(Opening Slide) Metacognition for Students *Exercise 1*

A college freshman's comment (fall 2012):

"*I entered this semester with the mindset that studying was the equivalent of reading a textbook and nothing more*."

1. What do you wish your students did differently (for studying)?

2. What convinces a student to change/improve?

Metacognition for Students:

Helping students understand their own learning by self-testing,

while also

Teaching about experimental design, controls, and sources of error.

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From a Noyce Add-on Course & a class for College Freshmen

"How Students Learn" BIOL 455

Outline: Metacognition Experiments for Learning -- Noyce Workshop

1. **Opening**
   - What do you wish your students did differently or understood about learning?

2. **What is a metacognition experiment** (as part of classroom assessment)?
   - Metacognition: definition & references
   - Example 1: Sleep on mental mathematics
   - Exercise 2: A metacognition experiment on ourselves(*two treatment groups – at each table, assign ½ to each treatment L vs. D*)

3. **Sample metacognition experiments** (college freshmen)
   - Quick summary, then time to read/skim handouts
   - Q&A

4. **Sample class metacognition experiment** (designed & run by pre-service teachers)
   - Quick summary, then time to read/skim handouts
   - Q&A

5. **Design an experiment** to learn the bacterial ruler (one experiment per table; they need not be unique)
   - Summary explanation of the Bacterial ruler
   - Q&A

   (A) THEN: Each table/group to develop a:
   - Purpose statement (what are you testing/comparing)
   - Method (maximum of 5 minutes allowed to do the experiment)
   - Analysis (each table/group needs decision rules)

   (B) NEXT
   - Run your experiment & collect data
   - Analyze (make a decision, consider biases and sources of error)
   - Report Results and Conclusions

Metacognition - Some definitions & references

- Thinking about how you think
- Thinking about your own learning
- Understanding your own learning
  - In two ways:
    1. Biological -- Neuroscience
    2. Methods for effective learning

Why does it matter?

1. Research: metacognition can improve learning
   - Readable summary:
     How People Learn 2000 (Ch 1-3)
     National Academies Press. **Free**: Google search on "How People Learn NAP"; it should be the first hit.
   - A recent paper. 2012.
     Investigating high school students' conceptualizations of the biological basis of learning.
     RM Fulop & KD Tanner.
     Advances in Physiology Education 36: 131-142
   - There are many more….
2. Student reports on transformative changes

What causes students to change the way they learn/study?

My List (and maybe yours)

1. Motivation (often Desperation)
2. Courage
3. Good learning methods
4. Practice / Experience (Experiments with N = 1)
5. Coaching / Feedback from:

- Professors or Peer Tutors
- Exam results
- Metacognition
  - ❑ *Am I learning better?*
  - ❑ *How do I **know** that I know X?*

Metacognition Experiments address 3, 4, & 5:

1. Motivation (often Desperation)
2. Courage
3. Good learning methods
4. Practice / Experience (Experiments with N = 1)
5. Coaching / Feedback from:
   - Exam results
   - Metacognition
     - ❑ *Am I learning better?*
     - ❑ *How do I **know** that I know X?*

Good Methods

Study methods handout:
Results of research on what works (and doesn't)

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Improving Students' Learning With Effective Learning Techniques: Promising Directions From Cognitive and Educational Psychology

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Table 4. Utility Assessment and Ratings of General

Technique	Utility
Elaborative interrogation	Moderate
Self-explanation	Moderate
Summarization	Low
⇩Highlighting	Low
The keyword mnemonic	Low
Imagery use for text learning	Low
⇩Rereading	Low
Practice testing	High
Distributed practice	High
Interleaved practice	Moderate

Table 1. Learning Techniques

Technique	Description
1. Elaborative interrogation	Generating an explanation for why an explicitly stated fact or concept is true
2. Self-explanation	Explaining how new information is related to known information, or explaining steps taken during problem solving
3. Summarization	Writing summaries (of various lengths) of to-be-learned texts
4. Highlighting/underlining	Marking potentially important portions of to-be-learned materials while reading
5. Keyword mnemonic	Using keywords and mental imagery to associate verbal materials
6. Imagery for text	Attempting to form mental images of text materials while reading or listening
7. Rereading	Restudying text material again after an initial reading
8. Practice testing	Self-testing or taking practice tests over to-be-learned material
9. Distributed practice	Implementing a schedule of practice that spreads out study activities over time
10. Interleaved practice	Implementing a schedule of practice that mixes different kinds of problems, or a schedule of study that mixes different kinds of material, within a single study session

