Reflection Activity

1. Why might we care about scientific communication?
   When will we need to communicate science?

2. What makes you feel that any communication has been successful?
   As a receiver?
   As a sender?

What makes you feel that communication has been successful?

As a receiver?

Clear message, logic flows, you can find your way around, visual appeal

As a sender?

Reward (citation, grade, funding), good feedback: questions or criticism

We often blame ourselves for struggling to understand talks or papers…

“I got stuck here. I feel like there was a huge logical leap I couldn’t follow.”

“There’s way too much going on in this plot. What am I supposed to be looking at?”

but poor communication is often the barrier, not your scientific understanding.

In these workshops, we'll turn your instincts as a reader of science into tools for identifying…

WHEN scientific communication is confusing

WHY it's confusing

HOW to fix the problem

…and start applying these tools to your 20.109 work.

What we'll do in a workshop:

1. Discuss an example from the field
2. Derive principles and strategies
3. Practice strategies
4. Go home with a checklist/rubric

Practice with a fellow at the

be.mit.edu/communicationlab

Designing Effective Figures

20.109 Communication Workshop 1

Dr. Prerna Bhargava and Dr. Sean Clarke

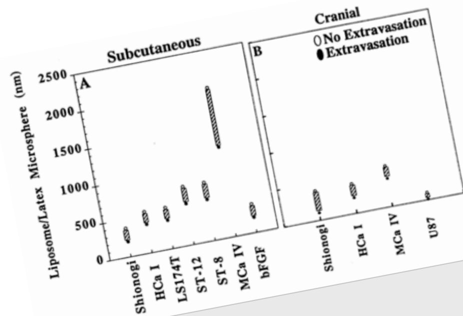
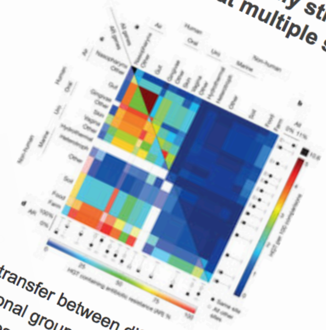


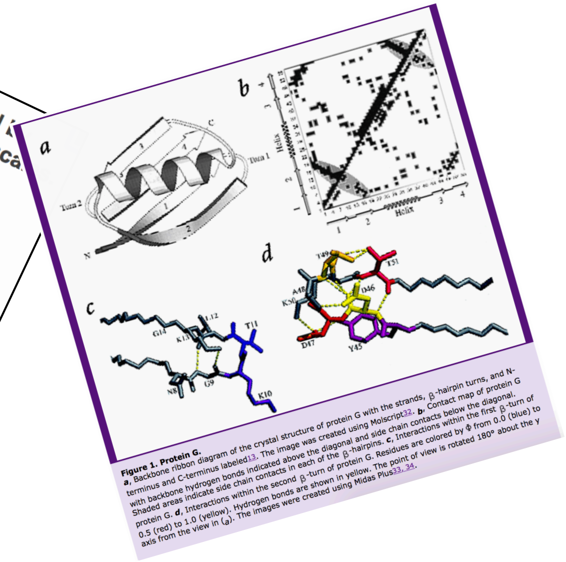
Figure 1

The vascular pore cutoff size for six different types of tumors grown in the dorsal c
tumors grown in the cranial window (*B*) was evaluated. The solid circles represe
extravasation at the indicated long-circulating liposome or latex bead size. Th
extravasation at the indicated liposome/latex bead size. The size range be
extravasated and the first particle that did not extravasate indicates the va
(hatched bar). The majority of tumors have a vascular pore cutoff size range b
when grown subcutaneously in the dorsal chamber. The interaction of the tumor wi
microenvironment (*B*) leads to a smaller vascular pore cutoff size than the interaction of
with the subcutaneous microenvironment (*A*). Comparison of bFGF-induced vessels (bFGF)
induced vascular pore sizes demonstrates that the presence of bFGF alone can lead to pores of

Figure 3: **HGT is ecologically structured i functional class and at multiple spatial sca**



The frequency of transfer between different environments is shown for all functional groups (**a**, **b**) and for antibiotic resistance (AR) genes only (**c**, **d**). Box widths indicate the number of genomes from each environment. **a**, When all genes...



Figures (and captions)

Why start here?

Figures must convince your audience of your data's impact and credibility.

Science AAAS

Article | Figures & Data | Info & Metrics | eLetters | PDF

PNAS

Abstract | Full Text | Authors & Info | Figures | Metrics | Related Content | PDF

- Expert audiences may ONLY read: Title
  Abstract
  FIGURES
- Figures help tell your story compellingly and honestly.
- Figures present your "naked" data for evaluation.

Activity: Identify the basic figure components

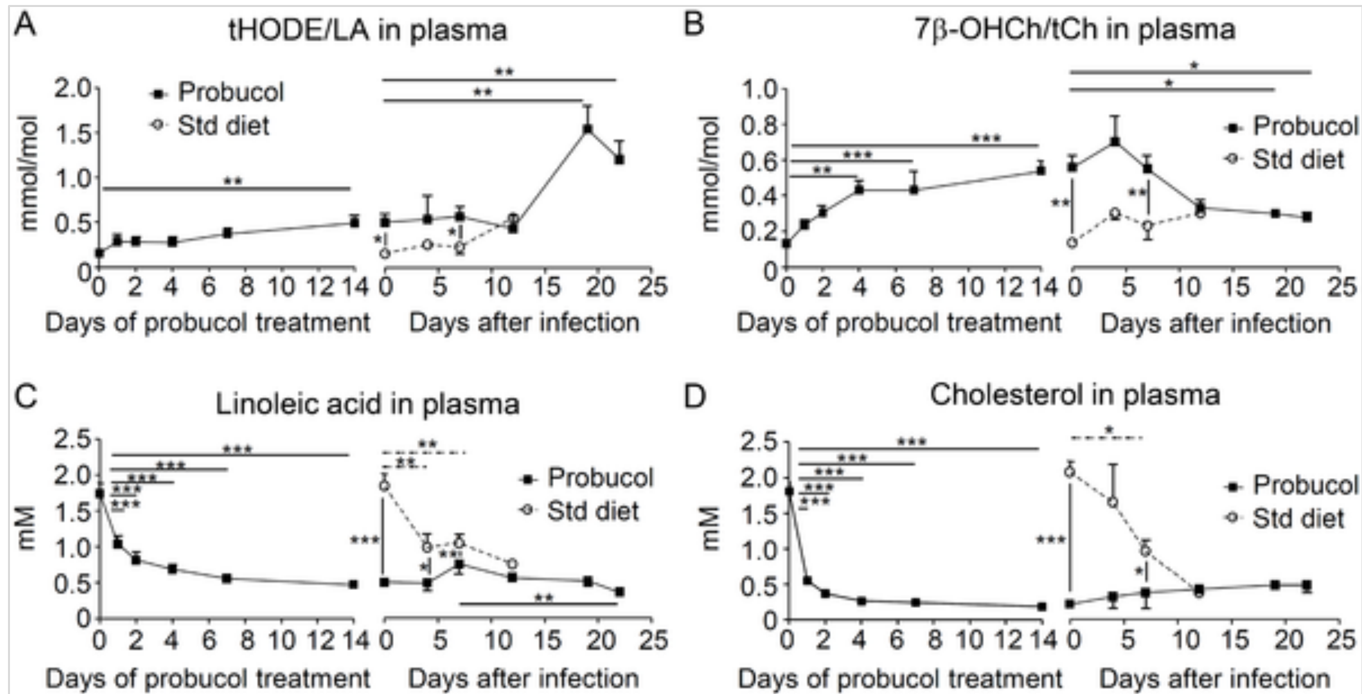


Fig 4. The ratios of lipid peroxidation products to parent lipids in plasma increased after probucol pre-treatment. Six-week-old C57BL/6J mice were treated with 1% w/w probucol in the diet for 2 weeks and then infected with 0.2 mL of 1×10^5 erythrocytes /mL infected with *Plasmodium yoelii* XL-17. Plasma samples were obtained at day 0, 1, 2, 4, 7, and 14 after starting the probucol diet (n = 5 per group) and at day 0, 4, 7, 12, 19, and 22 post-infection (n = 2 to 7). The ratio of total hydroxyoctadecadienoic acid (HODE), a peroxidation product of linoleic acid (LA), to linoleic acid (tHODE/LA) in plasma (A) and the ratio of 7β-hydroxycholesterol (7β-OHCh), a peroxidation product of cholesterol, to total cholesterol (7β-OHCh/tCh) in plasma (B) were measured. The concentration of LA (C) and tCh (D) were measured by using gas chromatography-mass spectrometry (GC-MS). All data are expressed as mean ± SE. Statistical analysis was carried out by analysis of variance (ANOVA). $*p < 0.05$, $**p < 0.025$, and $***p < 0.001$. The solid bars indicate the significant changes in probucol-treated groups and the dotted bars indicate the significant changes in standard (Std) diet-fed mice.

Figure = message + data

Choice of data

- Only data critical to the conclusion

Presentation choices

- Type of graph or display, legends & labeling, design choices
- Uncluttered elements
- Allow quick evaluation of conclusions without relying on the legend or caption.

