Page 1 and 2 provide some guidelines on what you can do during the discussion. As you read through the articles in the document set, use a highlighter or pen to make notes, draw connections, or highlight important points. Just be prepared to share your understanding of the reading with the class. See you on Tuesday.

HARKNESS SKILLS

- Be prepared! Do your readings prior to attending your session!
- Talk directly to your classmates, not to the teacher
- Ask questions, no matter how simple or complex
- Ground your comments with evidence from the sources as much and where possible
- Answer questions from your classmates
- Contribute ideas on all readings
- Point out connections to other problems or issues
- Help find a common solution to problems
- Always stay involved in the discussion
- When the discussion seems to stall, attempt to summarize to that point or even synthesize ideas
- Do all that you can to help the class progress
- Remember that we are not here to debate the sources but to investigate and better understand the sources

SPECIFIC BEHAVIOURS TO ENGAGE IN DURING DISCUSSION

Students and teachers participate in discussion in a number of constructive and different ways. Among other ways, they may:

OPEN discussion with a reaction to or interpretation of the reading(s)

- "I was challenged by the readings, I thought that ______ was really challenging what I understood to mean scientific knowledge"

AFFIRM a previous comment

- "I agree with Sue that we don't know as much as we think we do"

CHALLENGE a previous comment

- "Fred, how can you say that? There are a lot of things that we know very well"

ASK for more information (invite completion of thought or to draw out others)

- "Ann, you have not said anything yet. What do you think about what Rick said?"
- Or, "I am a little confused by what the meaning of 'conflicting theories' on page 7, can someone explain that to me?"

CITE evidence from the assigned reading(s)

- "If you could look at page 3, third full paragraph….the author states……"

TEST understanding of the text or a previous comment

- "Okay, so if I understand what you are all saying would that mean that if I have X then I get Y?"

DEFINE term(s)

- "What is meant by ____________?" Or, "What do you think the author meant by ___________?"

DEVELOP an idea with new material

- "This is similar to ______________"

CLARIFY differences in opinion

- "We seem to be at an impasse here, with Sue stating ____ and Rick stating ______. Is that about right?"

TRANSITION to a new or old topic

- "I would like to move on to another idea presented in the reading."

SUMMARIZE a new line of inquiry

- "We have moved on to a new topic for discussion and it seems that this is what we have come to thus far……"

RETURN to 'lost points' or points made previously

- "You know, we never really addressed ___________. We sort of got off topic."

SYNTHESIZE seemingly disparate points

- "The creativity seen in math is very similar to what is seen in the arts."

CREATE closure

- "How can we come to a resolution on this?"

Source 1: The Lure Of The Unknown Drives Science Forward

by MARCELO GLEISER June 04, 2014 4:01 PM ET

We are surrounded by mystery. This may sound like an anti-science statement but, actually, it's precisely the opposite. We just need to be careful about how we define mystery or the mysterious. Take Albert Einstein, for example:

"The fairest thing we can experience is the mysterious. It is the fundamental emotion which stands at the cradle of true art and true science. He who does not know it and can no longer wonder, is as good as dead, a snuffed-out candle."

To Einstein, the mysterious could be equated with the unknown.

As I explore in my new book *The Island of Knowledge: The Limits of Science and The Search for Meaning*, just out, the mysterious need not have anything to do with the supernatural. It is what is beyond the known.

The Island of Knowledge

The Limits of Science and the Search for Meaning

The essential question, then, is whether what is unknown, or part of it, is unknowable, beyond our grasp. This question has enormous relevance for science and for society, as it sets the essential limits to knowledge: Are there questions about the world and about ourselves that are unanswerable? What are they?

To answer, we need to examine how science operates. In this space, we can only scratch the surface.

Science can be seen as a process that amplifies our perception of reality. Our five senses are like antennae collecting different aspects of the physical world around us: we see, we hear, we touch, we smell, we taste. The brain is an amazingly complex entity, capable of integrating the stimuli from outside and generating what we call our everyday sense of reality.

