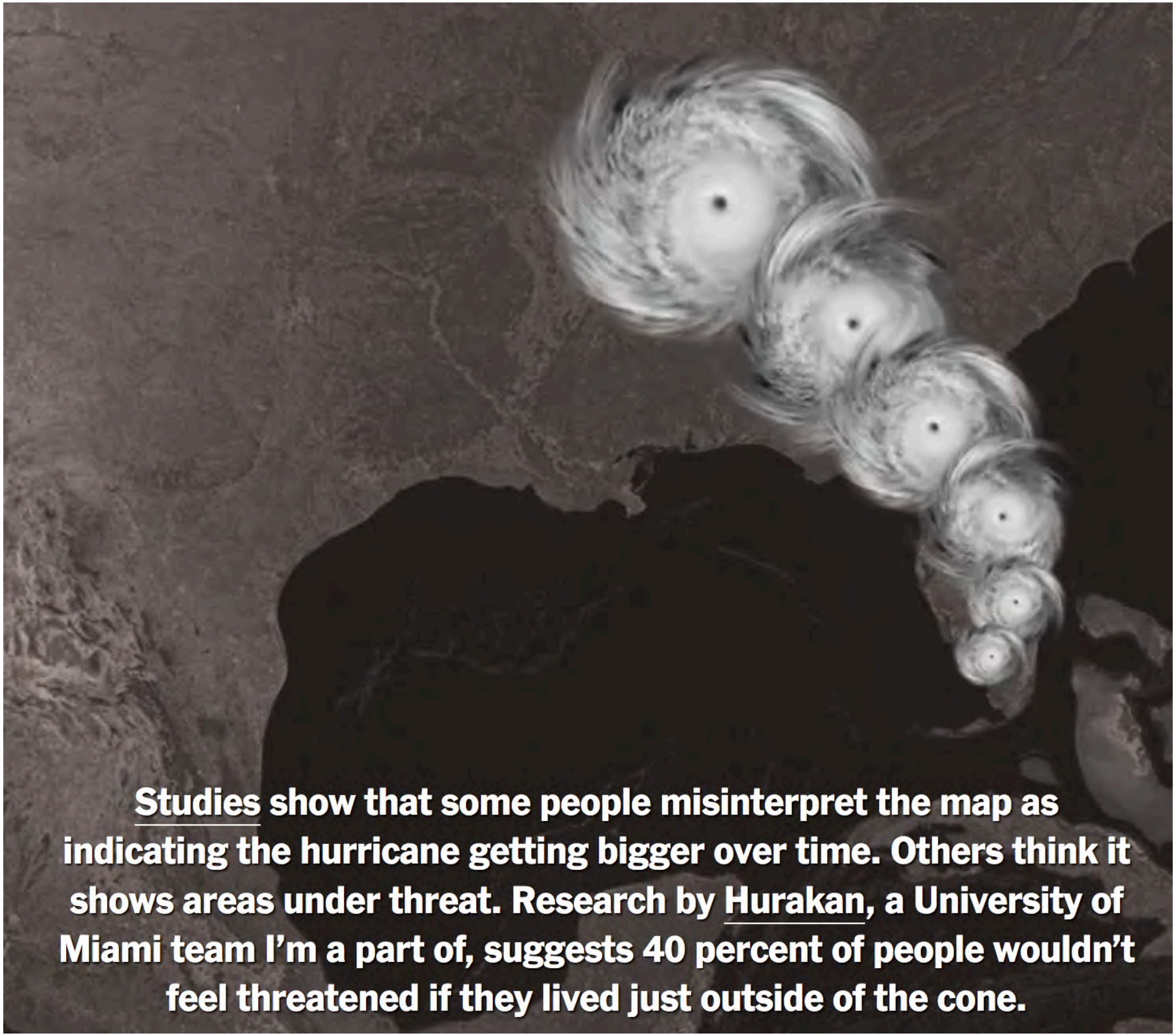
One response to the question, What is Life? is simply, Look Around!

-Frank M. Harold

→ Quick tangent into hurricanes, uncertainty, and “fake news”…

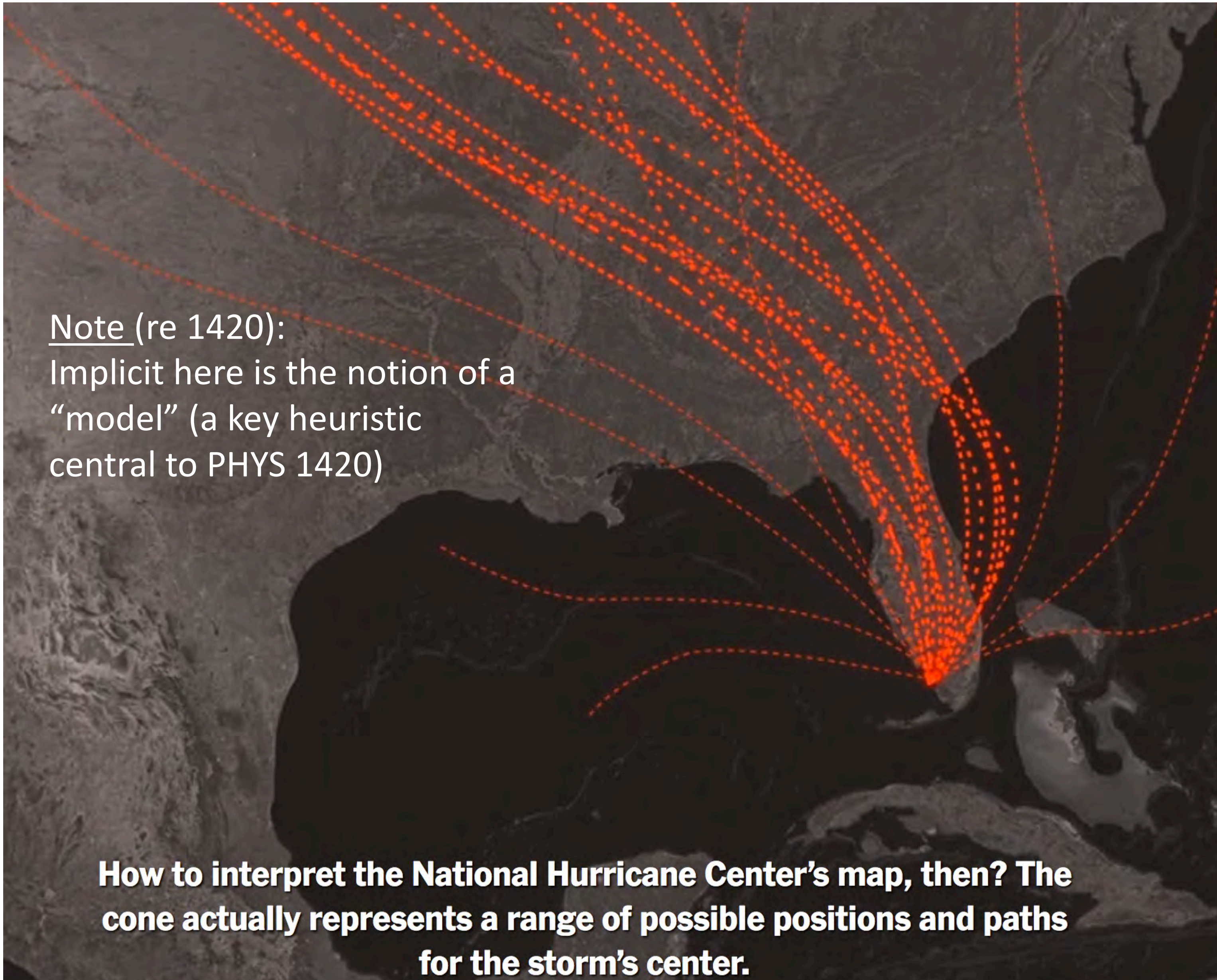


https://www.nytimes.com/interactive/2019/08/29/opinion/hurricane-dorian-forecast-map.html



https://www.nytimes.com/interactive/2019/08/29/opinion/hurricane-dorian-forecast-map.html