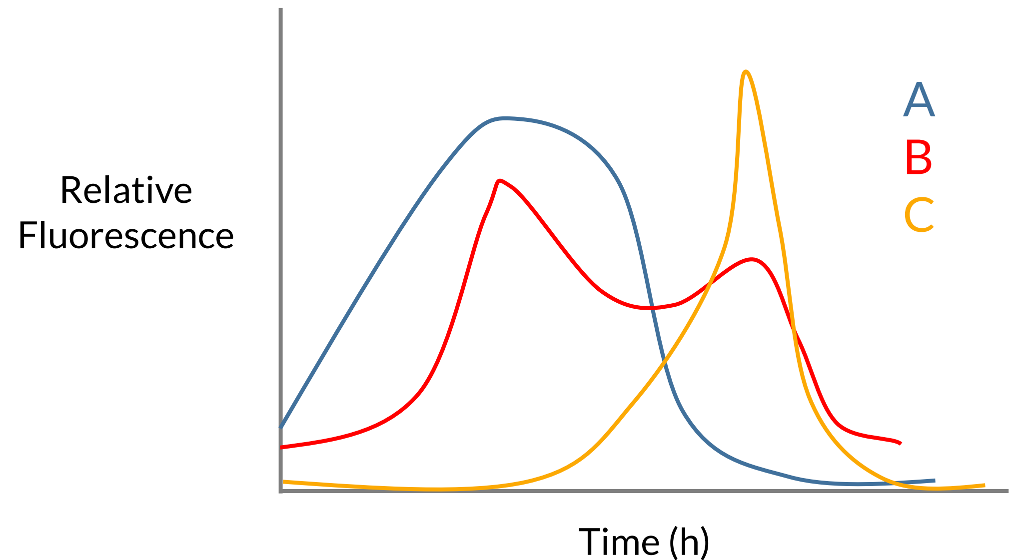


Figure 1. A, B, and C have different dynamics under Condition X. A, B, and C were sampled using Method 1 and their fluorescence quantified with Method 2. Fluorescence data normalized to negative control.

Figure titles express your message

Title

- Take-home ***message*** of the figure
- What conclusion should the reader evaluate when looking at the figure?

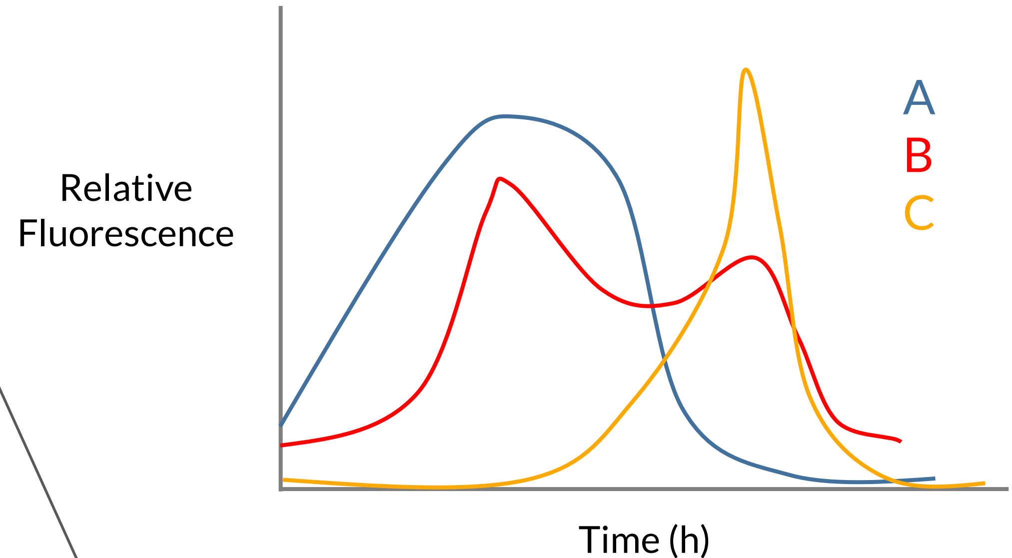
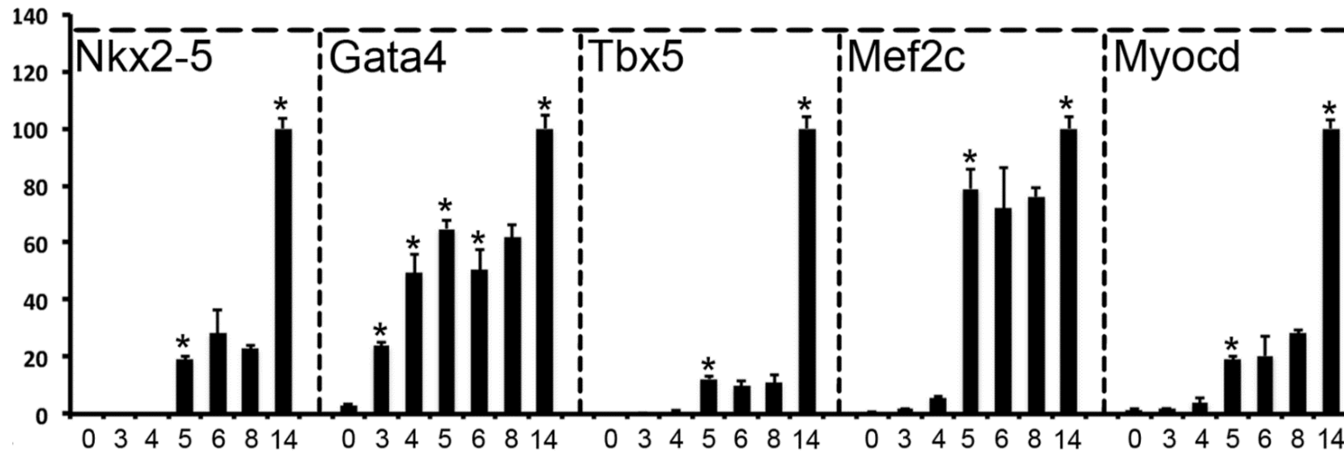


Figure 1. A, B, and C have different dynamics under Condition X. A, B, and C were sampled using Method 1 and their fluorescence quantified with Method 2. Fluorescence data normalized to negative control.

Message: Use titles to state a figure's message, not the method



Gene expression analysis performed on differentiating mouse iPS cells

Expression of early cardiac transcription factors increases over time in differentiating mouse iPS cells

Christoforou N, *et al.* (2013) PLoS ONE 8(6): e65963. doi:10.1371/journal.pone.0065963

The caption is how you got the data, without a message

Title

- Take-home ***message*** of the figure
- What conclusion should the reader evaluate when looking at the figure?

Caption

- Descriptive, not explanatory/interpretive
- Only enough methodological detail to make it clear how results were obtained.

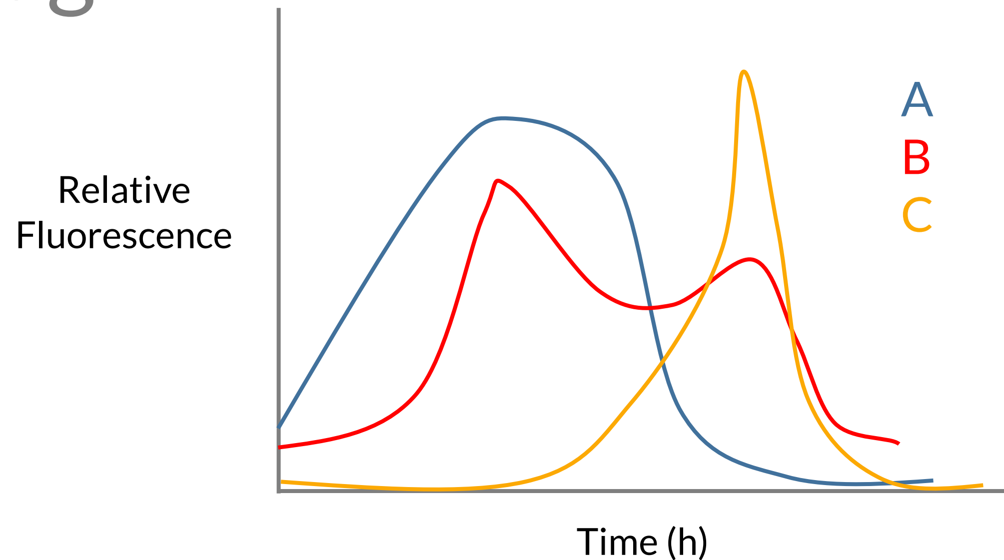


Figure 1. A, B, and C have different dynamics under Condition X. A, B, and C were sampled using Method 1 and their fluorescence quantified with Method 2. Fluorescence data normalized to negative control.

All figures you make need all of these components

Schematics

Diagrams

Photos

are figures too!