On the other hand, we know that our perception of the world is quite limited: what we see or hear, for example, is a small fraction of what's actually "out there." It follows that our construction of reality, based as it is on our five senses, is incomplete. The world is much more than what we perceive of it.

This is where science makes a triumphal entrance, with its tools of exploration. They are our *reality amplifiers*, allowing us to see and measure farther and with more detail, extending our grasp into realms foreign to our senses. We thus gather information from worlds billions of light year away, see bacteria and molecules, visualize brain activity, study elementary particles in a constant dance of creation and destruction, probe cosmic phenomena that took place near the beginning of time itself.

We see all this; but we don't see all. We can't.

Every tool of exploration has a range and a set precision. With a good pair of binoculars, we can see almost as well as Galileo with his telescope of 1610. We see craters and mountains on the moon, the four largest moons of Jupiter, etc. But we don't see galaxies. For that, we need bigger telescopes. And even those have their limits. We will always see more of nature, but never enough.

We will never see everything there is to see.

There is a persistent veil around our perception of reality, the mystery that surrounds us. This mystery, as Einstein remarked, has tremendous seductive power and has inspired some of the greatest works of art, science and literature. Fortunately, it won't go away.

Apart from technological limitations to how much we can see of reality, nature itself offers barriers to knowledge: the speed of light implies that we live literally within a bubble of information, our "cosmic horizon," with size equal to the distance light has travelled since the Big Bang. The universe most probably continues beyond the horizon; but we can't get information from "out there." The uncertainty principle at the heart of quantum mechanics, that so undid Einstein, is not going away either: there is a fundamental *unknowability* deep at the heart of matter. Even math and computer science have fundamental incompleteness problems. And understanding consciousness ...

But we can get back to these another day. For now, let's stay with the metaphor of the Island of Knowledge: the more it grows, the more grow the shores of our ignorance, the boundaries between the known and the unknown.

Source 2. Kepler telescope bags huge haul of planets

By Jonathan Amos Science correspondent, BBC News

The science team sifting data from the US space agency's (Nasa) Kepler telescope says it has identified 715 new planets beyond our Solar System.

This is a huge new haul.

In the nearly two decades since the first so-called exoplanet was discovered, researchers had claimed the detection of just over 1,000 new worlds.

Kepler's latest bounty are all in multi-planet systems; they orbit only 305 stars.

The vast majority, 95%, are smaller than our Neptune, which is four times the radius of the Earth.

Four of the new planets are less than 2.5 times the radius of Earth, and they orbit their host suns in the "habitable zone" - the region around a star where water can keep a liquid state.

Whether that is the case on these planets cannot be known for sure - Kepler's targets are hundreds of light-years in the distance, and this is too far away for very detailed investigation.

The Kepler space telescope was launched in 2009 on a $600m (£360m) mission to assess the likely population of Earth-sized planets in our Milky Way Galaxy.

Faulty pointing mechanisms eventually blunted its abilities last year, but not before it had identified thousands of possible, or "candidate", worlds in a patch of sky **in the constellations Cygnus and Lyra**.

It did this by looking for transits - the periodic dips in light that occur when planets move across the faces of stars.

Before Wednesday, the Kepler spacecraft had confirmed the existence of 246 exoplanets. It has now pushed this number up to 961. That is more than half of all the discoveries made in the field over the past 20 years.

"This is the largest windfall of planets that's ever been announced at one time," said Douglas Hudgins from Nasa's astrophysics division.

"Second, these results establish that planetary systems with multiple planets around one star, like our own Solar System, are in fact common.

"Third, we know that small planets - planets ranging from the size of Neptune down to the size of the Earth - make up the majority of planets in our galaxy."

When Kepler first started its work, the number of confirmed planets came at a trickle.

Scientists had to be sure that the variations in brightness being observed were indeed caused by transiting planets and not by a couple of stars orbiting and eclipsing each other.

