Science is a body of knowledge.

Science is also a way of learning.

All areas of science involve posing questions and discovering facts that can help answer those questions.

The process by which all "scientist" investigate is called the **scientific method**, and scientific method begins with logic and reason based in **inductive** and **deductive** thinking.

Notes

See page 15 for a *Scientific Method* review and exam specific examples on how to answer question on *Experimental Design*.

A. Scientific Method

Begins with:

1a. "Initial" Observation

- is using all your senses to find out all that you can.
- (this is distinct from data collection associated with directed/informed observation while "doing an experiment")

Name your 5 classical senses:
Touch, taste, smell, hearing and sight.

Also perhaps these too, according to *Wikipedia*…

Thermoception is the sense of **heat** and the absence of heat (**cold**)

Nociception (physiological pain) is the nonconscious perception of near-damage or damage to tissue

Equilibrioception, the **vestibular sense**, is the perception of **balance** or **acceleration**…

Proprioception, the **kinesthetic sense**, is the perception of **body awareness** and is a sense that people are frequently not aware of, but rely on enormously.

But probably not your *vomeronasal organ (VNO)*, a pheromone detector, but in adult humans is absent and/or not even wired into the brain.

1b. Classification

- is the organization of data.

Organization and Classification of the scientific investigator should lead to a specific **question** or **problem**.

2a. Inference

- is an educated guess, based on what you have observed about something that has happened. A **prediction** is an educated guess about something that is going to happen, based on what you observed.

The educated guess about the possible answer to a problem leads to the formulation of a **hypothesis**.

3. Hypothesis

- is the concept to be investigated. It is an inference or prediction that can be tested—usually by **Experimentation**. It gives direction to scientific investigation.

e.g., If skin cancer is **related** to ultraviolet light, **then** *people with a high exposure to uv light will have a higher frequency of skin cancer*.

- Where skin cancer is our dependent variable,
- And ultraviolet light is the independent variable.

Writing a Hypothesis

A **hypothesis** is a **tentative** statement that proposes a possible **explanation** to some phenomenon or event. A useful hypothesis is a testable statement which may include a prediction.

Examples:

1. Chocolate **may** cause pimples.
2. Salt in soil **may** affect plant growth.
3. Plant growth **may** be affected by the colour of the light.
4. Bacterial growth **may** be affected by temperature.
5. Ultra violet light **may** cause skin cancer.
6. Temperature **may** cause leaves to change colour.

All of these are examples of hypotheses because they use the tentative word "may." However, their form is not particularly useful. Using the word may does not suggest how you would go about proving it. If these statements had not been written carefully, they may not have even been hypotheses at all. For example, if we say "Trees will change colour when it gets cold." we are making a prediction. Or if we write, "Ultraviolet light causes skin cancer." could be a conclusion. One way to prevent making such easy mistakes is to formalize the form of the hypothesis.

Formalized Hypotheses examples:

1. **If** skin cancer is **related** to ultraviolet light, **then** people with a high exposure to uv light will have a higher frequency of skin cancer.

2. **If** leaf colour change is **related** to temperature, **then** exposing plants to low temperatures will result in changes in leaf colour.

Most commonly, hypotheses take three formats:

- a question, "Does temperature affect fermentation?"
- a conditional statement, "Temperature may affect fermentation."
- an **If, then** statement, "**If** fermentation rate is **related** to temperature, **then** increasing the temperature will increase gas production.

Caveat! Not all "**if-then**" statements are hypotheses. For

The **independent** (or **manipulated** / **experimental**) **variable** is the variable you purposely manipulate (change).
- Usually the x- axis on a graph

The **dependent** (**responding**) **variable** is the variable that is being observed, which changes in response to the independent variable.
- Usually the y- axis on a graph

The variables that are not changed, that remain constant for both the experimental and control groups are called **controlled variables**.

example, "**If** you warm yeast, **then** more gas will be produced." The problem with this (deductive) statement is that there is no clearly stated proposition to test. What is related to what? Is temperature a variable? Is yeast a variable? Is gas production a variable?

Q "**If** it's raining **then** the street gets wet."
a) hypothesis
b) deductive statement

Some more formalized examples:

1. **If** animal metabolism is **related** to temperature, **then** increasing ambient temperature will increase animal metabolism (carbon dioxide gas production).

2. **If** enzyme activity is **related** to temperature (or *p*H or quantity), then increasing the temperature will increase the products of an enzymatic reaction.

3. **If** diffusion efficiency is **related** to the ratio of surface to volume, **then** decreasing the S/V (increasing volume of a cell mass) will decreasing the rate of diffusing into a cellular mass (potato).