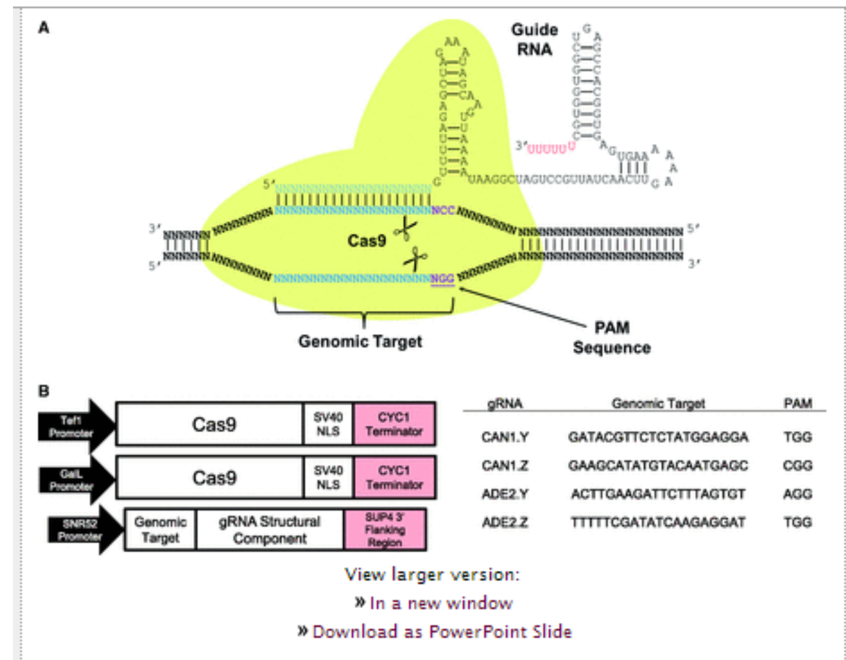


Figure 1.
Diagram of Cas9 complex and schematic of genetic constructs. (**A**) Illustration of Cas9 protein interacting with CRISPR gRNA to direct endonuclease activity proximal to the PAM sequence. (**B**) Design of the Cas9 and gRNA constructs. Cas9 gene contained a SV40 nuclear localization signal and was expressed under the Gal-L inducible promoter in CAN1 experiments and the TEF1 constitutive promoter in ADE2 experiments. The gRNA was

DiCarlo, *et al*., 2013 Nuc. Acids. Res.

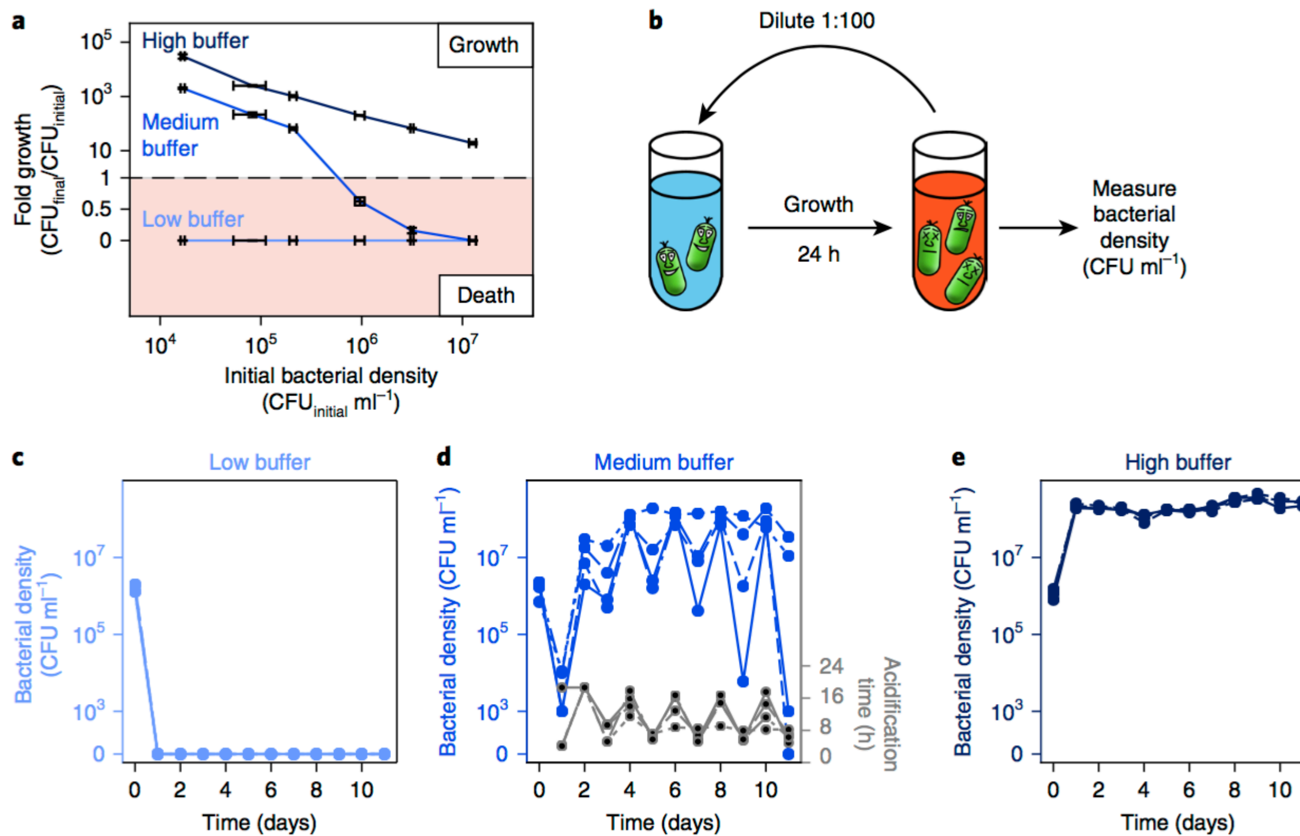


Fig. 2 | Ecological suicide can cause oscillations in the population size over time. a, At a low buffer concentration (10 mM phosphate), the bacteria commit ecologic suicide, whereas at a high buffer concentration (100 mM phosphate), the bacteria grow, in both cases independent of their initial density. However, at a moderate buffer concentration (26 mM phosphate), the bacteria die at high starting densities and grow at low starting densities. The fold growth at a high buffer concentration decreases for increasing initial bacterial densities, since the final bacterial density equals the carrying capacity and is therefore constant. Mean (solid lines) and s.e.m. (error bars) are shown for four replicates. The black horizontal dashed line corresponds to a fold growth of 1. **b**, To explore long time growth dynamics, the bacteria were grown in a daily dilution scheme with 24 h of incubation in well-mixed conditions followed by a 1:100 dilution into fresh medium. **c**,**e**, At low (10 mM phosphate; **c**) and high (100 mM phosphate; **e**) buffer conditions, the bacteria either die on the first day or grow to saturation every day. **d**, However, at medium buffer conditions, we measure oscillatory dynamics of the bacterial density. This is accompanied by oscillations in the time that the bacteria need to acidify the environment (acidification time, Supplementary Fig. 8). The exact type of oscillatory dynamics depends on the slope and shape of the curve in **a**, as discussed in more detail in the Supplementary Information. **c**–**e**, The four blue lines (solid, dashed, dotted, dashed-dotted; the separated curves can be seen in Supplementary Fig. 5) show different replicates. The strong differences between the replicates highlight the sensitivity of these oscillations to experimental conditions and that they probably do not show a limit cycle oscillation.

Ratzke, Denk, *et al.*, 2018, Nature Ecol & Evol.

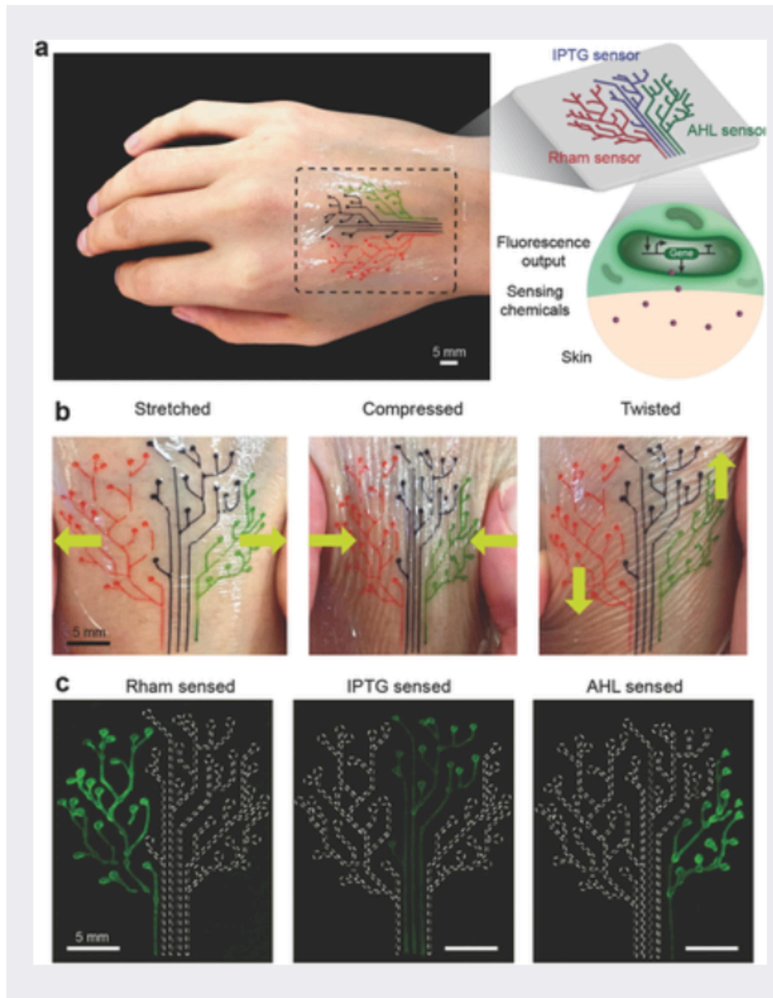


Figure 5

3D-printed living tattoo for chemical detection on human skin. a) The design of the living tattoo. The tattoo is printed as a tree-like pattern on a thin elastomer layer, which is then adhered to human skin. Hydrogels with different colors illustrate the different types of cells encapsulated. Inset: Schematic illustration of living sensors embedded in the tattoo, which can respond to different chemicals by emitting fluorescence. b) The living tattoo on skin in different states: stretched (left), compressed (middle), and twisted (right). Food dyes are added to facilitate visualization of the hydrogel pattern in (a) and (b). c) The response of the living tattoo on the skin smeared with Rham (left), IPTG (middle), or AHL (right).