Important insights:

1. Memory traces are built by your retrieval (recall).
2. Memory traces become enduring from recall on multiple days (twice/day).
3. Unless recalled, memory traces fade away.
4. Experiment on yourself; collect evidence for what works.

Important insights (expanded):

1. Memory traces are built by recall, and *NOT by re-reading, re-seeing, or re-hearing*.
   - Practicing recall is an essential part of "*Practice Testing*"

2. For problem solving without error (on exams)
   (A) Memorize the steps by recall practice
   (B) Practice solving problems using your memorized steps
   - These are versions of *Practice Testing*.

3. Memory traces become enduring because of recall on multiple days
   - Rule of thumb: practice recall twice/day for each thing (chunk) you want to remember
   - Over multiple days, practice twice/day
     - (ALWAYS check if you don't remember—don't guess)
     - Practice recall of something 6, 8 or 10 times in one day? *Rarely worth it!*
       - (*Most of the extra practice time on that day will be wasted*)
     - Is three times/day better than twice/day? *Maybe: test yourself doing both and find out.*

4. Unless recalled, memory traces fade away: *what we don't think about, we lose.*
   - For some things, make clear study materials for fast review for future recall practice

5. Experiment to find what works for you
   - No biases allowed; collect evidence.

Format of a Metacognition Experiment

1. Does ___X___ help me learn better or faster?

2. For each experiment, write out:
   a. Purpose
   b. Methods
   c. How I'll reach a conclusion (from the data you'll gather)
   d. Results (what happened)
   e. Conclusion (do I know enough to make a decision?)

Examples *(college freshman metacognition experiments)*

1. Effect of amount of **sleep** on mental math
2. Reading a chapter with **white noise** (ocean waves) versus music and/or silence
3. Effect of **mind mapping** versus outlining / rereading
4. Effect of **retrieval practice** versus outlining (time matched)
5. Effect of **sketching** with folded lists versus rereading/rewriting/ reviewing notes
6. Reading **with versus without phone and internet** on (*actually, no one did this, but I want them to*)
7. Effect of single session versus **distributed practice**

Metacognition Experiments

Title: _____

Purpose: (*To test whether ___x__ helps me learn better or faster?)*

Method:

Analysis (*How I'll reach a conclusion: is it better or faster?*):

Results:

Conclusion:

Metacognition Experiment example: Sleep & problem solving

Title: Amount of Sleep and Problem Solving *(by 2 different students)*

Purpose: to test whether the number of hours I sleep affects my ability to solve problems in my head.

Method (condensed): Methods were discussed in class in small groups.

- In advance, write out two sets of multiplication problems of equivalent difficulty
- Choose numbers at random; assign problems to treatments at random.
- Solve one set 2 hours after waking up on a night with 8 hr sleep, and the other set 2 hr after waking up on a night with 6 hr sleep.
- Record:
    - The time it takes to solve each problem
    - Whether or not I got the right answer.
    - If an answer was wrong, did I notice?
    - How confusing it felt (if it felt confusing at all).

Analysis: Decision rule: If I am just as fast to solve problems and have no more errors on 6 hours as 8 hours of sleep, then 6 hours of sleep does not affect my ability to solve this kind of problem in my head.

