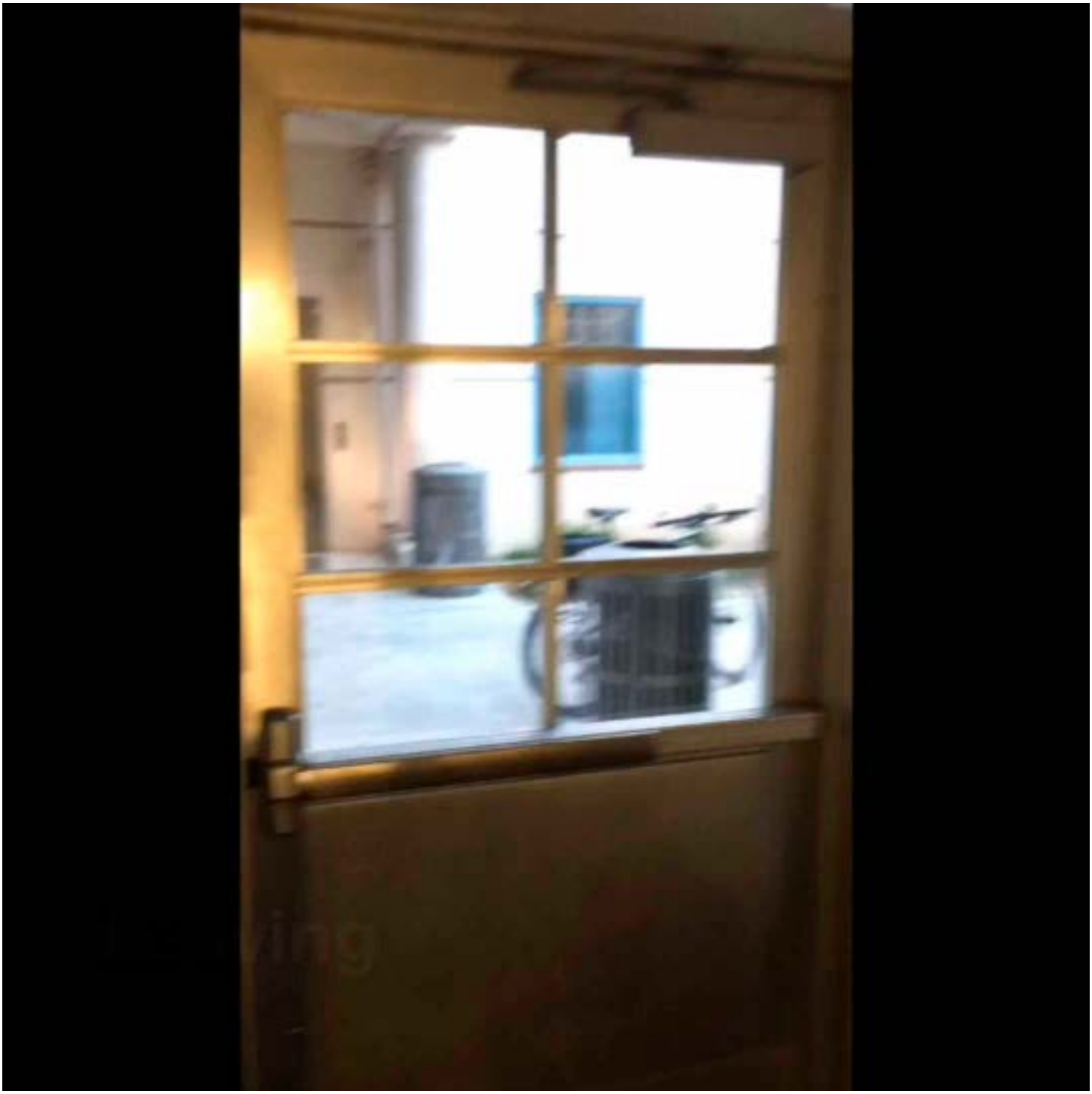
A Genetics Class Trailer



Introduction

This document (GATC: Genetics Assets & Tools Companion, also called the "class manual") is meant to serve as a single source of resources I will reference during the semester. Some will be resources that you will be required to use (MICROLECTURES; CASE STUDIES); some will be for optional consumption when you are inclined to do so (EXTENSION). These resources include links to lecture videos and websites containing data and analysis tools we will use, as well as references to published research literature and other case studies that you will read and we will then discuss during class.