Liu, *et al.*, 2017, Adv. Materials

Steps to turn your pile of data into figures…

1 MESSAGE

What is the message of each figure?

2 DATA

What data do you include in each figure to convey your message?

How can you present your data to support your message?

3 DESIGN

What are some key design choices to think about?

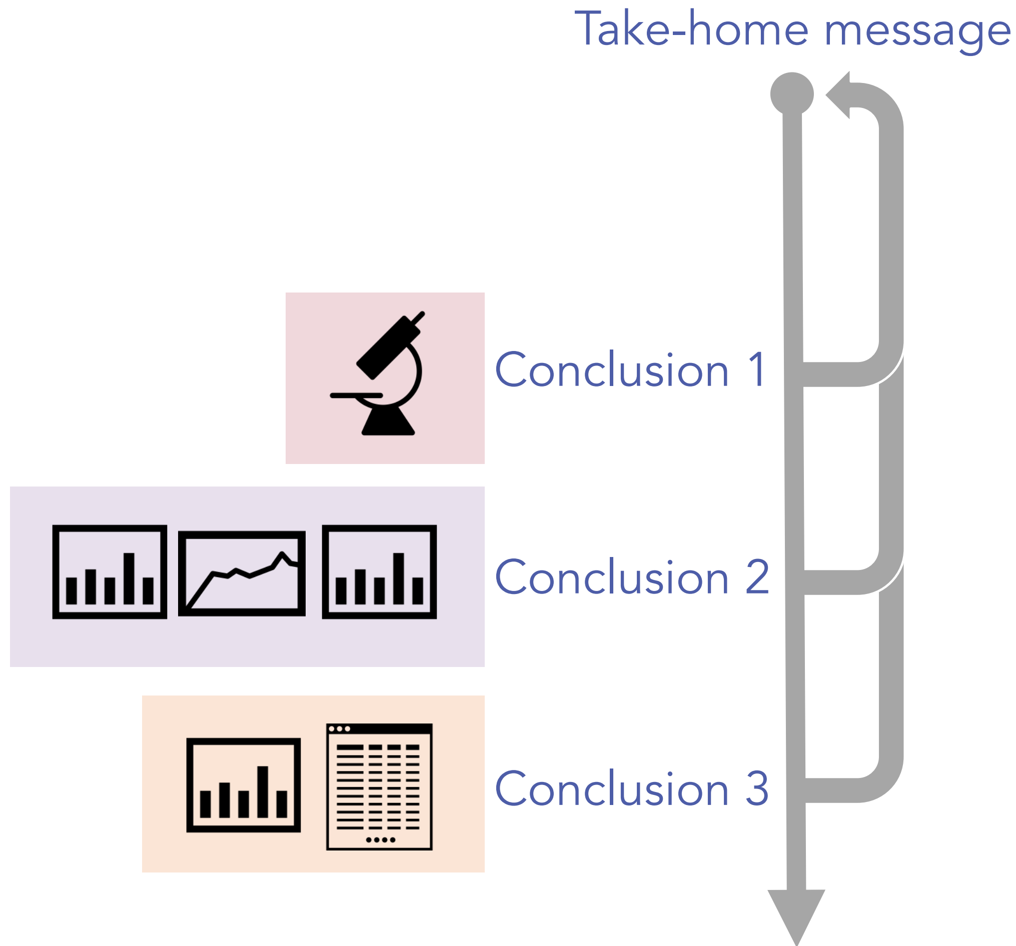
Organize your figures to build one storyline

Rearrange until you've created a **logical series** of conclusions.

Identify **modules** that correspond to **conclusions**.

Organize figures to build a single storyline

Identify **modules** that correspond to **conclusions**.



Message: All the data in a figure should support one clear message.

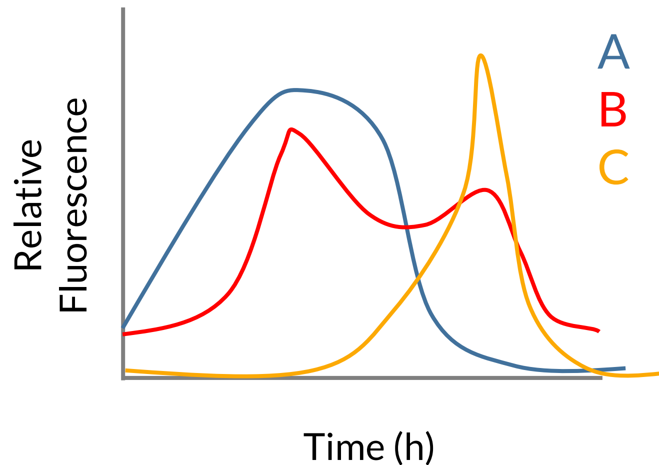


Fig. 1: A, B, and C have different dynamics under Condition X. A, B, and C were sampled using Method 1 and their fluorescence quantified with Method 2. Fluorescence data normalized to negative control.

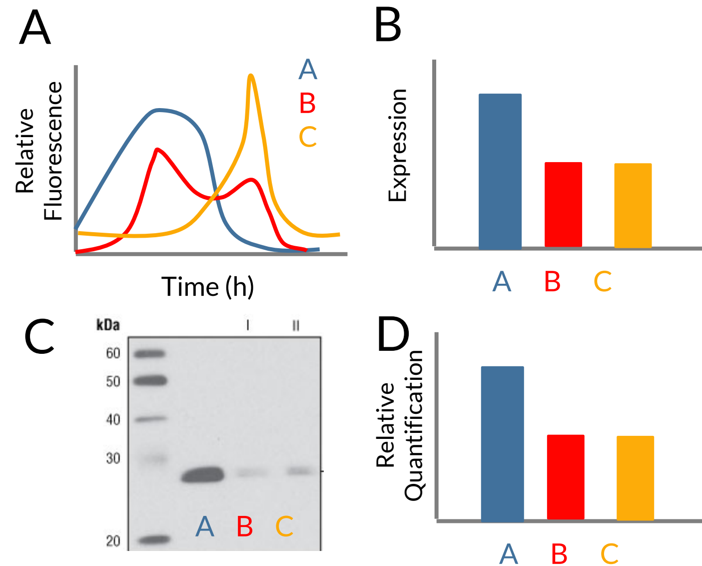


Fig. 1: A, B, and C have different dynamics under Condition X. A) A, B, and C were sampled using Method 1 and their fluorescence quantified with Method 2. Fluorescence data normalized to negative control. B) Gene expression data of samples A, B, and C, under condition X. Samples were collected at time T. C) Western blot analysis of samples A, B, and C, under condition X. D) Quantification of Western Blot.

Steps to turn your pile of data into figures...

1 MESSAGE

What is the message of each figure?