The follow-up work required to make this distinction - between candidate and confirmation - was laborious.

But the sudden dump of new planets announced on Wednesday has exploited a new statistical approach referred to as "verification by multiplicity".

This rests on the recognition that if a star displays multiple dips in light, it must be planets that are responsible because it is very difficult for several stars to orbit each other in a similar way and maintain a stable configuration.

"This technique that we've introduced for wholesale planet validation will be productive in the future. These results are based on the first two years of Kepler observations and with each additional year, we'll be able to bring in a few hundred more planets," explained Jack Lissauer, a planetary scientist at Nasa's Ames Research Center.

Sara Seager is a professor of planetary science and physics at the Massachusetts Institute of Technology. She is not involved in the Kepler mission.

She commented: "With hundreds of new validated planets, Kepler reinforces its major finding that small planets are extremely common in our galaxy. And I'm super-excited about this, being one of the people working on the next generation of space telescopes - we hope to put up direct imaging missions, and we need to be reassured that small planets are common."

Source 3. The Truth? It's Out There In The Fog

by MARCELO GLEISER
April 09, 2014 9:00 AM ET

In the past two weeks, I explored here some of the consequences of the remarkable observation by the scientists of the BICEP2 experiment in the South Pole. The data, potentially revolutionary, points to a period of extremely fast cosmic expansion at the very beginning of time, a signal imprinted in the cosmos for 13.8 billion years.

This is really mind-boggling.

When I was starting my career in the mid-'80s, I never expected that the theories and models that my colleagues and I were working on could be tested in my lifetime. It was all way too eccentric, too far-removed from our everyday reality. And now, here we are, testing and putting limits on models that deal with physics at energies that are trillions of times higher than our most powerful machine, the Large Hadron Collider, in Switzerland, can probe directly.

But before popping the champagne bottle open, we need to make sure we are not being duped. (And this goes to many scientists who have already opened their bottles.)

This kind of observation is very different from what we can do in the laboratory, where we can control the system under study. We can't control the universe, and much less so near the beginning of time. On the other hand, observing distant objects is astronomy's bread and butter, and there is nothing controversial in this. It's true that we can't control stars in the lab (unless we do it through computer simulations, like 13.7's own Adam Frank does). But we can study them methodically by collecting the light and other kinds of radiation they emit.

Still, there is an essential difference between observing galaxies and stars — through direct study of the radiation they emit — and observing an ancient signal impressed on the cosmic microwave background radiation (CMB), as is the case with the BICEP2 experiment. Recall that the CMB radiation is the leftover fossil from the epoch when the first atoms of hydrogen were formed, some 400,000 years after the Big Bang that marked the beginning of time. The signal that BICEP2 detected was imprinted on the CMB radiation from events that happened *much* earlier. It is as if we were measuring signals from radioactive isotopes — that existed pretty much since the origin of the Earth — on the blocks used to make the pyramids of Egypt, built much more recently.

Every scientific observation must be carefully scrutinized to avoid errors. It's easy, when the exciting data comes in, to get carried away. But nature, of course, doesn't get carried away. The BICEP2 team was extremely careful and meticulous in its data analysis, trying to eliminate all sorts of errors, including possible signals from galactic sources. And we do hope that the results survive, even though the signal is way more powerful than what has been so far reported, even surprisingly so. Many people remain skeptical, as they should be.

If the results prevail, many theoretical models that attempt to describe the mechanism that would propel the cosmos into a period of accelerated expansion would be wrong. In fact, most would.

For example, a model by the Italian physicist Gabriele Veneziano called "pre Big Bang" would be ruled out, as would models called ekpyrotic, where the cosmos emerges from the collision of flat slabs of space called "branes," as a mythic god that would create and destroy universes by clapping his hands. Also, most superstring-inspired models of the fast expansion would be in serious trouble.

This is all good; ruling out models with data is precisely what a mature science should do.