I have organized the content of this class into four broad sections, or "Themes," in genetics. Within each Theme, individual chapters, or "Topics," offer opportunities to delve into more details about essential concepts and competencies, often focused on a few case studies of scientific experiments that have been performed. Unlike many genetics textbooks, I have not organized the Topics chronologically. Rather, we will start our study of genetics based on physical scale, beginning with the chemical structure of the DNA molecule ("Molecular Genetics"). Next, we will explore how the information stored in DNA is used by our cells to produce proteins ("The Central Dogma"). Then, we will learn how cellular components know which parts of our DNA encode proteins and when to produce proteins from each gene ("Gene Expression Regulation"). Finally, we will study the principles of how our DNA is passed from one generation to the next and how that process can result in the great diversity we observe in life around us ("Transmission Genetics"). I find that this organization makes intuitive sense, and I hope you will also find this to be true!

To reiterate, the four Themes we will explore are:

1. Molecular Genetics: "What your genes are made of, where they're found, and how we learn about them"
2. The Central Dogma: "What your genes do"
3. Gene Expression Regulation: "How your genes are activated and deactivated by the cells they are located in"
4. Transmission Genetics: "Where your genes came from and where they will go"

Dr. Joseph Ross

Each Topic will be introduced with a brief "Trailer" video, with the goal of answering the question, "Why do I need to learn this?" I strive to explain the relevance of the material to research and cultural or societal events. The goal(s) and outcome(s) of the Topic will be provided, with examples of types of questions you should be able to answer by the end of the study of the Topic.

The content of each Topic will be organized into:

- Descriptions of readings in our OpenStax textbooks
- Links to microlecture videos, hosted at YouTube, that you will watch before class
- References to case studies (both classical and recent). You will need to locate these published articles on your own. In each of the Themes, I have tried to include at least one case study in animal, plants, and bacterial species.
- Extension material: resources for your additional study, if you are motivated to use them

Within each Topic, important vocabulary terms will appear in BLUE SMALL CAPS. Embedded throughout the manual will be tips and activities for practicing the

application of knowledge and for developing a growth mindset.

At the end of each Topic, I describe the Tasks you should be able to accomplish and also how the Topic integrates with the course STUDENT LEARNING OUTCOMES (SLOs).

Three critical things to understand about how I have structured this course

1) How the structure of this class is designed to help you succeed this semester:

The structure of this class employs an approach that has been termed BLENDED LEARNING. This approach is nothing new. Briefly, in our class, we will use a great deal of your valuable in-class time interacting with each other to resolve questions and practice applying information to difficult problems in solo and in group settings. I have assigned you readings and videos to watch before each class, to help prepare you with the basic information and concepts you will need to be effective during class and to help you formulate and ask questions that will help you better learn the material, concepts, and practices. The format of this class will be as effective as possible only if you prepare yourself for each class meeting by attempting the assigned practice problems and by reading and watching assigned textbook and microlecture video content. The entire goal of this process is for you to identify your own questions and uncertainties to ask about during class. The majority of each class period will be devoted to answering your questions and leading you through additional practice problems and applications of course content.

Peer Instruction and Group Work

You should benefit from many features of this class design. First, the opportunity to work with peers will give you feedback about your understanding of class material relative to your peers. This should help us all evaluate whether I am doing an effective job at helping you learn new concepts, and hopefully it will generate a classroom atmosphere in which you feel comfortable developing and asking questions.

Mindset

The opportunity to interact with peers and with me during class is also meant to help fortify a growth mindset in all of the students in class. One incredibly important characteristic common to most successful students I have mentored is that, when confronted with an immediately insurmountable obstacle, they do three critical things:

i) they don't give up

ii) they immediately reflect by themselves on trying to define, as best they can, what exactly they need, or think they need, or don't understand, or are confused about

iii) they then take that information to reach out to others for advice and support

Put another way, high-achievers can be described as:

- tenacious
- thoughtful / introspective
- collaborative / communicative

This concept was broadly popularized in Carol Dweck's popular book "Mindset: the new psychology of success." In this book, Dweck generally describes successful and unsuccessful people in terms of whether they have a GROWTH MINDSET or a FIXED MINDSET, respectively.

Briefly, people with a growth mindset:

- believe that intelligence can grow over one's life
- are willing to face challenges

- don't give up when they encounter obstacles
- understand that nothing comes easily; that practice is critical
- build on criticism
- learn from (and help) others succeed

Those with a fixed mindset, on the other hand:

- feel that intellectual ability is inherent
- do not enjoy challenges
- feel that if something isn't easy, it isn't worth doing
- don't see the need to practice
- do not build from constructive criticism
- don't want to help others succeed

One of my missions is to help students more on the "fixed" end of the mindset spectrum move toward the "growth" end. One benefit of the blended learning model of instruction is that I try to foster a culture of peer support in the classroom. Although I ask you initially to access the course material outside of class (thus often on your own), we will spend our in-class time working together on making sense of course content and using (applying) that content in practice. Another way to think about this process is that I am initially and purposefully setting you up to FAIL (which, in this case, stands for "First Attempt In Learning"). The way this approach will work best for all of us is if you seize the opportunities to try to learn on your own outside of class, and come to class willing to share what you do not understand, and where you were unable to make progress in answering a take-home practice question.