2 DATA

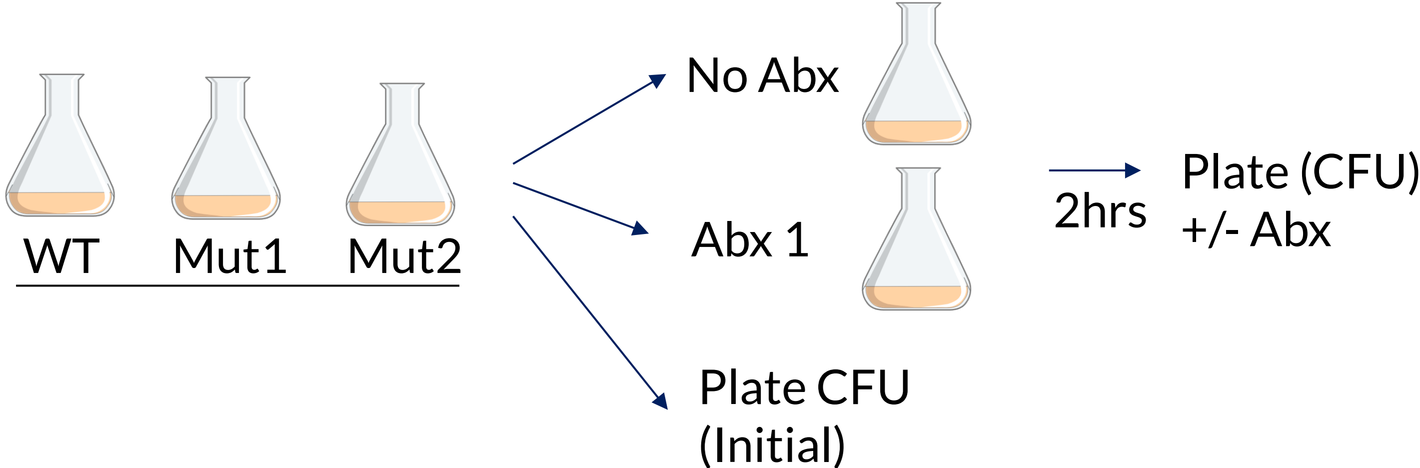
What data do you include in each figure to convey your message?

How can you present your data to support your message?

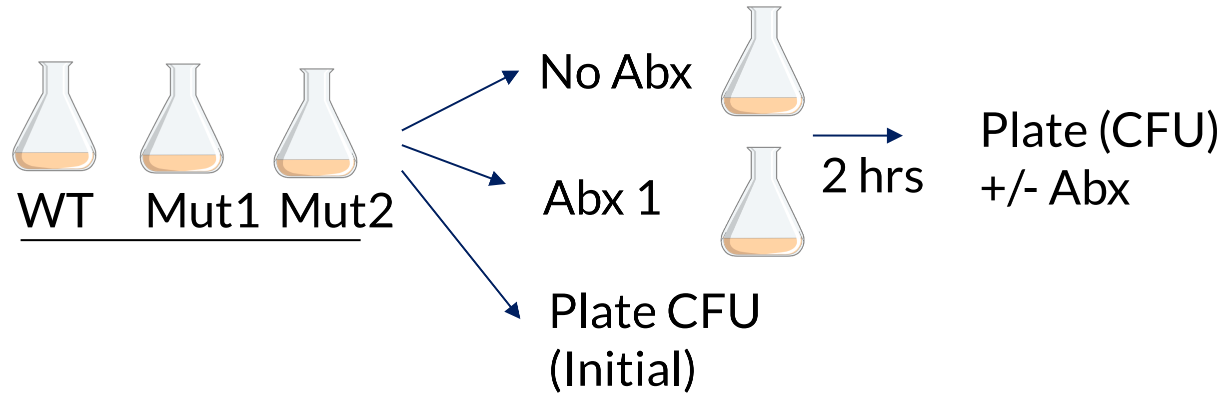
3 DESIGN

What are some key design choices to think about?

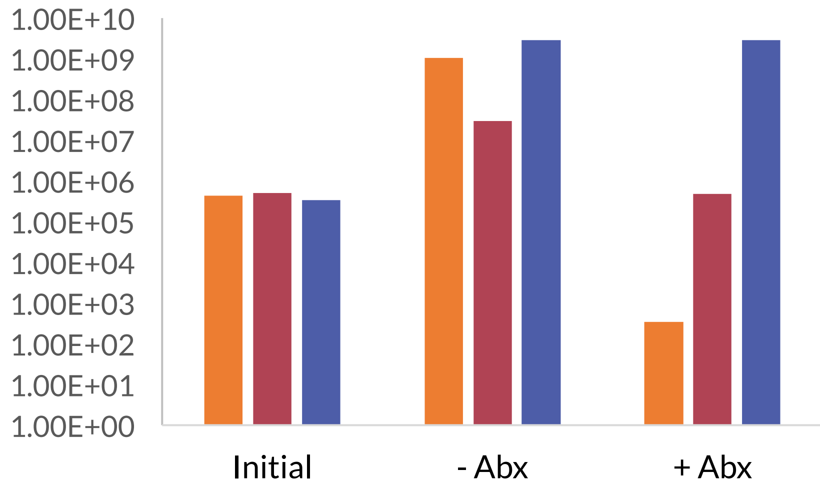
Activity: Here's an experiment



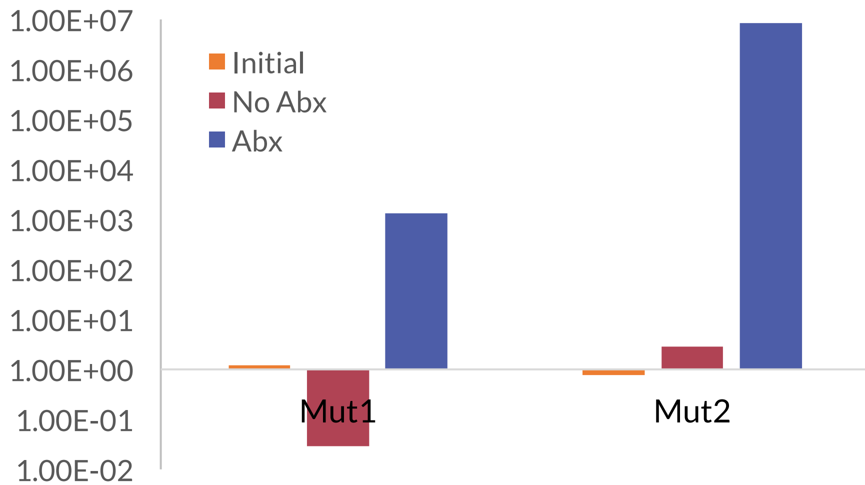
Activity: How can we present this data?



Strain	Condition	Replicate 1	Replicate 2	Replicate 3	Average
WT	Initial	1.8e5	3.2e5	7.8e5	4.3e5
WT	- Abx	1.0e9	1.3e9	8e8	1.0e9
WT	+ Abx	2.3e2	2.8e2	5.5e2	3.5e2
Mut1	Initial	2.5e5	8.3e5	4.6e5	5.1e5
Mut1	- Abx	5.5e7	2.3e7	1.1e7	3.0e7
Mut1	+ Abx	4.3e5	7.5e5	2.2e5	4.7e5
Mut2	Initial	5.3e5	3.2e5	1.3e5	3.3e5
Mut2	- Abx	3.4e9	2.2e9	3.0e9	2.9e9
Mut2	+ Abx	2.2e9	5.3e9	1.2e9	2.9e9


1.00E+10
1.00E+09
1.00E+08
1.00E+07
1.00E+06
1.00E+05
1.00E+04
1.00E+03
1.00E+02
1.00E+01
1.00E+00
Initial
- Abx
+ Abx

1.00E+04
1.00E+03
1.00E+02
1.00E+01
1.00E+00
1.00E-01
1.00E-02
1.00E-03
1.00E-04
WT
Mut1
Mut2
No Abx
Abx


1.00E+07
1.00E+06
1.00E+05
1.00E+04
1.00E+03
1.00E+02
1.00E+01
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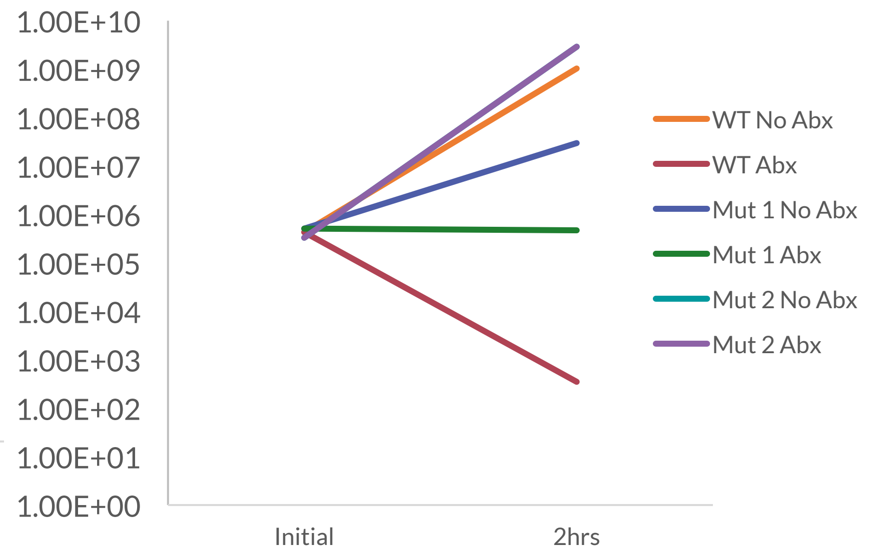
1.00E-01
1.00E-02
Initial
No Abx
Abx
Mut1
Mut2


1.00E+10
1.00E+09
1.00E+08
1.00E+07
1.00E+06
1.00E+05
1.00E+04
1.00E+03
1.00E+02
1.00E+01
1.00E+00
Initial
2hrs
WT No Abx
WT Abx
Mut 1 No Abx
Mut 1 Abx
Mut 2 No Abx
Mut 2 Abx

Activity: Improve this published figure

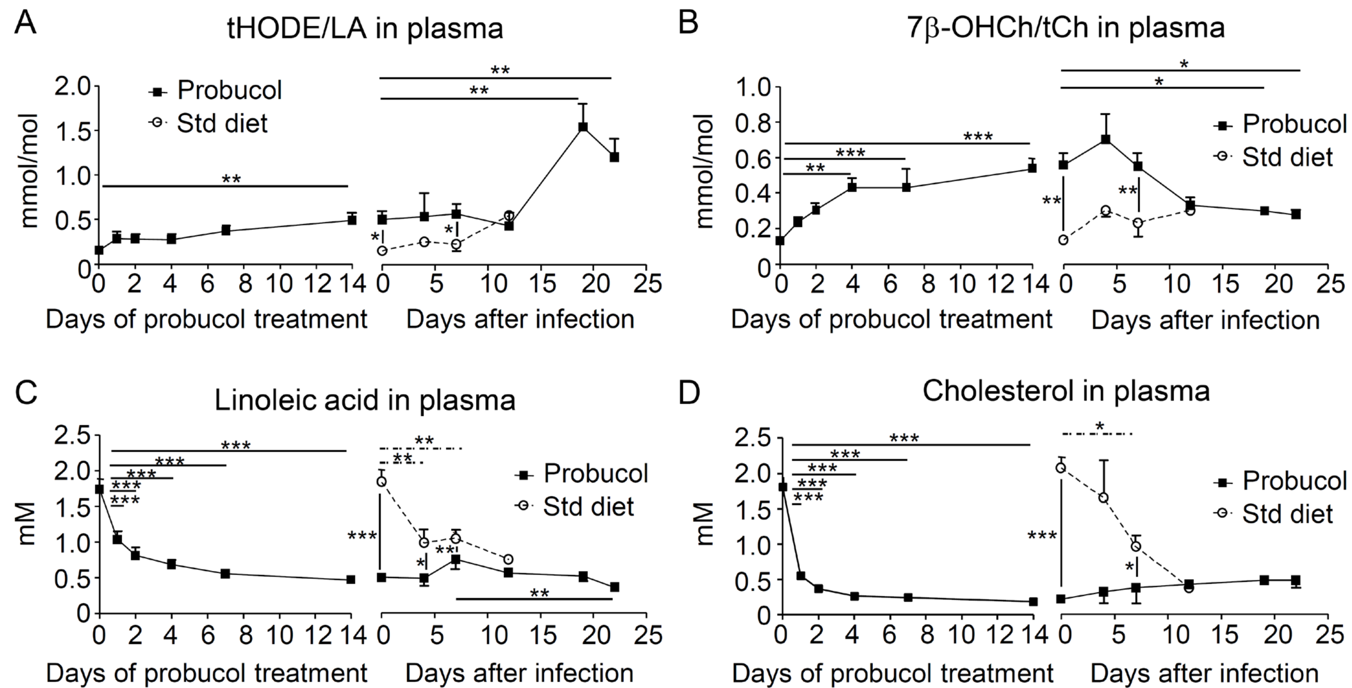


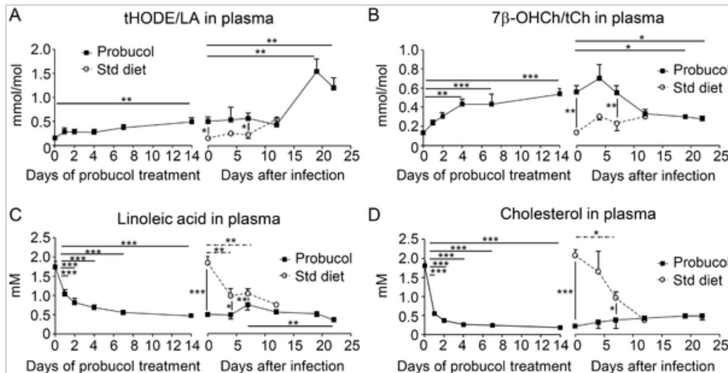
Fig 4. The ratios of lipid peroxidation products to parent lipids in plasma increased after probucol pre-treatment.
Six-week-old C57BL/6J mice were treated with 1% w/w probucol in the diet for 2 weeks and then infected with 0.2 mL of 1×10^5 erythrocytes /mL infected with *Plasmodium yoelii* XL-17. Plasma samples were obtained at day 0, 1, 2, 4, 7, and 14 after starting the probucol diet (n = 5 per group) and at day 0, 4, 7, 12, 19, and 22 post-infection (n = 2 to 7). The ratio of total hydroxyoctadecadienoic acid (HODE), a peroxidation product of linoleic acid (LA), to linoleic acid (tHODE/LA) in plasma (A) and the ratio of 7β-hydroxycholesterol (7β-OHCh), a peroxidation product of cholesterol, to total cholesterol (7β-OHCh/tCh) in plasma (B) were measured. The concentration of LA (C) and tCh (D) were measured by using gas chromatography-mass spectrometry (GC-MS). All data are expressed as mean ± SE. Statistical analysis was carried out by analysis of variance (ANOVA). *$p < 0.05$, **$p < 0.025$, and ***$p < 0.001$. The solid bars indicate the significant changes in probucol-treated groups and the dotted bars indicate the significant changes in standard (Std) diet-fed mice.

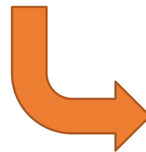
Herbas MS *et al* (2015) **PLoS ONE** 10(8): e0136014.

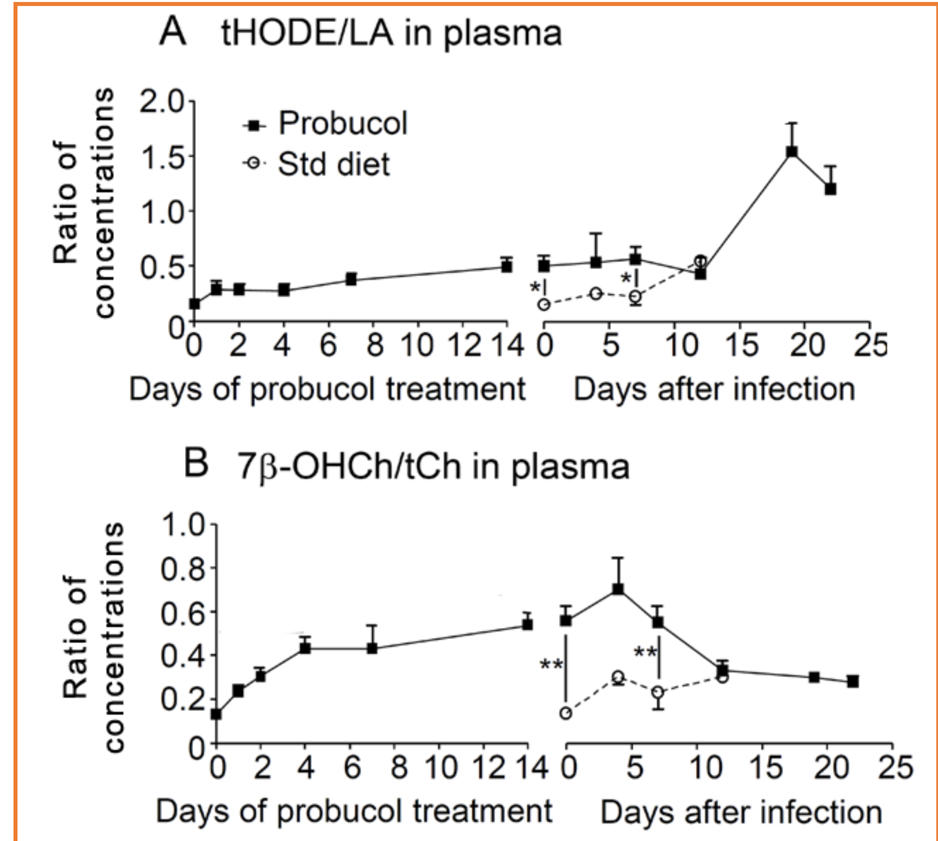
Evaluating figure choices

- Is the central message validated by the data shown?
- Which data are irrelevant?
- Are there any data/labels missing?
- What could be done to better highlight the most important data?
- Is there a better way to present the data?
- Do the statistics actually add anything here?

Only include the minimum information necessary to draw a conclusion.







Steps to turn your pile of data into figures…

1 MESSAGE

What is the message of each figure?

2 DATA

What data do you include in each figure to convey your message?

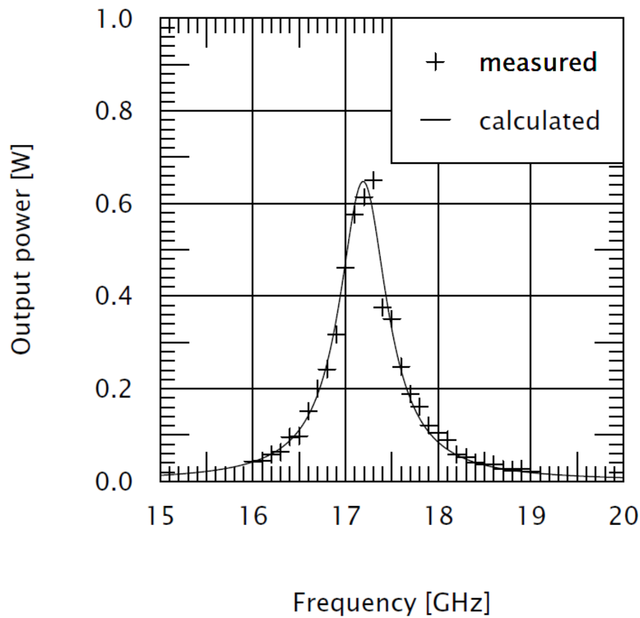
How can you present your data to support your message?

3 DESIGN

What are some key design choices to think about?

Design: Maximize signal-to-noise

State your message.
Eliminate anything that distracts from it.



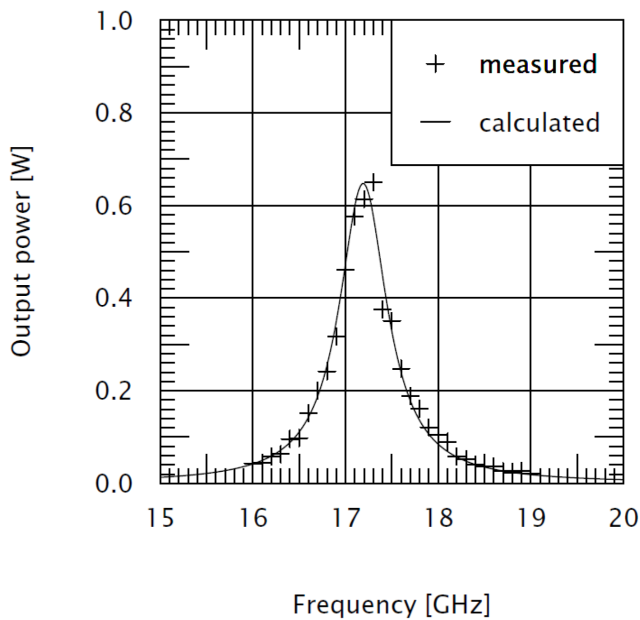
Low signal-to-noise ratio

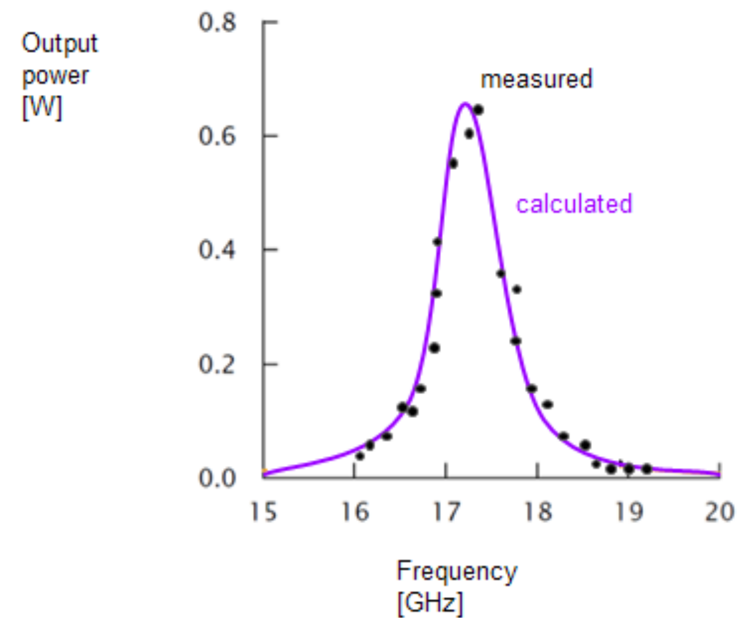
The background interferes with the data.

Adapted from Jean-luc Doumont, *Trees, Maps, and Theorems*

Design: Maximize signal-to-noise

State your message.
Eliminate anything that distracts from it.





Low signal-to-noise ratio

The background interferes with the data.

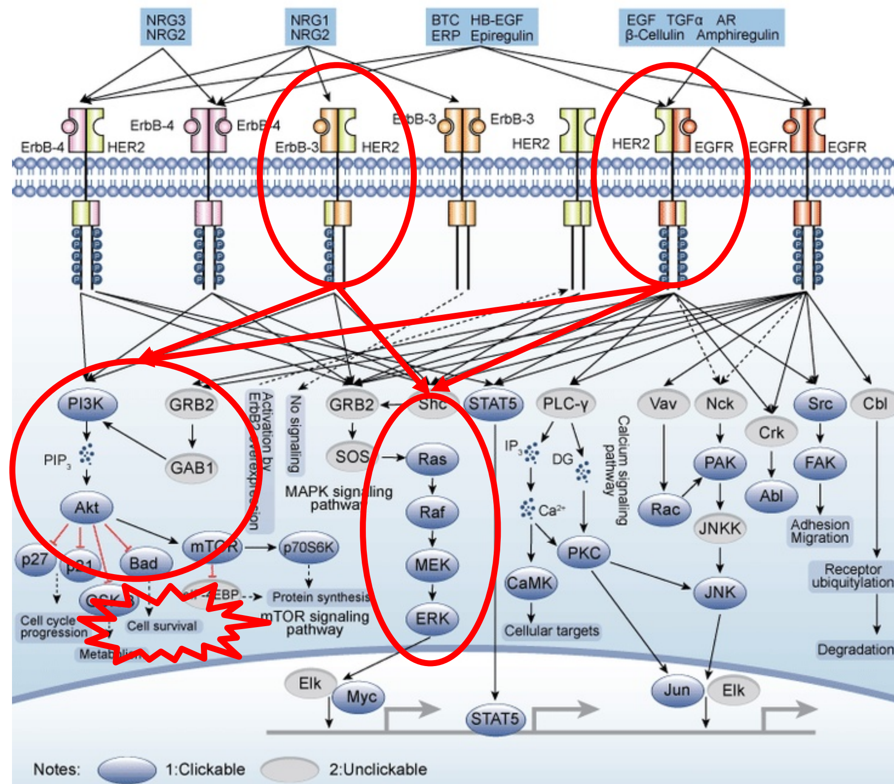
High signal-to-noise ratio

Only the necessary information is shown.

Adapted from Jean-luc Doumont, *Trees, Maps, and Theorems*

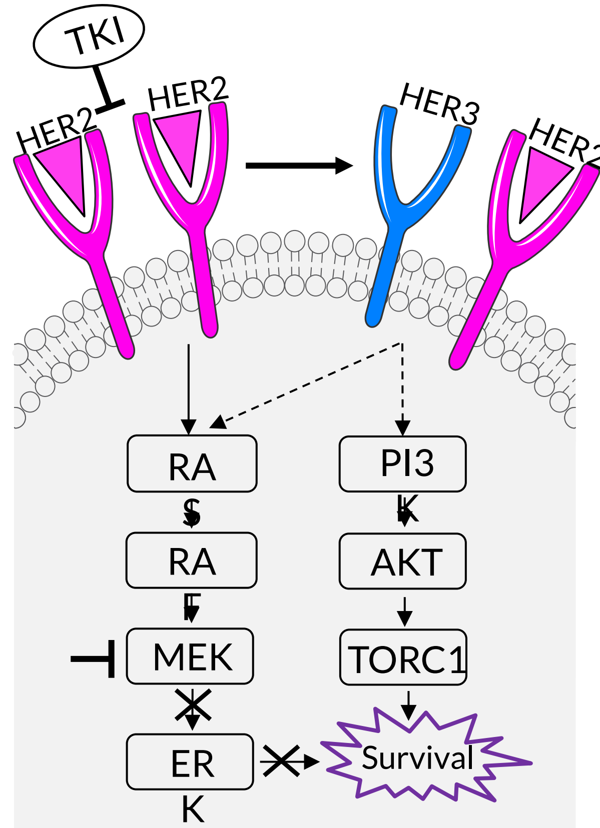
Design: Schematics should include info that reinforces your message

receptor tyrosine kinase signaling pathway



Slide credit: L. Stopfer & G. Sun

Design: Schematics should include info that reinforces your message

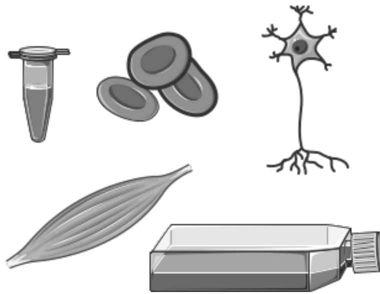


Slide credit: L. Stopfer & G. Sun

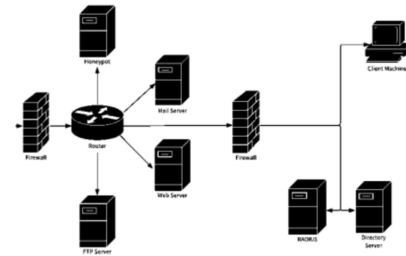
Design: You don't need to reinvent the wheel

Servier Powerpoint Image Bank & Biorender

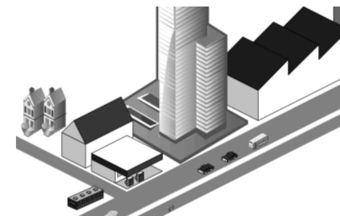
Biology, lab equipment
(free)

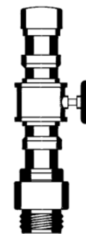


MS Visio & Lucidchart
Networks, engineering, circuits, charts
($$) & (free)



Noun Project
Everything
(free)

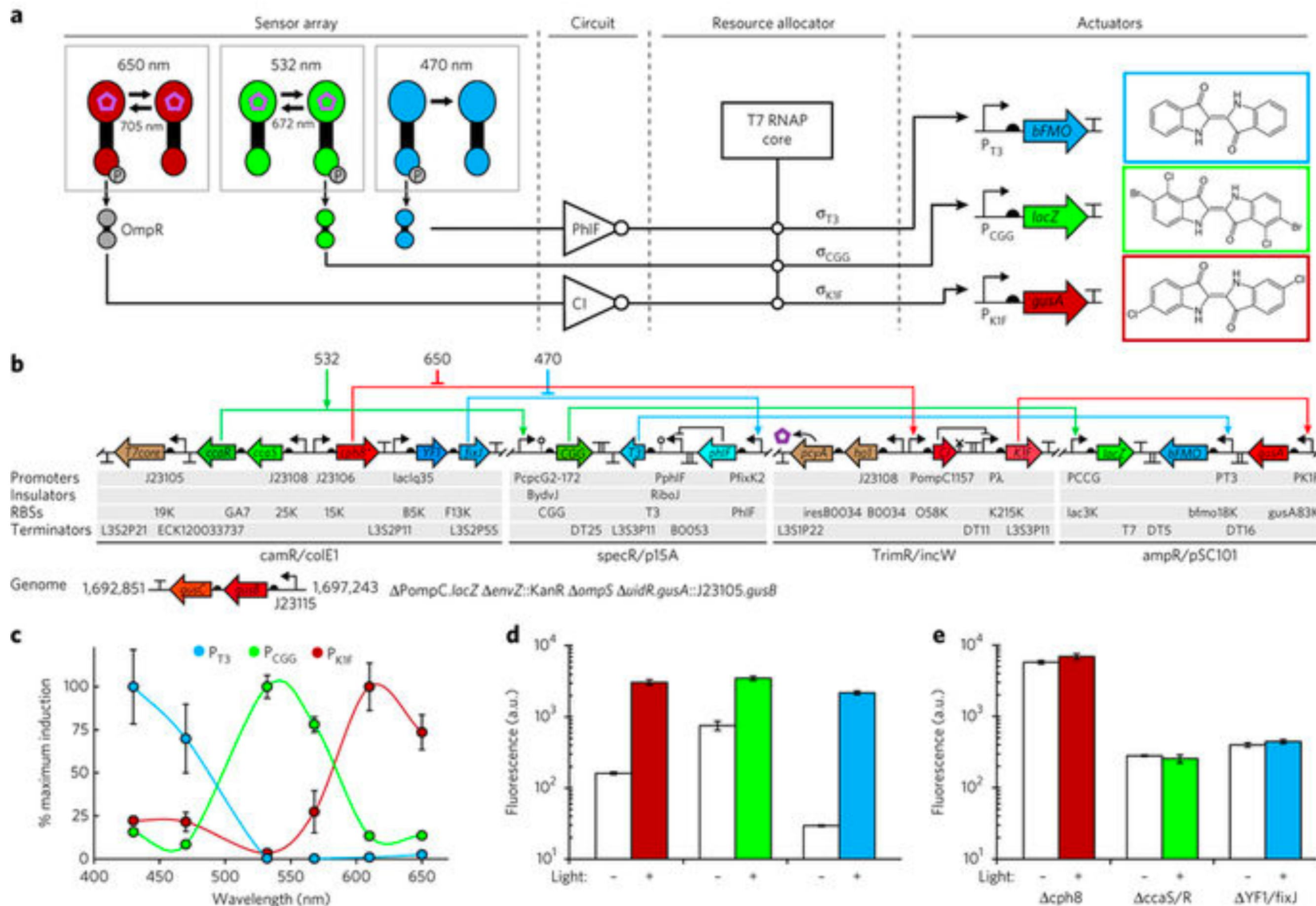




Design: Maximize signal-to-noise

Minimize # style choices and be consistent

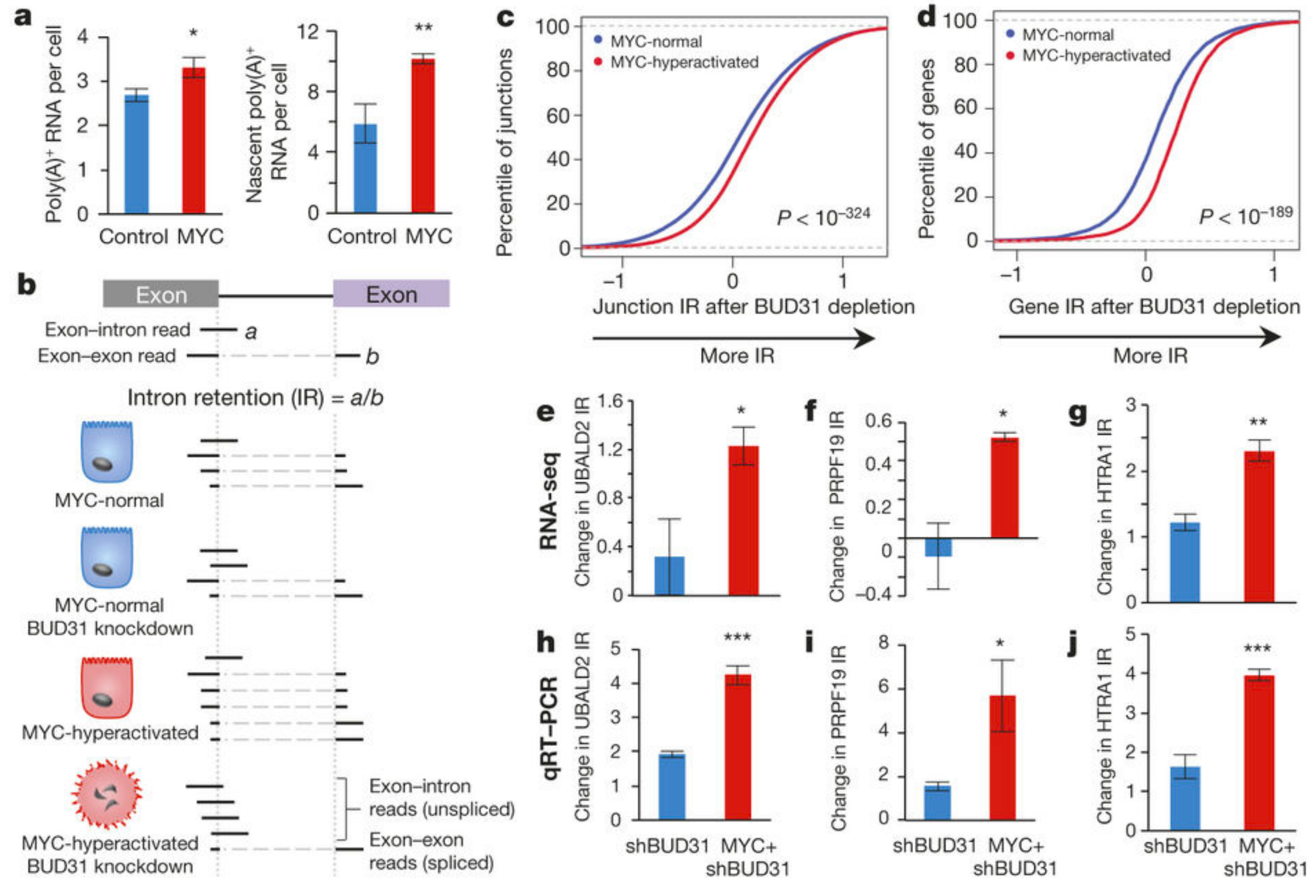
- Grayscale or a few consistent colors



Design: Maximize signal-to-noise

Minimize # style choices and be consistent

- S, M, L font sizes
- Consistent fonts and line thickness
- Consider alignment in making figures



These are our next steps

- Slides and tips will be on the wiki
- Put these tips to work on your 109 figures today and beyond
- Make an appointment with a Comm Fellow by M1D5
- We’re happy to help with all parts of data summary drafts
- In 2 weeks… Titles and Abstracts!

Optimize your figures with these reminders

High-level questions

- *Strategic purpose:*
  - What do you want to convey?
  - How will you and/or your audience use this figure?
- *Organizational structure:*
  - Where does this figure fit into the communication?
  - Why?

Checklist

- ❑ Choice of data
- ❑ Title/caption
  - Can figure stand alone?
- ❑ Consistent layout
  - Fonts, spacing, colors
- ❑ Text amount and placement
- ❑ Scale, axes, tick marks
- ❑ Error analysis
- ❑ Ink-to-whitespace ratio