The curious aspect of all this is that the data won't be able to do more; we can't use it to select which model is right, only to eliminate those that are incorrect. This is a lesson on how science works: We can only rule out models, prove them wrong. The models that do work only do so temporarily, insofar as they survive testing.

This is a very peculiar situation, if you think of it. It means that we really don't ever know the "truth" of how nature works. All we have are approximations, tricks that explain the data we have at hand. Accepted theories are simply narratives that are good at describing what we can measure.

The 17th-century French thinker Bernard de Fontenelle knew this well when he wrote that "all philosophy is based on two things only: curiosity and poor eyesight ... the trouble is, we want to know more than we can see."

The reader should thus beware of claims of full understanding, especially when it comes to the boundaries of knowledge, as is the case here. For example, BICEP2 results could *never* prove the existence of the multiverse, the hypothetical expanse that encompasses many universes, including our own. In fact, nothing can. We can say that our current models make the idea of an ensemble of universes *compelling*, but we cannot claim we know the multiverse exists.

There is a persistent fog out there, and we would do well to celebrate our achievements for what they are and not more.

SOURCE 4: WHY WE DON'T BELIEVE IN SCIENCE (2/20/2013)

Posted by *Jonah Lehrer*

A new study in *Cognition*, led by Andrew Shtulman at Occidental College, helps explain the stubbornness of our ignorance. As Shtulman notes, people are not blank slates, eager to assimilate the latest experiments into their world view. Rather, we come equipped with all sorts of naïve intuitions about the world, many of which are untrue. For instance, people naturally believe that heat is a kind of substance, and that the sun revolves around the earth. And then there's the irony of evolution: our views about our own development don't seem to be evolving.

This means that science education is not simply a matter of learning new theories. Rather, it also requires that students *unlearn* their instincts, shedding false beliefs the way a snake sheds its old skin.

To document the tension between new scientific concepts and our pre-scientific hunches, Shtulman invented a simple test. He asked a hundred and fifty college undergraduates who had taken multiple college-level science and math classes to read several hundred scientific statements. The students were asked to assess the truth of these statements as quickly as possible.

To make things interesting, Shtulman gave the students statements that were both intuitively and factually true ("The moon revolves around the Earth") and statements whose scientific truth contradicts our intuitions ("The Earth revolves around the sun").

As expected, it took students much longer to assess the veracity of true scientific statements that cut against our instincts. In every scientific category, from evolution to astronomy to thermodynamics, students paused before agreeing that the earth revolves around the sun, or that pressure produces heat, or that air is composed of matter. Although we know these things are true, we have to push back against our instincts, which leads to a measurable delay.

What's surprising about these results is that even after we internalize a scientific concept—the vast majority of adults now acknowledge the Copernican truth that the earth is not the center of the universe—that primal belief lingers in the mind. We never fully unlearn our mistaken intuitions about the world. We just learn to ignore them.

Shtulman and colleagues summarize their findings:

When students learn scientific theories that conflict with earlier, naïve theories, what happens to the earlier theories? Our findings suggest that naïve theories are suppressed by scientific theories but not supplanted by them.

While this new paper provides a compelling explanation for why Americans are so resistant to particular scientific concepts—the theory of evolution, for instance, contradicts both our naïve intuitions and our religious beliefs—it also builds upon previous research documenting the learning process inside the head. Until we understand why some people believe in science we will never understand why most people don't.

In a 2003 study, Kevin Dunbar, a psychologist at the University of Maryland, showed undergraduates a few short videos of two different-sized balls falling. The first clip showed the two balls falling at the same rate. The second clip showed the larger ball falling at a faster rate. The footage was a reconstruction of the famous (and probably apocryphal) experiment performed by Galileo, in which he dropped cannonballs of different sizes from the Tower of Pisa. Galileo's metal balls all landed at the exact same time—a refutation of Aristotle, who claimed that heavier objects fell faster.