Note (re 1420):
Implicit here is the notion of a "model" (a key heuristic central to PHYS 1420)



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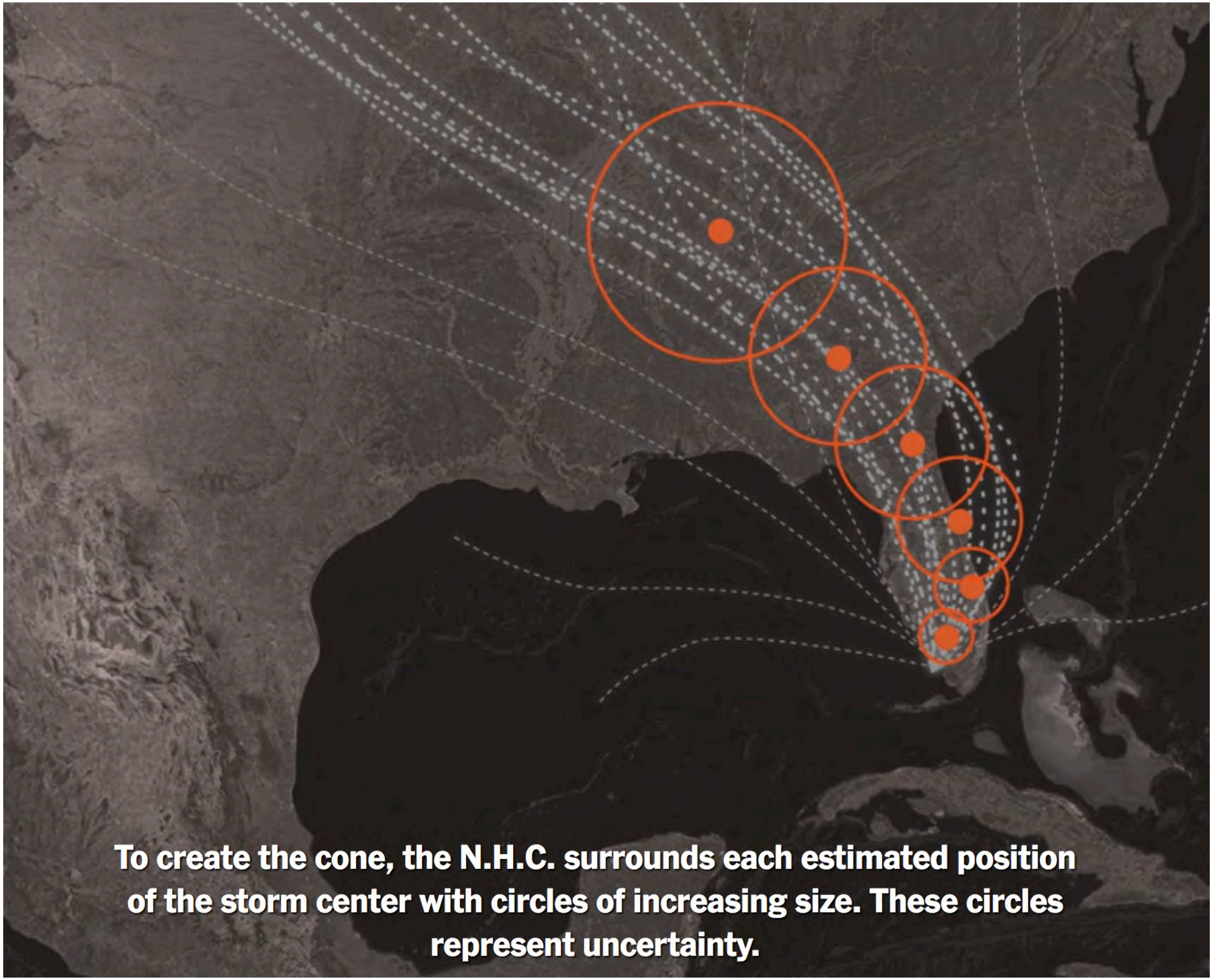

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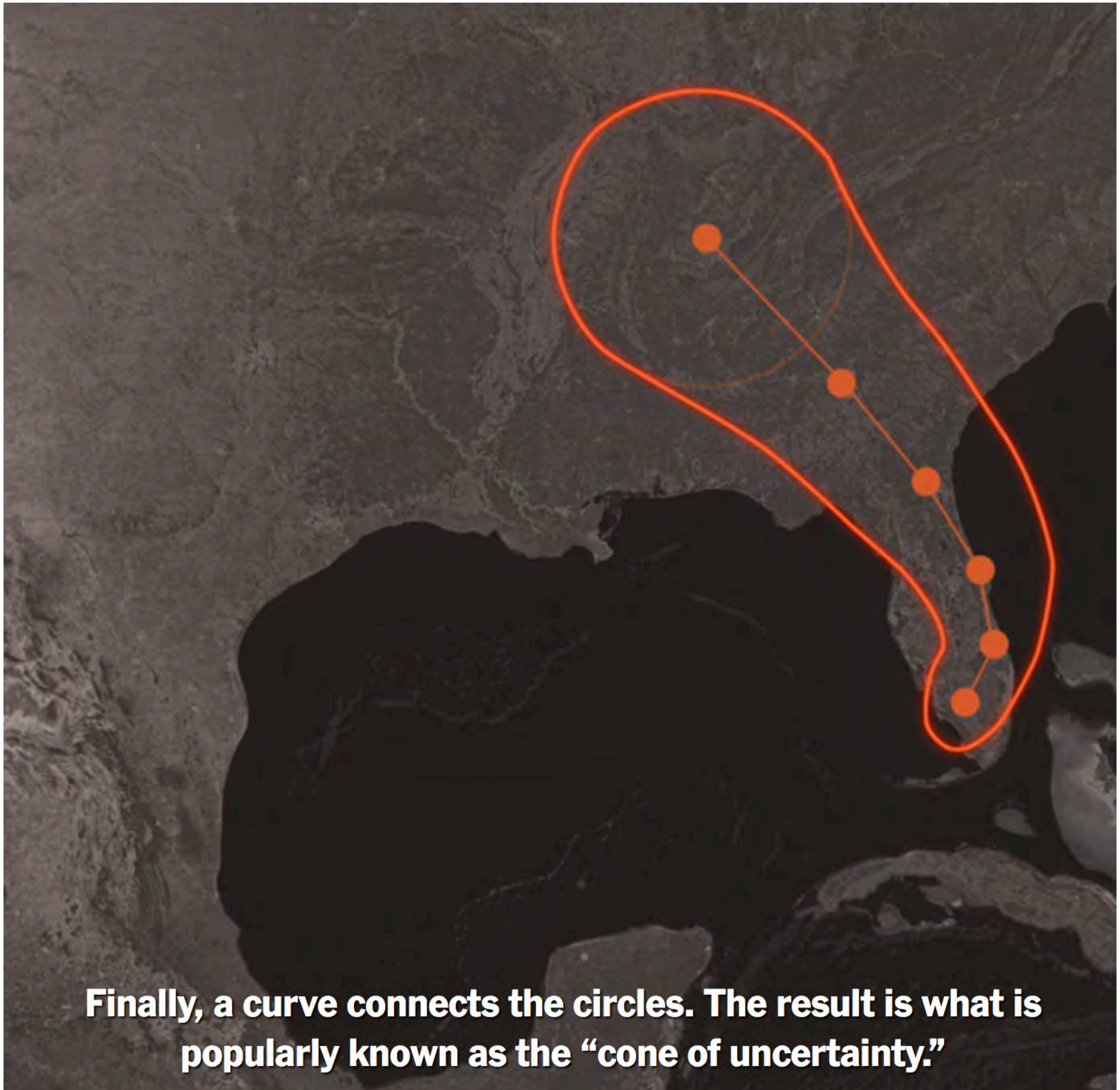


https://www.nytimes.com/interactive/2019/08/29/opinion/hurricane-dorian-forecast-map.html

Aside: Fake news?

Aug. 29, 2019

https://www.clickorlando.com/weather/hurricane/updates-track-computer-models-satellite-for-hurricane-dorian

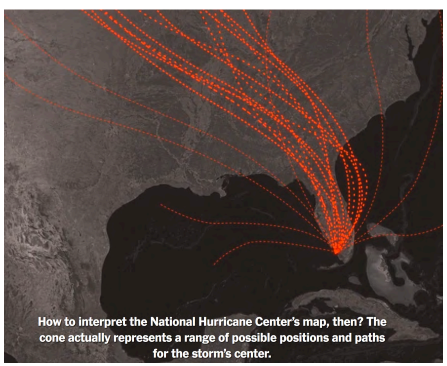
Aside: Fake news?

Aug. 29, 2019

https://www.clickorlando.com/weather/hurricane/updates-track-computer-models-satellite-for-hurricane-dorian

See also: https://www.nhc.noaa.gov/archive/2019/DORIAN_graphics.php?product=5day_cone_no_line_and_wind

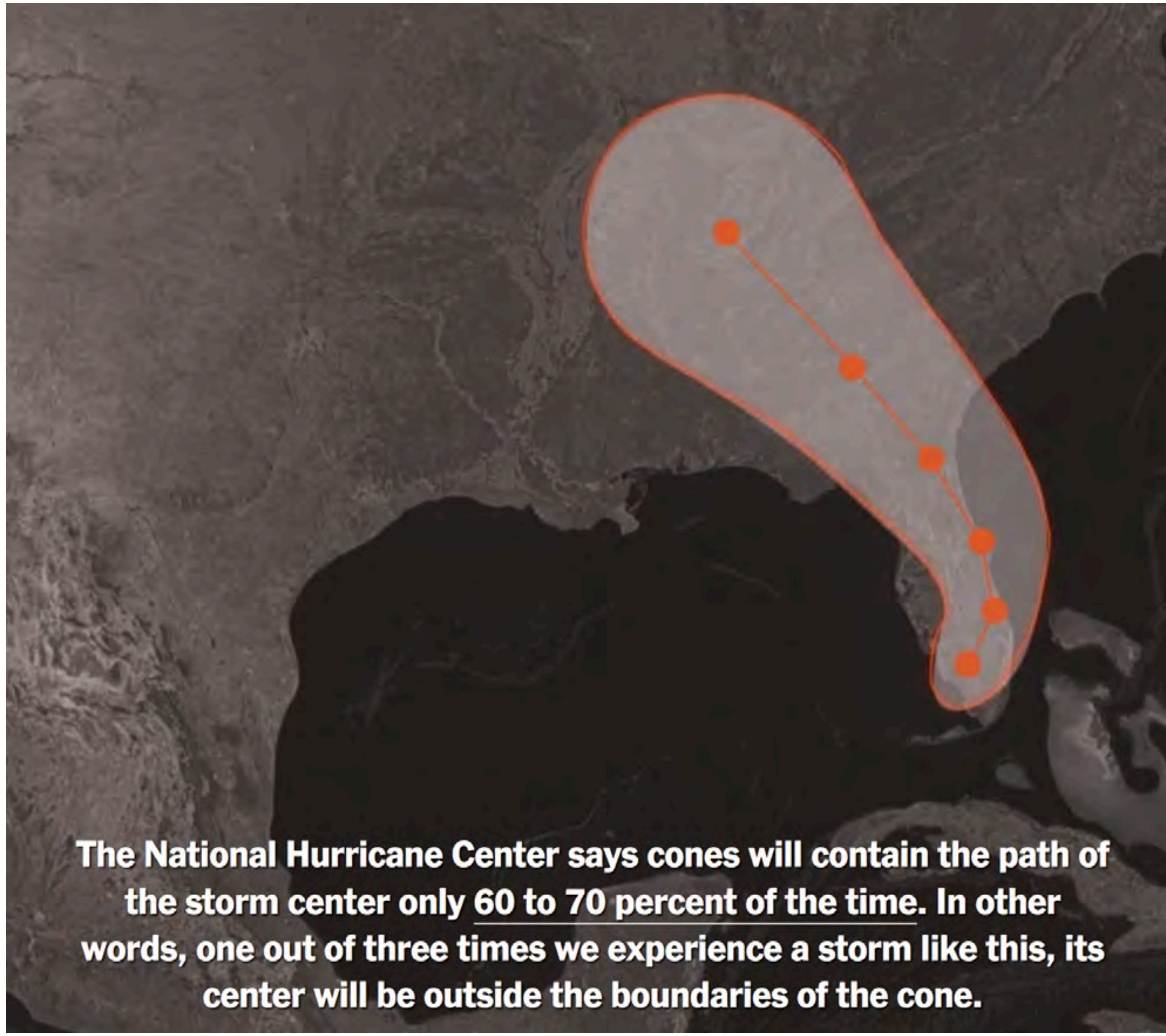
Sept. 1, 2019



→ Weather modeling & prediction is highly challenging!

https://www.wtnh.com/weather/hurricane-dorian-strengthens-and-shifts-now-expected-to-hit-the-carolinas-live-updates/

→ Life (like weather) is *stochastic*



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Female hurricanes are deadlier than male hurricanes

8782–8787 | PNAS | June 17, 2014 | vol. 111 | no. 24

Do people judge hurricane risks in the context of gender-based expectations? We use more than six decades of death rates from US hurricanes to show that feminine-named hurricanes cause significantly more deaths than do masculine-named hurricanes. Laboratory experiments indicate that this is because hurricane names lead to gender-based expectations about severity and this, in turn, guides respondents' preparedness to take protective action. This finding indicates an unfortunate and unintended consequence of the gendered naming of hurricanes, with important implications for policymakers, media practitioners, and the general public concerning hurricane communication and preparedness.

gender stereotypes | implicit bias | risk perception | natural hazard communication | bounded rationality

Note: [https://en.wikipedia.org/wiki/Dorian_(name)]

Dorian is a unisex given name of Greek origin. In Greek, the meaning of the name Dorian is of Doris, a district of Greece; or of Doros, a legendary Greek hero. Doros was the son of Helen of Sparta (who was the daughter of Zeus and Leda). Doros was the founder of the Dorian tribe, and the most likely origin of Doros' name was the Greek word "doron", meaning 'gift'.

Theme: What is Life? (REVISTED)

Islands of venomous fire ant colonies spotted floating in rising floodwaters in Houston

→ How do they "know" (how) to do this?!

Theme: Notion of "information"

(plus the idea of *emergence* from *complex systems*)

http://www.dailymail.co.uk/news/article-4833342/Islands-fire-ants-floating-Houston-floodwaters.html

Theme: Bridging "micro" and "macro"-scopic scales

http://www.thisiscolossal.com/2017/09/elements-film-maxim-zhestkov/

Pop Quiz

How many neurons are there in the human brain? Synapses?

Human brain contains ~10^{11} (100 billion) neurons!
(with 100 trillion+ connections inbetween)

Aside: Neurons

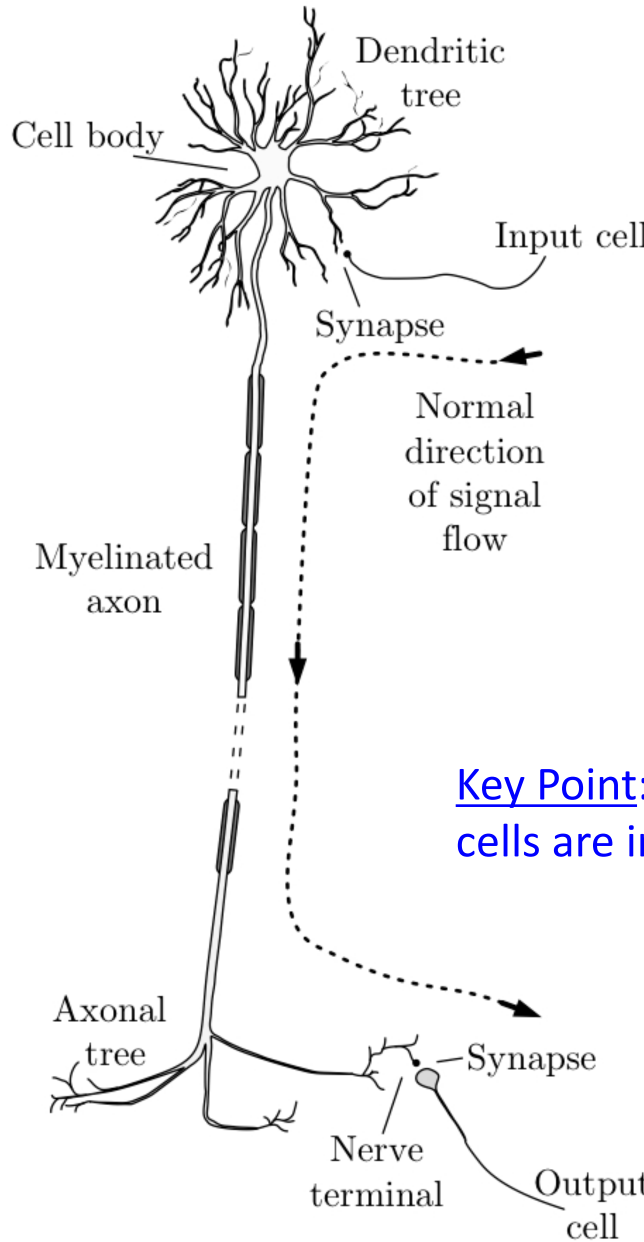


Figure 1.22

Neurons (“fibers”)
= Information highway

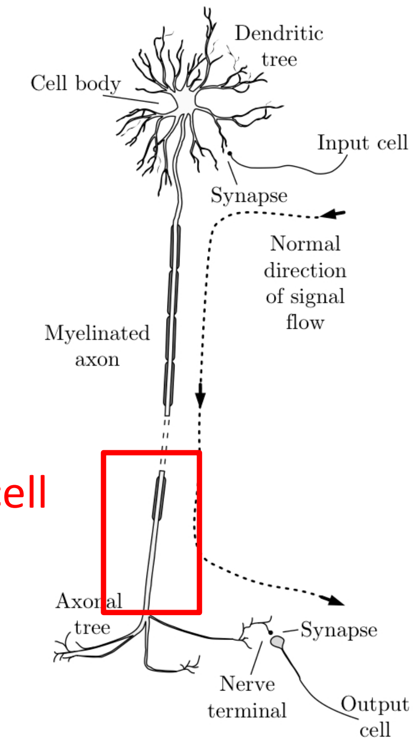
Key Point: Electrical properties of cells are important

Weiss (1996)

Aside: Cell membranes

- Membrane primarily consists of a "lipid bilayer" (to separate inside from outside)

- All sorts of "stuff" embedded inside, to allow for "communication" across membrane



zoom in on cell membrane

Figure 1.22

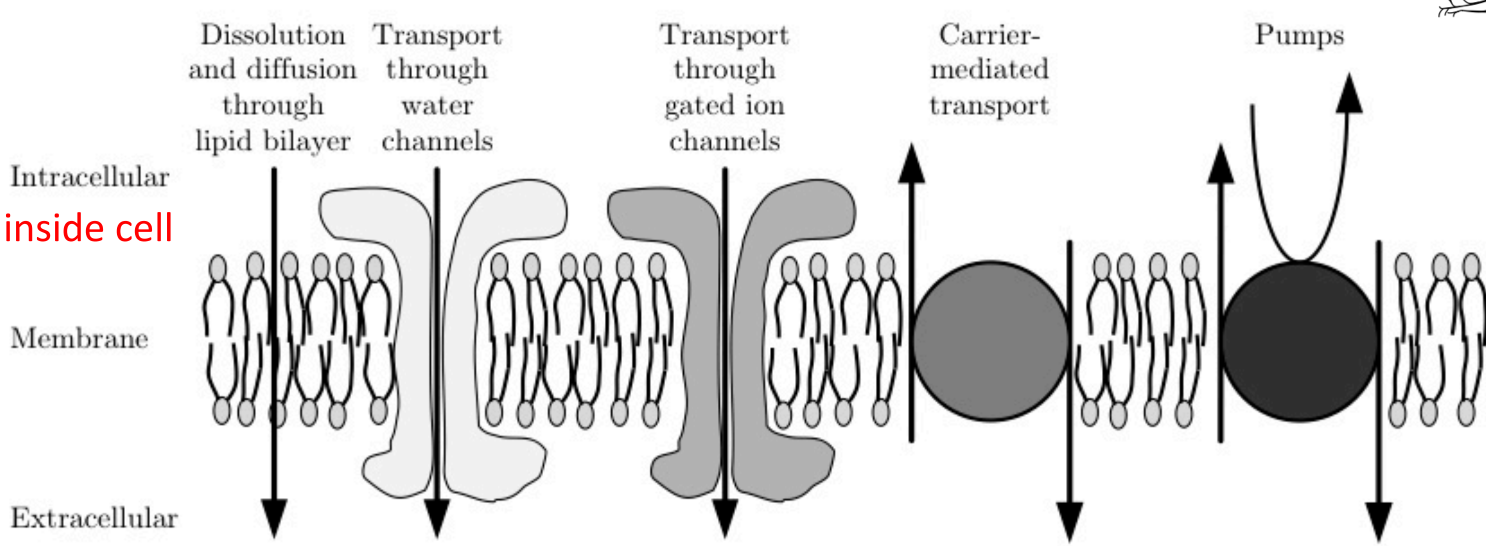


Figure 2.19

Weiss (1996)

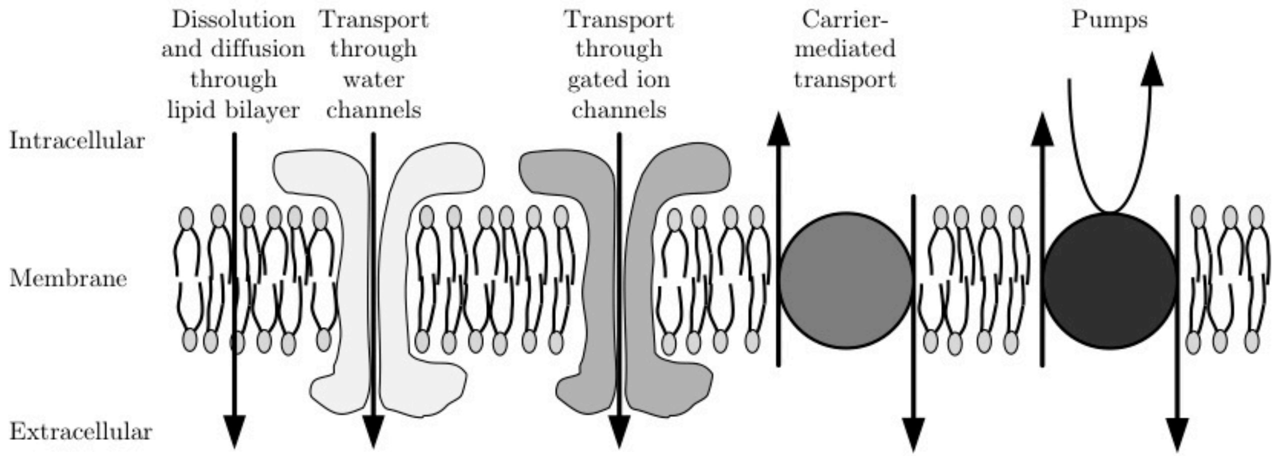
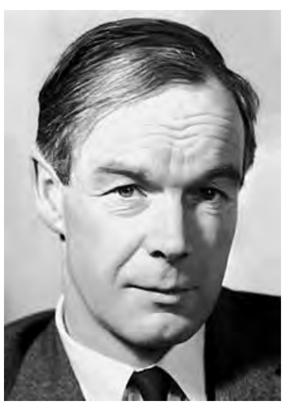


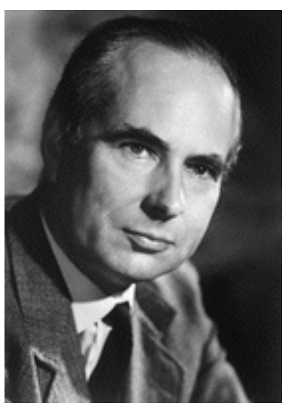
Figure 2.19

(crazy idea) Model the cell membrane as an electric circuit

Hodgkin Huxley model

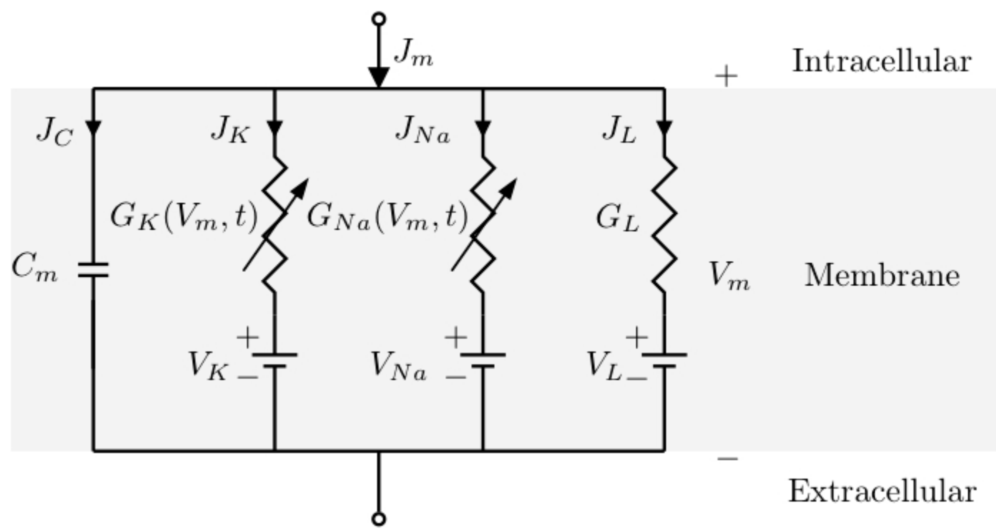


Alan Hodgkin



Andrew Huxley

1963 Nobel Prize



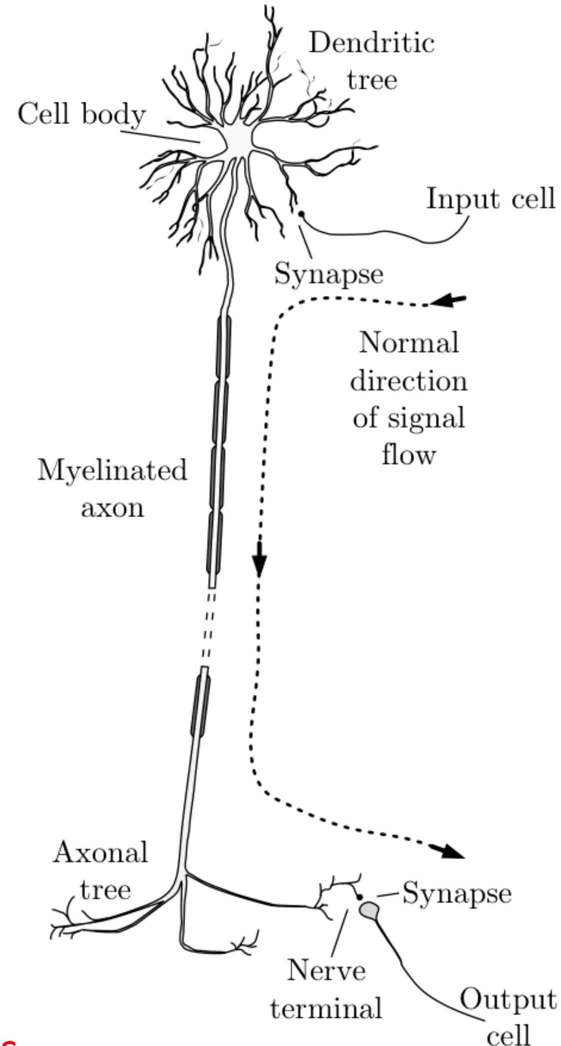


Figure 1.22

Theme (REVISTED): Bridging "micro" and "macro"-scopic scales

Theme: Neuroscience and the brain

Note: Take BPHS 4080 (Cellular Electrodynamics) if you really want to delve into this properly…

http://www.thisiscolossal.com/2017/09/elements-film-maxim-zhestkov/

BIOPHYSICS @ YORK

redefine THE POSSIBLE.

UNIVERSITÉ
UNIVERSITY

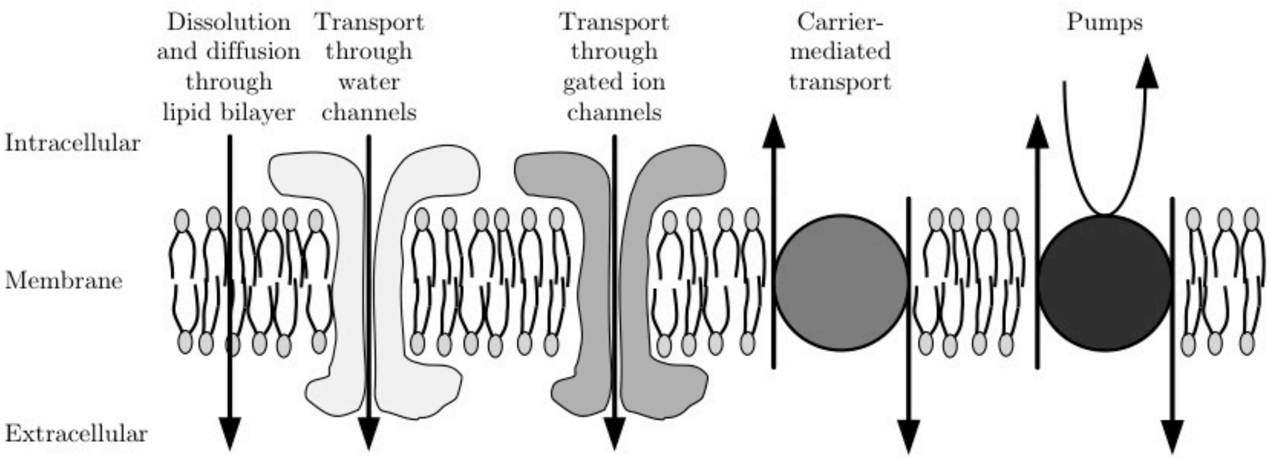
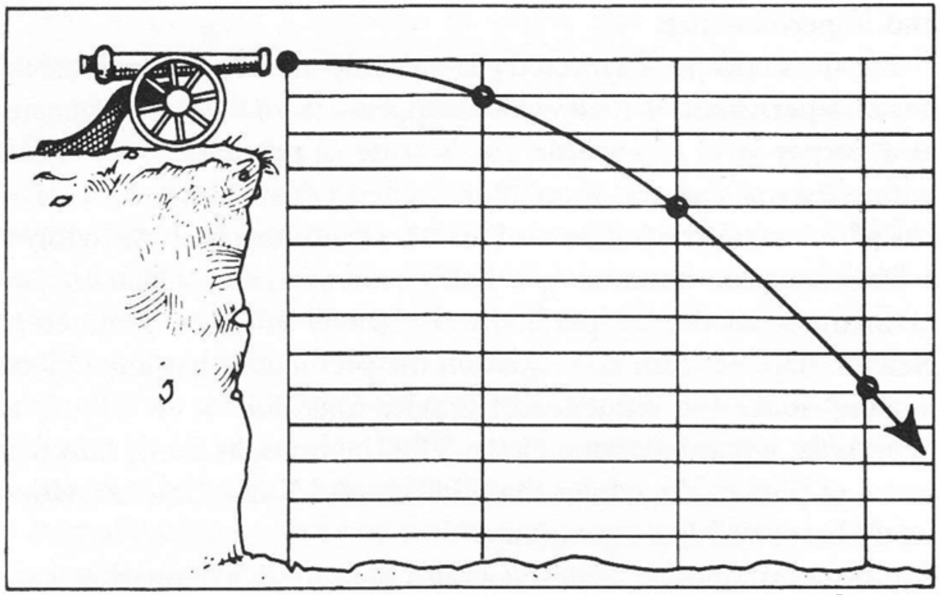


Figure 2.19

Note: Studying how stuff "moves" across a cell membrane is the same basic thing as the more general "how does stuff move?"

→ We'll start delving into that next week via "mechanics" and easier sorts of "stuff" to study

e.g., "classical mechanics"

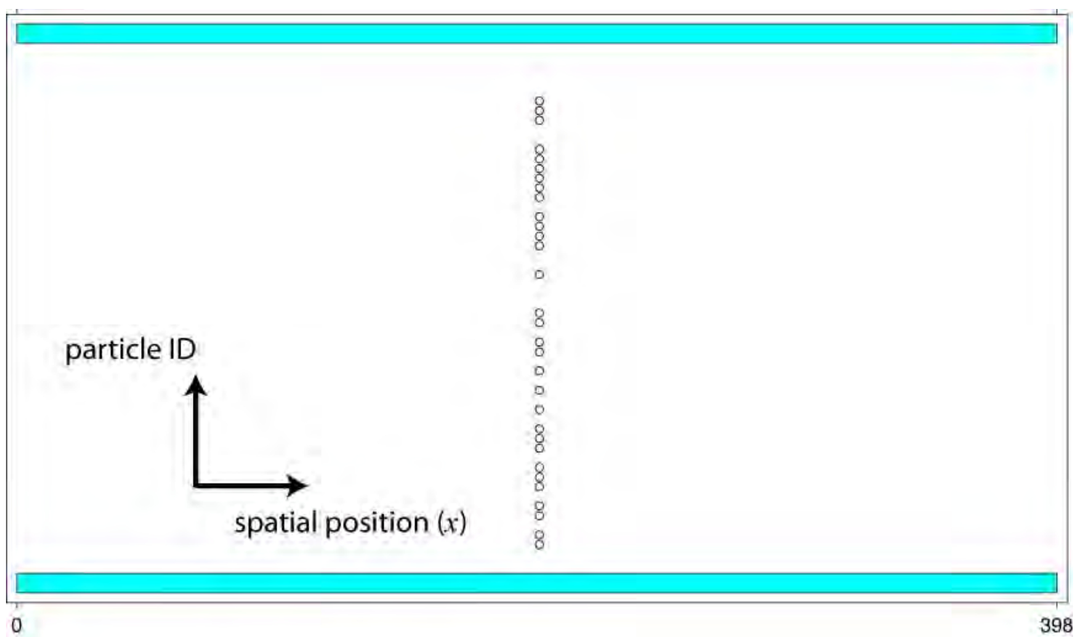


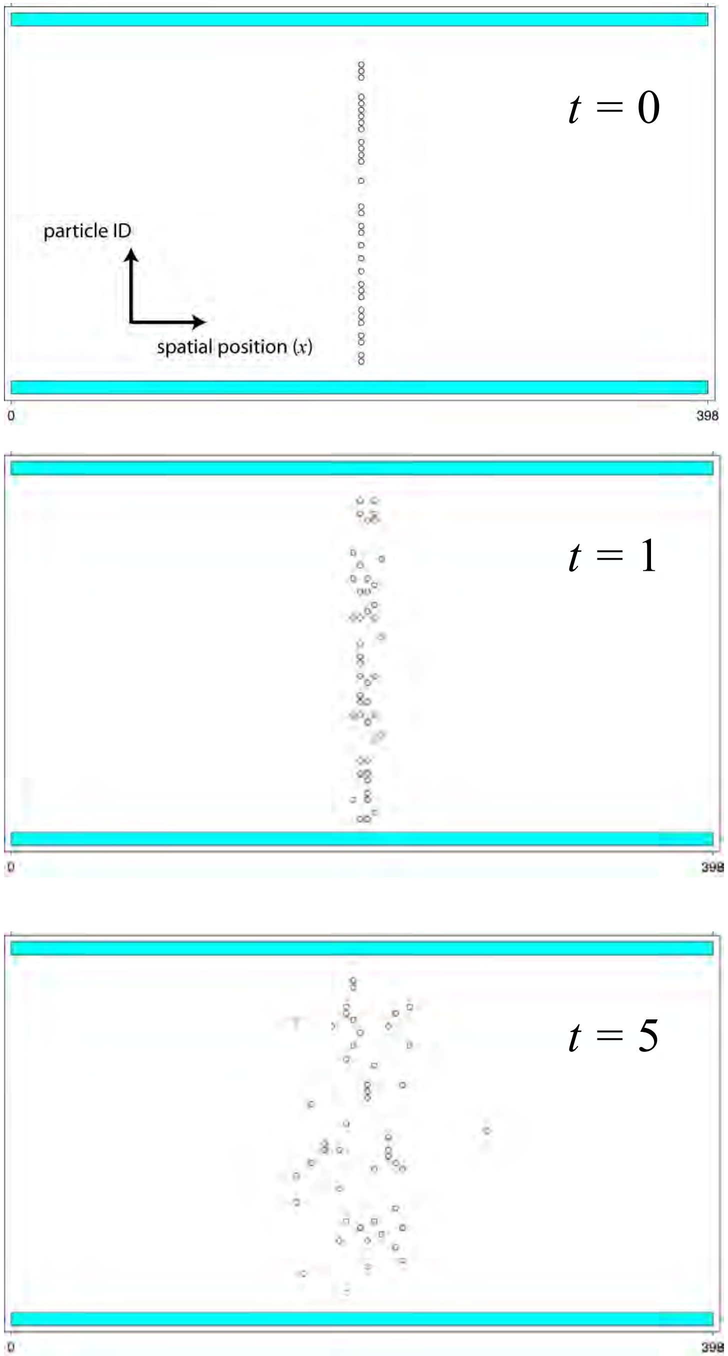
von Baeyer

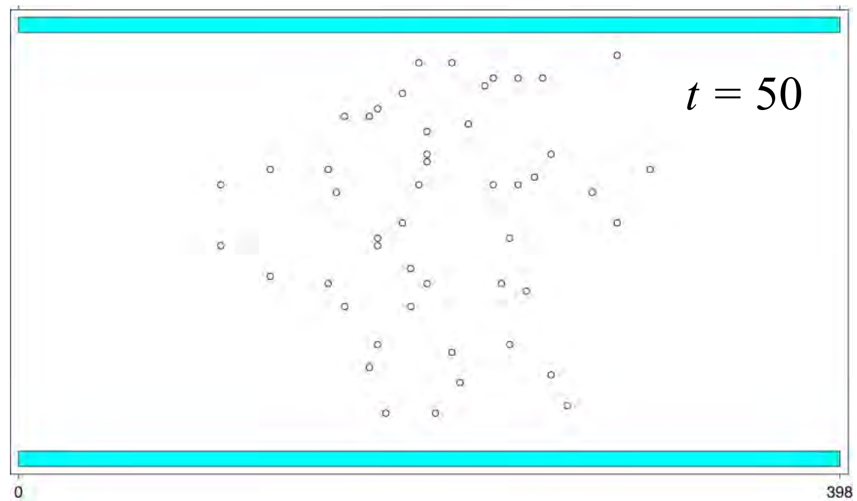
<u>Aside:</u> Microscopic basis for diffusion

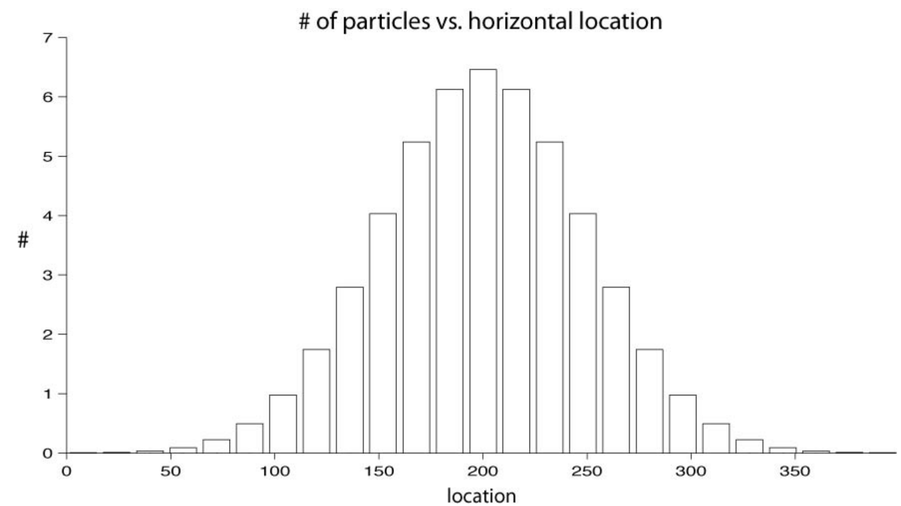
Brownian motion $\Rightarrow$ 'Random Walker' (1-D)

Ensemble of Random Walkers









→ Diffusion (for which Brownian motion is the *microscopic* basis)

```
% NOTE: the loop is set up in such a way to average x2ave across walkers
for r= 1:N
    x=0;    % initialize position for r'th walker
    position(r,1)= 0;
    % loop to go through M steps for r'th walker
    for nn=1:M;
        % conditional determines whether step is to the left or right
        if (rand<bias),  x=x+1;
        else    x=x-1;  end;
        x2ave(nn)=x2ave(nn)+x^2;    % store squared displacement (handles averging across r)
        position(r,nn+1)= x;          % store displacment for each walker and step
    end;
end;
x2ave= x2ave/N;     % Divide by number of walkers
% plot MSD
figure(1);
plot([1:1:M], x2ave, 'k'); hold on;
title(['MSD for 1-D random walk (average from ',num2str(N),' walkers)']);
xlabel('Step number'); ylabel('Mean-Squared Distance (x^2)');
% plot a subset of individual traces
figure(2); clf; hold on; grid on;
for nn=1:K
    shade= 1-(nn-1)/K;
    plot(position(nn,:),'Color',[1 1 1]-shade);
end
xlabel('Step number'); ylabel('Position'); title('Representative traces');
plot([0 M],[1 1]*sqrt(x2ave(end)),'g--','LineWidth',2) % include MSD bounds at step M
plot([0 M],[-1 -1]*sqrt(x2ave(end)),'g--','LineWidth',2)
plot(M,sqrt(mean(position(:,end).^2)),'ro');    % reality check (another way to compute final MSD)
disp(['Final mean (non-squared) distance = ',num2str(mean(position(:,end)))]);
```

- *On the Movement of Small Particles Suspended in Stationary Liquids Required by the Molecular-Kinetic Theory of Heat* (Brownian motion)

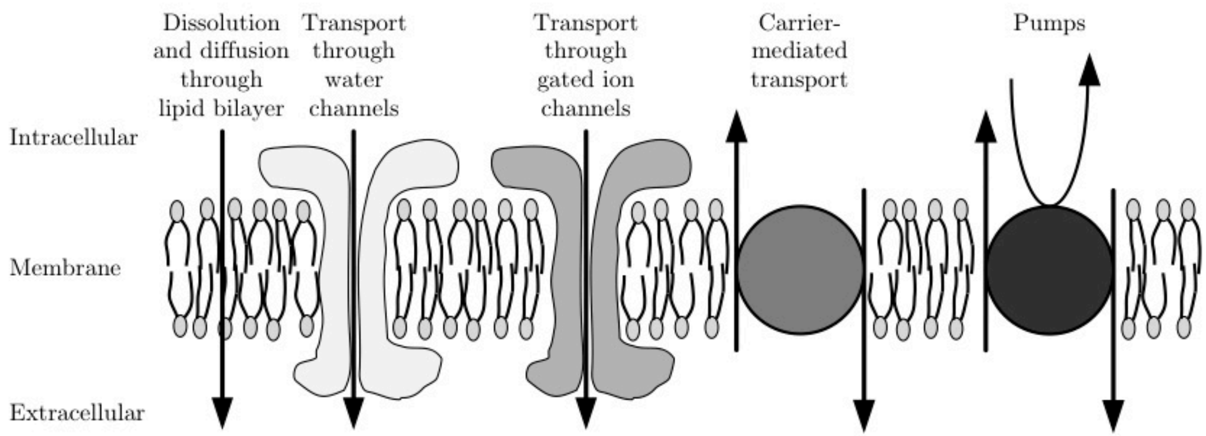
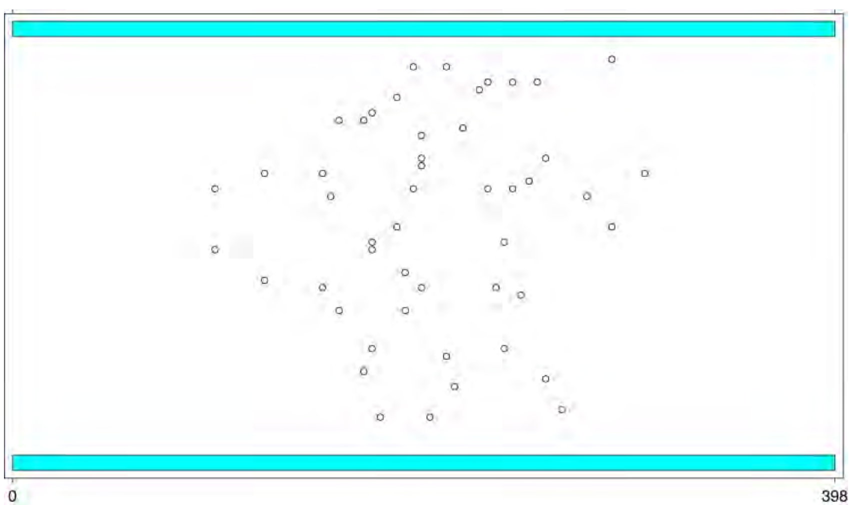
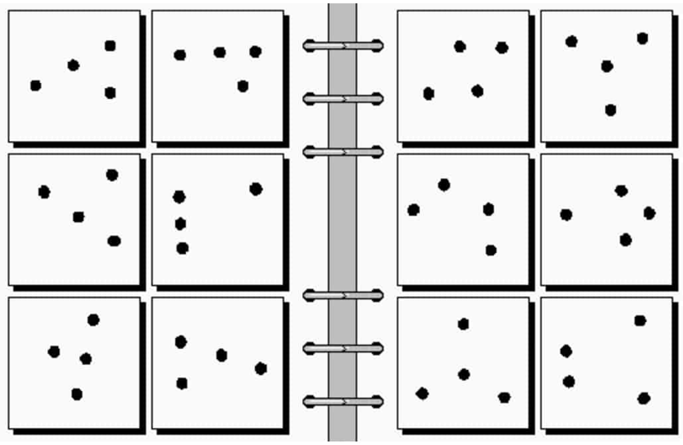


Figure 2.19




```
% NOTE: the loop is set up in such a way to average x2ave across walkers
for r= 1:N
    x=0;    % initialize position for r'th walker
    position(r,1)= 0;
    % loop to go through M steps for r'th walker
    for nn=1:M;
        % conditional determines whether step is to the left or right
        if (rand<bias),  x=x+1;
        else    x=x-1;  end;
        x2ave(nn)=x2ave(nn)+x^2;    % store squared displacement (handles averging across r)
        position(r,nn+1)= x;          % store displacment for each walker and step
    end;
end;
x2ave= x2ave/N;     % Divide by number of walkers
% plot MSD
figure(1);
plot([1:1:M], x2ave, 'k'); hold on;
title(['MSD for 1-D random walk (average from ',num2str(N),' walkers)']);
xlabel('Step number'); ylabel('Mean-Squared Distance (x^2)');
% plot a subset of individual traces
figure(2); clf; hold on; grid on;
for nn=1:K
    shade= 1-(nn-1)/K;
    plot(position(nn,:),'Color',[1 1 1]-shade);
end
xlabel('Step number'); ylabel('Position'); title('Representative traces');
plot([0 M],[1 1]*sqrt(x2ave(end)),'g--','LineWidth',2) % include MSD bounds at step M
plot([0 M],[-1 -1]*sqrt(x2ave(end)),'g--','LineWidth',2)
plot(M,sqrt(mean(position(:,end).^2)),'ro');    % reality check (another way to compute final MSD)
disp(['Final mean (non-squared) distance = ',num2str(mean(position(:,end)))]);
```

(side-)Theme: Computational approaches (i.e., programming)



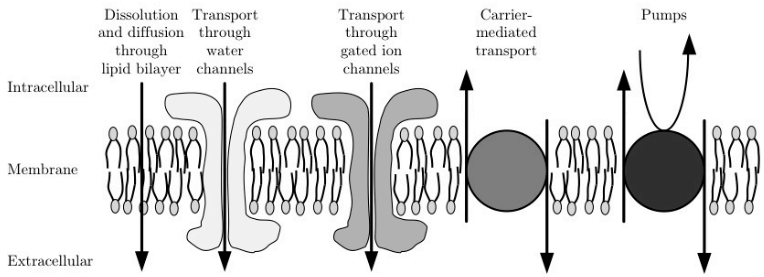
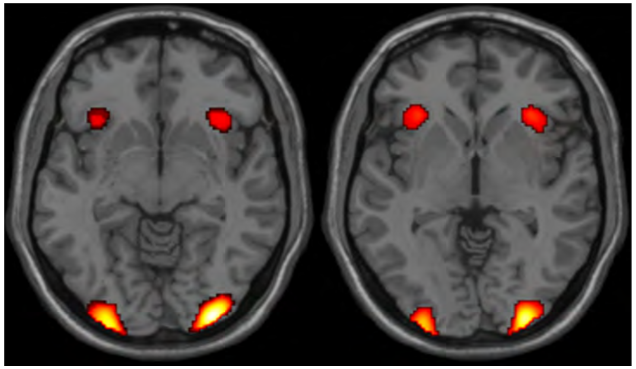


Figure 2.19

Your brain/community is “programmed” to solve problems...

... so how might you “program” a computer to solve these problems?



Lennart Nilsson

Mathematics of Vision Workshop

October 17-18, 2019
Fields Institute, Toronto, ON Canada

<u>Invited Speakers</u>

- Stephanie Palmer (U. of Chicago)
- Alexandre Pouget (U. of Geneva)
- Odelia Schwartz (U. of Miami)
- Tatyana Sharpee (UCSD, Salk Inst.)
- Lai-Sang Young (NYU)
- Richard Zemel (U. of Toronto & Vector Inst.)

∴ Website ⇒ http://www.fields.utoronto.ca/activities/19-20/vision
∴ Pre-registration ⇒ https://forms.gle/k9NA82w9gTCBn67V7
∴ Questions? ⇒ MOVfields2019@gmail.com

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