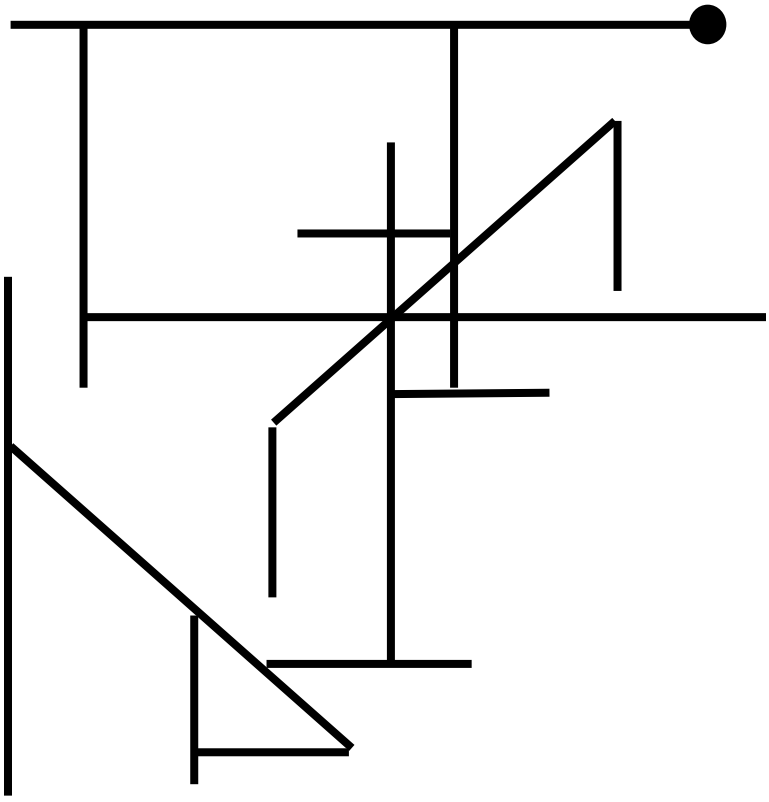
Results and Conclusions

Trial 1 – **8 hrs of Sleep**		Trial 2 – **6 hrs of sleep**	
8x4	instantaneous	6x7	instantaneous
6x34	0:07	7x83	0:09
8x957	0:15	9x203	0:10
3x2578	0:17	9x3842	0:40
18x92	0:24	38x46	0:37
71x312	0:42	31x923	1:24
983x471	2:50-Incomplete	232x549	2:00-Incomplete

Student 1: "It took me nearly twice as long to solve the problems with six hours of sleep as opposed to eight. There wasn't a big difference in the level of complexity that I could handle."

Problem	8 hours of sleep	6 hours of sleep
1x1	Instant	Instant
1x2	4 seconds	12 seconds
1x3	22 seconds	20 seconds (wrong answer)
2x3	32 seconds (easy number)	112 seconds
3x3	could not solve	could not solve

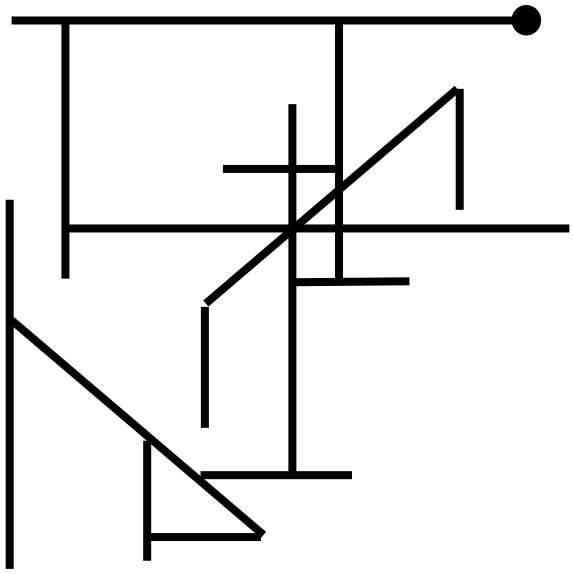
Student 2: "On 6 hours of sleep it was much harder to hold all of the individual pieces that I had to work with in my working memory…I would have to go through each step several times in my head until I could actually work with that chunk."



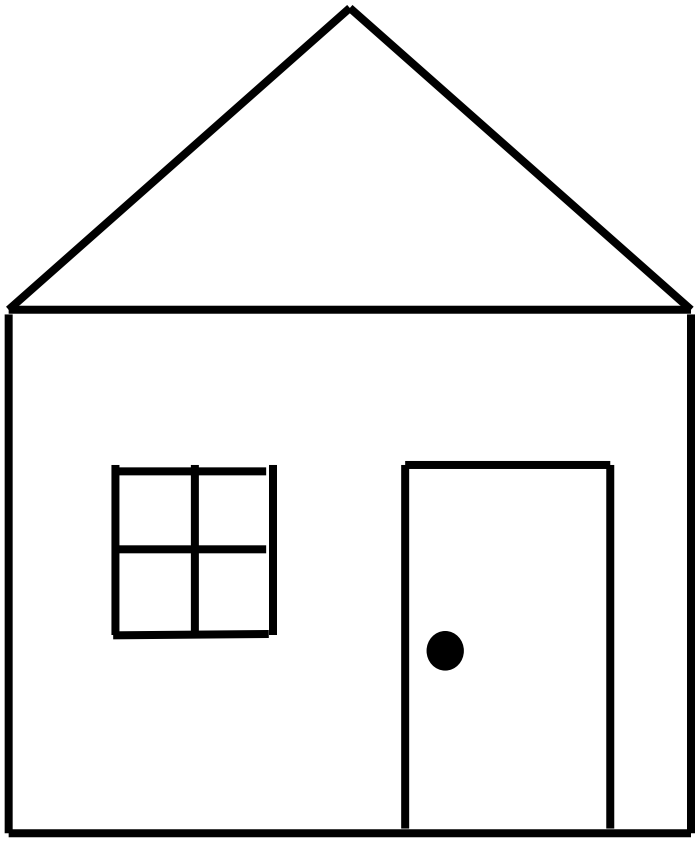
Wait 10 seconds (count to 10), then draw from memory:

Number correct:

(Or number of errors):



Let's try again, with the same lines rearranged.

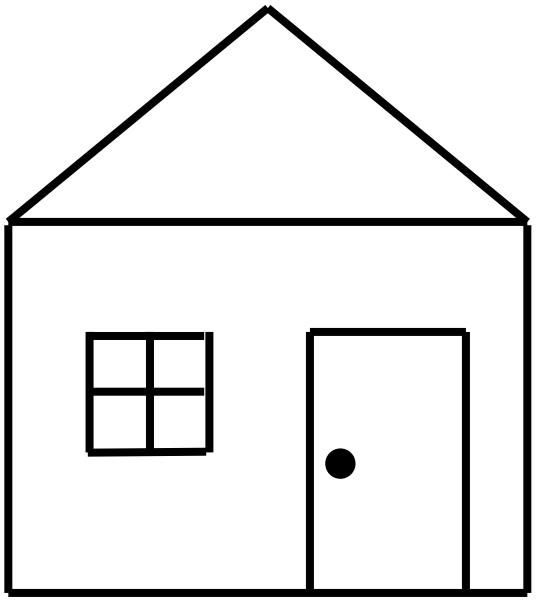


Exercise 2

Wait 10 seconds (count to 10), then draw from memory.

Number correct:

(Or number of errors):

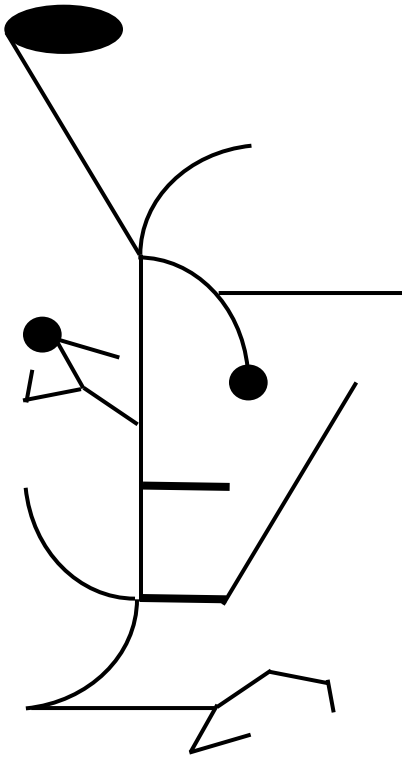


Two groups:

Group 1: Looking: *Look at the figure for 2 minutes.*
Try not to look away or close your eyes (except to blink)

Group 2: Sketching*: Redraw the figure as many times as you can for 2 minutes.*

After two minutes, the test will be: draw the sketch from memory.



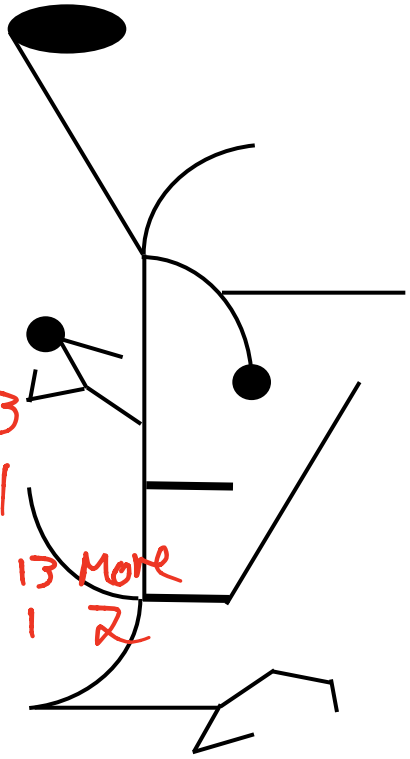
Count to ten, and then draw the sketch from memory

Number approximately correct:

(Confirm your result with your neighbor)

"Look" Group: 6 7 8 9 11 13 4 1 3 1 2 1

"Draw" Group: 5 1 2 1 3 1 2 12 13 More



Please hand in your practice and test sketches now

- **Results and Conclusion?**

Notice*:*

- *This was an experiment (not just a demonstration) for assessment.*
- *We gathered data and we might reach a conclusion.*
  - *One method **may** have worked better, on average.*

Context and interpretation.

(1) This tested '*memorizing an unfamiliar pattern*'

(2) Drawing might (or might not) assist by …
   a. Chunking
   b. Sequence
   c. Practice testing (retrieval practice)
   d. Developed neostriatal cortex "skill" or "kinesthetic" or "motor" memory (different words for the same thing)

(3) To decide whether the learning method is more effective than "looking" for this kind of task, you and your students do not need to know (2).

(4) For learners, average results are much less useful than their personal results.
   - Each learner needs to discover what works for him/her, **not for an"average"**.
   - The "population" to test = 1 (just that learner)

Checklist of things to consider for metacognition experiments

(generated in a class discussion with college freshmen)

Assessment (Decision Rules) – potential ways to measure effectiveness of a method

- Time
- Rating - comfort and understanding
- Number of mistakes - drawing, words/terms
- Number of pauses
- Number of questions correct at the end of the chapter
- Ability to explain
- Stress level
- Focus level
- Interest level
- Problem solving (multiplication without paper or other aids)

Biases – potential problems that could invalidate your conclusion

- Comfort level old/new - old is familiar, might be more comfortable
- Uncontrollable variables - other classes/assignments, life events, amount of sleep if multiple-day trials
- Content -> unequal level of difficulty
- Non-random assignment of treatments
- Comparison of mind map to outline (apples to oranges comparisons)
- Preconceptions
- Confirmation Bias (human tendency to believe things that confirm our beliefs or hypotheses
- Bias tending to make us believe that recent behavior was THE cause of some event (Correlation does not equal causation – *The sun rises every morning when I get up; therefore, the sun rises because I get up* [a perfect correlation, but not causation])

To Reduce Bias

- Quantitative comparisons
- Controls when possible
- Multiple trials (runs)
- Convince a friend (or enemy) to try it

Sample Experiments

Experiments A, B, & C (individual college freshmen)

(A) Mind maps with sketches versus reading, rereading, & writing notes

(B) Reading & then mind mapping versus reading while mind mapping

(C) The effect of guessing versus not guessing on learning

Questions?

Experiment D (designed & conducted by a class of Noyce Scholars)

(D) Folded lists versus “Standard Methods” to learn something new

Questions?

Design your own metacognition experiment — Exercise 4

Design an experiment : Learn the bacterial ruler (or part of it).