While the students were watching the footage, Dunbar asked them to select the more accurate representation of gravity. Not surprisingly, undergraduates without a physics background disagreed with

Galileo. They found the two balls falling at the same rate to be deeply unrealistic. (Intuitively, we're all Aristotelians.) Furthermore, when Dunbar monitored the subjects in an fMRI machine, he found that showing non-physics majors the correct video triggered a particular pattern of brain activation: there was a squirt of blood to the anterior cingulate cortex, a collar of tissue located in the center of the brain. The A.C.C. is typically associated with the perception of errors and contradictions—neuroscientists often refer to it as part of the "Oh shit!" circuit—so it makes sense that it would be turned on when we watch a video of something that seems wrong, even if it's right.

This data isn't shocking; we already know that most undergrads lack a basic understanding of science. But Dunbar also conducted the experiment with physics majors. As expected, their education enabled them to identify the error; they knew Galileo's version was correct.

But it turned out that something interesting was happening inside their brains that allowed them to hold this belief. When they saw the scientifically correct video, blood flow increased to a part of the brain called the dorsolateral prefrontal cortex, or D.L.P.F.C. The D.L.P.F.C. is located just behind the forehead and is one of the last brain areas to develop in young adults. It plays a crucial role in suppressing so-called unwanted representations, getting rid of those thoughts that aren't helpful or useful. If you don't want to think about the ice cream in the freezer, or need to focus on some tedious task, your D.L.P.F.C. is probably hard at work.

According to Dunbar, the reason the physics majors had to recruit the D.L.P.F.C. is because they were busy suppressing their intuitions, resisting the allure of Aristotle's error. It would be so much more convenient if the laws of physics lined up with our naïve beliefs—or if evolution was wrong and living things didn't evolve through random mutation. But reality is not a mirror; science is full of awkward facts. And this is why believing in the right version of things takes work.

Of course, that extra mental labor isn't always pleasant. (There's a reason they call it "cognitive dissonance.") It took a few hundred years for the Copernican revolution to go mainstream. At the present rate, the Darwinian revolution, at least in America, will take just as long.

Source 5. **Mega-Earth messes with models**

An artist's conception shows the Kepler-10 system, home to two rocky planets. In the foreground is Kepler-10c, a planet that weighs 17 times as much as Earth and is more than twice as large in size. Planet formation theorists are challenged to explain how such a massive world could have formed. Credit: Harvard-Smithsonian Center for Astrophysics/David Aguilar

November 19, 2013

Astronomers have discovered a rocky planet that weighs 17 times as much as Earth and is more than twice as large in size. This discovery has planet formation theorists challenged to explain how such a world could have formed.

"We were very surprised when we realized what we had found," said astronomer Xavier Dumusque of the Harvard-Smithsonian Center for Astrophysics, Cambridge, Massachusetts, who led the analysis using data originally collected by NASA's Kepler space telescope.

Kepler-10c, as the planet had been named, had a previously measured size of 2.3 times larger than Earth, but its mass was not known until now. The team used the HARPS-North instrument on the Telescopio Nazionale Galileo in the Canary Islands to conduct follow-up observations to obtain a mass measurement of the rocky behemoth.

It was thought worlds such as this could not possibly exist. The enormous gravitational force of such a massive body would accrete a gas envelope during formation, ballooning the planet to a gas giant the size of Neptune or even Jupiter. However, this planet is thought to be solid, composed primarily of rock.

"Just when you think you've got it all figured out, nature gives you a huge surprise -- in this case, literally," said Natalie Batalha, Kepler mission scientist at NASA's Ames Research Center in Moffett Field, California. "Isn't science marvelous?"

Kepler-10c orbits a sun-like star every 45 days, making it too hot to sustain life as we know it. It is located about 560 light-years from Earth in the constellation Draco. The system also hosts Kepler-10b, the first rocky planet discovered in the Kepler data.

The finding was presented today at a meeting of the American Astronomical Society in Boston. Read more about the discovery in the Harvard-Smithsonian Center for Astrophysics news release.

Notes: