BIMM 194: **GENOMICS, BIG DATA AND HUMAN HEALTH** (Winter 2018)

Lecture 4: **A 12 step guide to reading primary research articles**

https://bioboot.github.io/bimm194_W18/
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Overview:
You might have tried to read scientific papers before and been frustrated by the dense, stilted writing and the unfamiliar jargon. I remember feeling this way! Reading and understanding research papers is a skill that every single scientist and doctor has had to learn. You can learn it too, but like any skill set it takes patience and practice.

I want to help you acquire these skills and thus become more scientifically literate. We will start at the beginning and assume that your first goal is to obtain a *basic* understanding of a given scientific paper and decide whether or not it's a reputable study.

The type of scientific paper I'm discussing here is referred to as a **primary research article**. It's a peer-reviewed report of new research on a specific question (or questions).

Another useful type of publication is a **review article**. Review articles are also peer-reviewed, and don't present new information, but summarize multiple primary research articles, to give a sense of the consensus, debates, and unanswered questions within a field. (I'm not going to say much more about them here, but be cautious about which review articles you read. Remember that they are only a snapshot of the research at the time they are published. A review article on, say, genome-wide association studies from 2001 is not going to be very informative in 2018. So much research has been done in the intervening years that the field has changed considerably).

General advice:
Reading a scientific paper is a completely different process than reading an article about science in a blog or newspaper. Not only do you read the sections in a different order than they're presented, but you also have to take notes, read it multiple times, and probably go look up other papers for some of the details. Reading a single paper may take you a very long time at first. Be patient with yourself. The process will go much faster as you gain experience.

Most primary research papers will be divided into the following sections:

- **Abstract,**
- **Introduction,**
- **Methods,**
- **Results, and**
- **Conclusions/Interpretations/Discussion**.

The order will depend on which journal it's published in. Some journals have additional files (called **Supplementary Online Information**), which contain additional details of the research, but are published online instead of in the article itself (make sure you don't skip these files).

The 12 steps for effectively reading a research paper

- ***Step 1.***

Before you begin reading, take note of the authors and their institutional affiliations. Some institutions (e.g. University of California, San Diego) are well-respected; others (e.g. the Discovery Institute) may appear to be legitimate research institutions but are actually agenda-driven.

> **Tip:** Google *"Discovery Institute" to see why you don't want to use it as a scientific authority on evolutionary theory.*

Also take note of the journal in which it's published. Reputable (biomedical) journals will be indexed by Pubmed.

Beware of questionable journals.

- ***Step 2.***

As you read, write down **every single word** that you don't understand. You're going to have to look them all up (yes, every one. I know it's a total pain. But you won't understand the paper if you don't understand the vocabulary. Scientific words have extremely precise meanings).

- ***Step 3.***

Read the **introduction first**, not the abstract.

The abstract is that dense first paragraph at the very beginning of a paper. In fact, that's often the only part of a paper that many non-scientists read when they're trying to build a scientific argument. (This is a terrible practice—don't do it.). When I'm choosing papers to read, I decide what's relevant to my interests based on a combination of the

title and abstract. But when I've got a collection of papers assembled for deep reading, I always read the abstract last. I do this because abstracts contain a succinct summary of the entire paper, and I'm concerned about inadvertently becoming biased by the authors' interpretation of the results.

- ***Step 4.***

Identify the **BIG QUESTION!**

Before you focus in on the question "what is this paper about?", identify the bigger question, namely: **"<u>What problem is this entire field trying to solve?</u>"**

This helps you focus on why this research is being done and how it might fit in to advancing our knowledge or technical capabilities. By "our knowledge" I mean that of the entire field.

- ***Step 5.***

Summarize the background in five sentences or less.

<u>TIP</u>: Here three questions to guide you in summarizing a papers background:

- What work has been done before in this field to answer the BIG QUESTION?
- What are the limitations of that work?
- What, according to the authors, needs to be done next?

The five sentences part is a little arbitrary, but it forces you to be concise and really think about the context of this research. You need to be able to explain why this research has been done in order to understand it.

- ***Step 6.***

Identify the **SPECIFIC QUESTION(S)** addressed in this paper

What exactly are the authors trying to answer with their research? There may be multiple questions, or just one. Write them down. If it's the kind of research that tests one or more hypotheses, identify it/them and write them down.

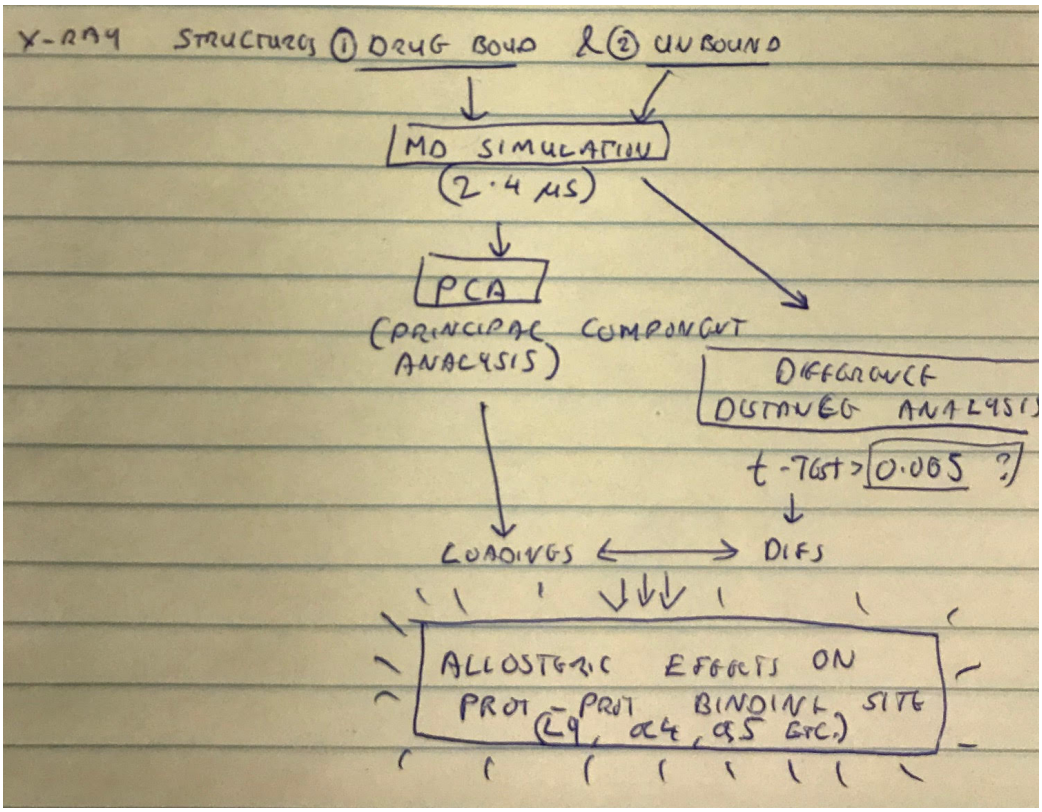
- ***Step 7.***

Identify the approach as stated in the introduction section.
What are the authors going to do to answer the SPECIFIC QUESTION(S)? We will find more details of the approach in the methods section addressed below.

- ***Step 8.***

Now read the **methods section**. Draw a diagram for each experiment, showing exactly what the authors did.

I mean literally draw it. Include as much detail as you need to fully understand the work. As an example, here is what I drew to sort out the methods for a paper I read today.



This is much less detail than you'd probably need, because it's a paper in my field of specialty and I use these methods all the time. But if you were reading this, and didn't happen to know what some of the terms mean, then you would need to look them up.

TIP: At this stage of your career you don't need to understand the methods in enough detail to replicate the experiments - that's something domain level experts and reviewers have to do - but you're not ready to move on to the results until you can explain the basics of the methods to someone else.

- ***Step 9.***

Now it is time to read the results section and write a paragraph or two that summarizes the results for each experiment, each figure, and each table. Don't yet try to decide what the results mean, just write down what they are.

You'll find that, particularly in good papers, the majority of the results are summarized in the figures and tables - typically one major figure (or figure panel such as A, B, C etc.) per major experiment.

Side-note: It is at this point where difficulties can arise particularly if statistical tests are employed in the paper and you don't have enough of a background to understand them. I can't teach you all the stats you will need in this course, but here, here, and here are some basic resources to help you. You could also attend my BIMM-143 course ;-) to find out more about quantitive data analysis in biomolecular science and bioinformatics generally.

TIP: Some typical things to pay attention to in the results section include:

- Any time the words "**significant**" or "**non-significant**" are used. These have precise statistical meanings. Read more about this here.
- If there are graphs, do they have error bars on them? For certain types of studies, a lack of confidence intervals is a major red flag.
- The sample size. Has the study been conducted on 10, or 10,000 people? (For some research purposes, a sample size of 10 is sufficient, but for most studies larger is better).

- ***Step 10.***

Before moving on to the conclusions/discussion section ask yourself: Do the results answer the SPECIFIC QUESTION(S)? What do you think there results mean?

Don't move on until you have thought about this. It's okay to change your mind in light of the authors' interpretation in the next section - in fact you probably will if you're still a beginner at this kind of analysis - but it's a really good habit to start forming your own interpretations from the results presented before you read those of others.

- ***Step 11.***

Now it is time to read the conclusion/discussion/Interpretation sections.

What do the authors think the results mean? Do you agree with them? Can you come up with any alternative way of interpreting them? Do the authors identify any weaknesses in their own study? Do you see any that the authors missed? (Don't assume they're infallible!) What do they propose to do as a next step? Do you agree with that?

- ***Step 12.***

Finally it is time to go back to the beginning and read the **abstract**.

Does it match what the authors said in the paper? Does it fit with your interpretation of the paper?

Wrap-up:

After you have finished your 12 steps it can be very informative to find out what others say about this paper. Who are the acknowledged experts in this particular field? Do they have criticisms of the study that you haven't thought of, or do they generally support it? Here's a place where I do recommend you use google! But do it last, so you are better prepared to think critically about what other people say.

Fantastic job! Well done on getting this far. Reading the primary literature can be a significant amount of work for early stage scientists. It will however get much easer with practice and habit.

Acknowledgment:
Much of this guide was inspired and styled after a bog post Jennifer Raff, Department of Anthropology, University of Kansas. You can find more of Jennifer's excellent writing at the The Guardian science blog: https://www.theguardian.com/profile/jennifer-raff