- *one experiment per table; they need not be unique*
  [you may eavesdrop and borrow ideas from some other table's design…])

- I'll give a summary explanation of the Bacterial Ruler

  Questions?

(A) THEN: Each table/group to develop a:
- Purpose statement (what are you testing/comparing)
- Method (maximum of 5 minutes allowed to do the experiment)
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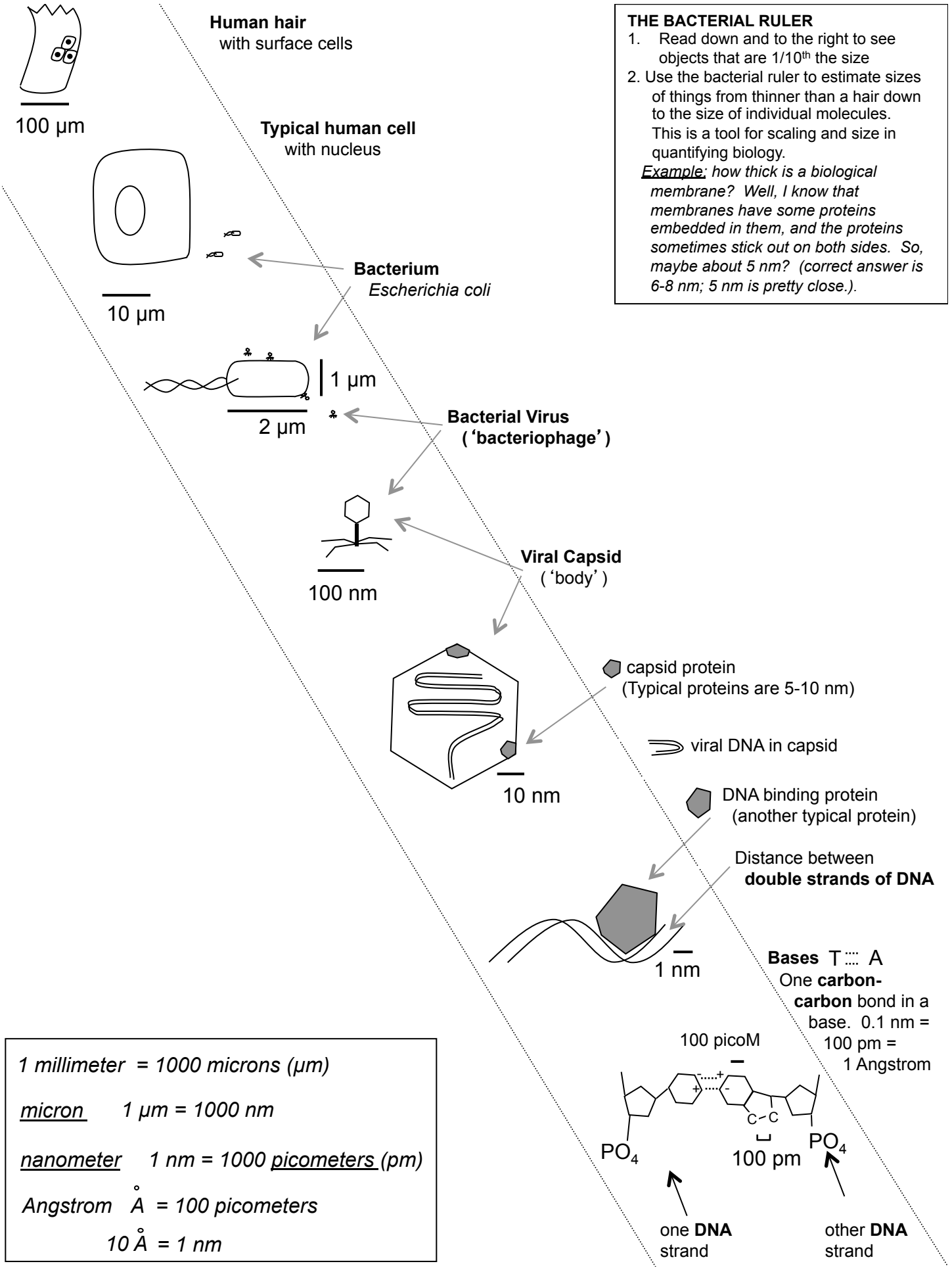

THE BACTERIAL RULER

1. Read down and to the right to see objects that are 1/10th the size
2. Use the bacterial ruler to estimate sizes of things from thinner than a hair down to the size of individual molecules. This is a tool for scaling and size in quantifying biology.

Example: how thick is a biological membrane? Well, I know that membranes have some proteins embedded in them, and the proteins sometimes stick out on both sides. So, maybe about 5 nm? (correct answer is 6-8 nm; 5 nm is pretty close.).

1 millimeter = 1000 microns (µm)

micron 1 µm = 1000 nm

nanometer 1 nm = 1000 picometers (pm)

Angstrom Å = 100 picometers

10 Å = 1 nm

Metacognition Experiments

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Method:

Analysis (*How I'll reach a conclusion: is it better or faster?*):

Results:

Conclusion:

Design your own metacognition experiment — Exercise 4

Design an experiment : Learn the bacterial ruler (or part of it).

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(B) NEXT

- Run your experiment & collect data
- Analyze (make a decision, consider biases and sources of error)
- Report Results and Conclusions

Volunteers to describe results?

Want more? ***Email me comments/questions/examples***

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Next steps?

THINGS TO DO:

There is lots more:

I can not distill all of this into one workshop!

Good luck.

Metacognition for Students: helping students understand their own learning by self-testing, while also teaching about experimental design, controls, and sources of error.

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Metacognition, thinking about one's own thinking and learning, can improve learning skills. An important step in improving learning skills can be development of self-testing skills for alternative approaches to learning and studying. Students who actively self-assess the effectiveness and efficiency of their study methods may gain concrete reasons to change. A challenge for teachers is how to help students learn to self-assess their own learning. This workshop from a Noyce add-on class ("How Students Learn") includes hands-on (more accurately, "minds-on") activities related to (1) students (first-semester freshmen) who designed and conducted experiments on their own learning as individuals, and (2) Noyce Scholars who designed and conducted an experiment on their own learning as a group. For example, freshmen designed experiments to test whether the amount they had slept affected their ability to solve problems, using a simple mental task (mental math) to assess problem-solving. Noyce Scholars designed and conducted an experiment on whether drawing-to-learn affected the accuracy and speed of learning new information (the Cyrillic alphabet). One outcome was that participants developed greater facility with experimental design, treatment controls, and sources of experimenter bias or experimental error. Noyce Scholars developed interest and confidence in working with high school students to help students self-assess their own learning. The workshop includes instructions and examples. Workshop participants will carry out portions of student-designed experiments and will also help develop and carry out a sample experiment during the workshop.

Outline:

Opening: *Exercise 1*

I. Definitions and background
   A. How students study and learn (recent review)
   B. How we would like them to change

II. Metacognition experiments as a strategy for useful change
   A. A student experiment:
      The effects of sleep hours on mental math
   B. A metacognition demonstration & experiment:
      Evaluating drawing (Exercise 2)
   C. More things to test (and more student experiments)
   D. Assessment (Decision Rules) for experiments
   E. Biases and sources of error in experiments

III. Outcomes: do students change their study behavior after doing experiments?

IV. Design a metacognition experiment (*to learn the "bacterial ruler" for size and scaling in biology*)
   A. for a class
   B. for an individual

V. Next steps – Plan one thing you might try with your students

1. Have you ever experimented on yourself to see whether you can learn better? *(Examples: I compared flashcards to rereading; I compared studying in the library to studying in your room/home; I compared studying with music to studying without music)*

2. What do you feel are weakness you might have when learning something new and challenging? *(Examples: I'm too easily distracted; I get bored with the material; bored by having to review or drill; my memory is too poor; can't motivate myself to start; fear of failure; I'm too busy/not enough time(!); not willing to keep trying once it gets hard; I'm 'addicted' to something else, such as web surfing, youTube, Facebook, TV, etc.)*

3. Use a SurveyMonkey website??? (to join in and report the results of our metacognition experiment)