One amusing example of changing a fixed mindset to a growth mindset can be found here:

Related video

If you watch this, please mentally replace the speaker's use of the term "rejection" with either "don't understand material" or "earn a lower grade than I hoped for." In the end, hopefully you will understand that the most critical part of this process (both the flipped classroom process, as well as the speaker's story) is, after rejection/FAILure, asking yourself the question "Why?" To make this directly applicable to your situation as my student, I'm asking you to ask yourself that same question, "Why?," every time you encounter an obstacle. If you will answer in as much detail as possible, and then communicate that answer to me, I will best be able to help you over that hurdle.

Example

You are answering a question about a specific cross between parents of two known genotypes. Your head is swimming in thoughts; you're not sure where to start; you start sweating a little bit. You keep glancing at the clock, because you feel like you're wasting time trying to figure out how to answer this question, and you have other things that you need to do next (go to class, work, sleep…)

You ask yourself, "Why am I not able to answer this question yet?"

Fixed mindset response: "My high school and introductory biology teachers never taught me this stuff; I don't get the terminology, and I don't even know where to start!"

Growth mindset response: "I still don't understand what you mean by a heterozygote at two loci! I'm

not even sure if that information is relevant to the question. Are you trying to trick me?"

Notice that the concerns that a student with a growth mindset have stated are more specific, and thus if they share that answer with me, then I am immediately better able to help address the critical obstacle.

2) How this class is structured to aid your long-term success in life


Related video (8:38)

You made a tough choice when deciding how to take college-level coursework. It used to be that brick-and-mortar institutions called Universities had a monopoly on advanced knowledge, and if you wanted that information, you had to pay the University to attend their school and learn from those experts (the professors). Back then, professors did just that: they professed (lectured). This was how you obtained factual and practical information: you sat and you wrote (copying from the blackboard, often).

Much of this expert information is freely available online today. Interestingly, it seems that the model of the University doesn't work as well when so many students want to attend a University to earn college degrees, because we are limited in the number of desks we can place in each classroom on a physical campus. Thus, online coursework is a major trend in higher education.

Surprisingly, it is often (though not exclusively) those of us who are employed by Universities who also put all of that information freely online. Why? It might partly because many of us just love to teach and to help others; we want to spread information as widely as we can. Our Universities also occasionally provide incentives to do so, to help position them to be able to launch their own online courses. Why would Universities do this? Money, usually: because enrollments are often limited by physical infrastructure, and because online courses are relatively inexpensive to teach, this may be the trend of how universities move forward to educate the populace.

I teach in-person classes, and I also make educational materials freely available online. I have never taught a fully-online course. I tell you this in the hopes that you will understand that I approach the online-vs-in-person conflict from a relatively neutral viewpoint.

How, then, do you choose between paying so much money to attend a university in person, as opposed to learning at home while wearing your pajamas and using your computer? Lots of costs and benefits come into play. Here are a few important questions to keep in mind as you continue to assess whether to pursue an in-person or an online education:

If professors are no longer the only source of information, what use are they now?

We professors had to work very diligently to earn doctoral degrees (Ph.D.s) in our disciplines. For example, after I graduated from my undergraduate university, I then spent six years in school at a university to earn my Ph.D. degree, and I also spent another six years performing biological research before I was able to be hired as a junior professor at Fresno State.

A major benefit of you having educational guidance from such a professor is that they can help provide both breadth and depth to your learning. Because of their extensive experience, they can help material become relevant to you, and they can help you understand the details of material. In other words, we are dynamic and can adapt to your needs.

Some online resources cannot do this for you. Some online coursework is extremely static, offering only fixed packages of material. In this regard, the way to make sure you get your money's worth out of paying for in-person instruction is, not surprisingly, to come to class! More important, though, is to find a professor

who will partner with you, as I will, to optimize your in-class time. Gone are the days when in-class time is necessarily for lecture. You can now get all of the nuts-and-bolts, factual information on your own without a professor being present. The best use of class time is for students to obtain feedback and attention from the teacher. Again, for many of us professors, our true expertise is in solving problems. That's why we are in front of you as leaders: not because we have all the answers (we usually don't!), but because we have tools we can show you for learning how to develop answers.

Why might I consider not teaching myself only using online resources?

I have seen many students led astray by inaccurate web-based information about various aspects of biology. A huge issue in society today (not just in higher education) is how to distinguish valid information from inaccurate data. This is called "INFORMATION LITERACY," and many of us are trying to learn how to better prepare students to become consumers, interpreters, and curators of information. In sum, one value of the in-person University experience (although this may soon wane) is that the sources of information you use have already been validated by professional educators. If, however, you browse the internet, or even take some online classes, you might not be as sure that you're receiving the quality and accuracy of the information you expect. Don't believe everything that you read!

What are other values of the in-person class experience?

Again, assuming that you have a professor who, like me, incorporates active learning in their class meetings, then I have great news! Your investment of time being in class has a great chance of helping you find and/or maintain employment in a good job with your college degree. As I was once a student (and still am, in almost every way), it is not surprising to me that students dislike many types of class activities and prefer sitting and listening to a lecture. However, after I explain the reasoning for why we ask you to do actively participate in the class (e.g. with group work and writing assignments), I hope you will at least appreciate the potential value of these tasks.

A recent estimate suggests that students in the last decade tend to have held thirteen jobs by the time they're 38 years old! We change jobs - a lot.

The majority of the top ten types of jobs (in terms of growth in the number of available positions) did not exist as types of jobs a decade ago! Thus, we, the professors, cannot remotely adequately prepare you, in terms of content knowledge, to continue to succeed in even one career (much less multiple careers) as you move through life.

There are a core set of skills we hope to help you develop as students in our physical classrooms at a University to help you be able to adapt, to learn, to think critically, to solve problems, and to innovate: to be successful! These skills are ones that the vast majority of employers are looking for now in their employees.

In 2013, the American Association of Colleges and Universities commissioned a study on the desires of employers: what characteristics would they like our graduates to exemplify to make them best suited for our current workforce?

93% of employers believe that "a demonstrated capacity to think critically, communicate clearly, and solve complex problems is more important than [a candidate's] undergraduate major."

95% say that they "prioritize hiring college graduates with skills that will help them contribute to innovation in the workplace."

95% think that "it is important that those they hire demonstrate ethical judgment and integrity; intercultural skills; and the capacity for continued new learning."

and 96% assert that "all college students should have experiences that teach them how to solve problems with people whose views are different from their own."

The top two skills desired by employers in the category of "intellectual and practical skills" were: oral communication and teamwork [https://

www.aacu.org/publications-research/periodicals/it-takes-more-major-employer-priorities-college-learning-and].

In sum, you must be able to adapt, to learn (on your own), and to think critically to be successful!

Adapt: to think critically, apply information in new ways, often in the presence of others: innovate, communicate, work with others

Learn: to know how to find and evaluate knowledge with healthy skepticism: information literacy

Think critically: choose a course of action based on reasoning

When you integrate these skills, you become a problem-solver, and maybe even an innovator, and that is valuable to the vast majority of employers!

This class is specifically designed to integrate practice of these skills. I cannot help you hone any of these abilities by lecturing content to you. If you come to class unprepared, expecting me to talk for the entire class period, sometimes that will work well for you, but some days you won't get nearly as much from our time together that will help you develop those life skills that employers and humankind really value. If you willingly and actively participate in this class as it has been designed, then you will get much more out of it. For example, if you ever ask me for a letter of recommendation (because practically every step you take beyond the doors of the University will require you to provide at least three recommendation letters), the strength of that letter will depend critically on whether you have provided me with evidence, from this class, of whether your strengths suit the needs of the workforce.

3) How the structure of this class is designed to improve your scientific abilities

In 2011, the American Association for the Advancement of Science released a report called "Vision and Change in Undergraduate Biology Education: A Call to Action." A main purpose of this policy document was to establish a set of CORE COMPETENCIES and CORE CONCEPTS that all undergraduates should demonstrate mastery of prior to graduation.

The Five Core Concepts:

1 Evolution: the diversity of life evolved over time by processes of mutation, selection, and genetic change

2 Structure and Function: basic units of structure define the function of all living things

3 Information Flow, Exchange, and Storage: the growth and behavior of organisms are activated through the expression of genetic information in context

4 Pathways and Transformations of Energy and Matter: biological systems grow and change by processes based upon chemical transformation pathways and are governed by the laws of thermodynamics

5 Systems: living systems are interconnected and interacting

Reflection

Which of these concepts do you think are relevant to genetics?

The Five Core Competencies:

1 Ability to apply the process of science: biology is evidence-based and grounded in the formal practices of observation, experimentation, and hypothesis testing

2 Ability to use quantitative reasoning: biology relies on applications of quantitative analysis and mathematical reasoning

3 Ability to use modeling and simulation: biology focuses on the study of complex systems

4 Ability to tap into the interdisciplinary nature of science: biology is an interdisciplinary science

5 Ability to communicate and collaborate with other disciplines: biology is a collaborative scientific discipline

Fortunately for all of us, these are concepts and competencies that will be introduced (I), emphasized (E), and mastered (M) in various courses you will take at Fresno State. The Department of Biology has mapped the curriculum of our genetics class in the following ways:

	Concept	Competency
1	E	E
2	E	E
3	E	I
4	-	I
5	-	I

The study of genetics forms the basis of the first three Concepts. At its most basic, genetics is the study of DNA. Changes to DNA are the basis of evolution (Concept 1). DNA is a molecule whose structure contains information, encoding the "cookbook" from which living organisms form (Concepts 2 and 3). The long history of the rigorous scientific study of genetics, including some of its mathematical underpinnings, make it very amenable to helping you practice using the scientific method and to analyze data (Competencies 1 and 2). This covers all of the Concepts and Competencies that will be Emphasized in this course.

Because of the impact of genetics on modern society, including in healthcare, environmental concerns, and public policy, we have a grand opportunity to help make the curriculum of our class relevant to our lives as global citizens. I will assign you tasks that will help develop you as ambassadors to help your friends and family understand biology as well (Competency 5).

As genetics spans a grand scale of levels of physical structure, from the atomic structure of DNA (involving chemistry) to the observation of whole organisms, we will introduce the connections between biology and other scientific (and non-scientific) disciplines (Competency 4).

Competency 3 (modeling) is, perhaps, the most vague concept, but working with models is an absolutely critical skill for everybody - particularly scientists. You have worked with models for your entire life, whether or not you're aware of this fact. One definition of a MODEL is, "a simplified, abstract or concrete representation of relationships and/or processes in the real world, constructed for some purpose. In other words, a model is a caricature of the real world that helps us better understand it" [Eaton *et al*. (2017) "A 'rule-of-five' framework for models and modeling to unify mathematicians and biologists and improve student learning." *biorXiv*].

All scientific studies seek to understand how our world works. In biology, we focus on how living systems function. We approach this study using the scientific method. Briefly, this involves:

1) making an observation about the living world (often stimulating a "How?" question like "How do I look more like my mother than my father, when my sisters both look like my father?")

2) forming a hypothesis (an educated guess, based on already-established "rules" or "laws" of biology)

   and then testing whether your hypothesis is supported by evidence (data) by:

3) collecting information (data)

4) evaluating those data to determine whether they support your hypothesis or not

   Ultimately, once a hypothesis is either supported or refuted, then we

5) incorporate that conclusion into our understanding of how the living world works

Each of these five steps involve a form of modeling. Because of this intimate relationship between the scientific method and modeling, this is a critical time for you to be consciously exposed to those five types of models. It has been proposed that those five types of models can be classified as: experiential, verbal, numerical, visual, and symbolic models. I have just presented them in their order of simplicity (or, in other words, I have arranged them by Bloom's level). I will reinforce your skills with modeling, using many of the enclosed case studies, in this same order. It may also useful for you to note that the scientific method and also the typical format of lab reports (and other forms of written scientific communication) tend to follow the same structure:

Order	Bloom's	Modeling	Scientific Method/ Manuscript
1	Understand	Experiential (observation - no prior knowledge needed)	Introduction
2	Apply	Verbal (make a prediction)	Hypothesis
3	Analyze	Numerical (collect data)	Results
4	Evaluate	Visual (create a plot of the data)	Results
5	Create	Symbolic (interpret and generalize the results)	Discussion

"Vision and Change" highlighted the need for undergraduates to have the ability to use modeling and simulation because it is critical for the use of the scientific method. One of the most important elements of this need is that models are simplifications. By being aware of circumstances in which assumptions of our models are invalid, we can most accurately apply our knowledge to the practice of genetics. A clear example of this process is the early belief by some humans that the world is flat and that a ship could sail off of the edge of the world. Testing that hypothesis, and proving it incorrect, helped us make a huge leap in our understanding of our physical world. No model is perfect, and the way we advance science, and our understanding of how our world works, is by performing experiments that allow us to make adjustments (usually minor) to existing models. Critically, no model is ever perfect. Likewise, all models have flaws that have yet to be identified and refined by you or by future generations of scientists. Thus, it is absolutely essential that we understand as many of the assumptions (*i.e.* oversimplifications) of the models we use.

Reflection

List three scientific models. For at least one, identify an assumption of the model.