Source: http://www.accessexcellence.org/LC/TL/filson/writhypo.html
Ans. (b)

• **Inductive Reasoning** (leads to the formation of an ***Inference*** ➜ which gives us our ***Hypothesis***)
Specific to General
examples ➜ rules

e.g., Having **observed** mould growing in the past, you **conclude** mould grows better in the dark, as opposed to the light.

Reasoning used to arrive at a hypothesis after observing the specific facts.

- A "bottom up" approach:
  Observation → Inference → Tentative hypothesis → Theory

• **Deductive Reasoning** (starts with a ***Hypothesis*** ➜ and leads to the formation of an ***Experiment*** *or experiments to test that hypothesis*)
General to Specific
rule ➜ examples

- Begins with a general statement that infers a specific conclusion an "***if***… ***then***…" statement

These two methods of reasoning have a very different "feel" to them when you're conducting research.

Inductive reasoning, by its very nature, is more open-ended and exploratory, especially at the beginning.

Deductive reasoning is more narrow in nature and is concerned with testing or confirming hypotheses.

Source:
http://www.socialresearchmethods.net/kb/dedind.htm

If mould growth is **related** to the substrate **then** mould should grow more rapidly on bread than a Twinkie. (*hypothesis*)

e.g., **If** moulds prefer bread to Twinkies, **then** we should be able to grow mould more easily in the lab if we use bread, rather than Twinkies. (*deductive statement*)

Allow scientists to determine the type of experiment or observation needed to support or refute a hypothesis.

- A "top down" approach:
  Theory → Hypothesis → Experiment → Confirmation

• **Experimentation** or investigation is based upon applying **Deductive Reason** to our hypothetical statement.
  - Results will either confirm or refute/falsify the inference or prediction, leading to a conclusion that supports or disproves the hypothesis.
    - If the hypothesis is not supported by the experiment, then it should be restated and tested again.

Generally,

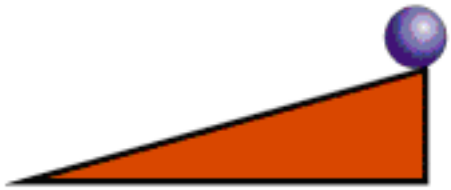
- Only a single variable is tested
- This variable is compared against some known quantity – the **Control**
- The **independent** (or **manipulated / experimental**) **variable** is the variable you purposely manipulate (change).
- The **dependent** (**responding**) **variable** is the variable that is being observed, which changes in response to the independent variable.
- The variables that are not changed, that remain constant for both the experimental and control groups are called **controlled variables**, e.g.

  The slope of an incline is changed and the time in takes the ball to roll down the incline is measured.

Independent variable: a new fertilizer
Dependent variable: growth rate

Experimental group: receives the fertilizer
Control group: does not

Controlled variables: each group would receive equal amounts of water and light, be potted in identical soil, and in identical pots. Failure to do so may affect the growth rate, and throw doubt on the actual cause of any differences in the growth rate — was it the fertilizer or was it that the experimental group received



The slope of the incline was varied to see how it affected the time it took the ball to roll down the incline. So, SLOPE is the independent variable and TIME is the dependent variable.

- To be valid the experiment must ultimately collect data from:
  - A large sample population;
  - Selected randomly ;
  - Be unaware of the test (i.e., use of Placebo, Double Blind testing);
  - Data collected should, preferably, be **quantitative** and **objective**, vs. **qualitative** and **subjective**;
  - And be free of any *inaccurate* **syllogisms**, **tautologies** (circular reasoning) or other false or biased logical faults.

- An important characteristic of a scientific theory or hypothesis is that it be "**falsifiable**."

- This means that there must be some experiment or possible discovery that could prove the theory untrue. For example, Einstein's theory of Relativity made predictions about the results of experiments. These experiments could have produced results that contradicted Einstein, so the theory was (and still is) falsifiable.

- On the other hand the theory that "there is an invisible pooka reading this over your shoulder" is not falsifiable. There is no experiment or possible evidence that could prove that invisible snorgs do not exist. So the Pooka Hypothesis is not scientific. On the other hand, the "Negative Snorg Hypothesis" (that they do not exist) is scientific. You can disprove it by catching one. Similar arguments

Falsifiable:
- confirmable: capable of being tested (verified or falsified) by experiment or observation
- the apparently paradoxical idea that a proposition or theory cannot be scientific if it does not admit consideration of the possibility of its being false.

Syllogisms:
- A *valid* syllogism typically consists of three sentences; two related premises, one conclusion. If the premises were valid, the conclusion must be valid, i.e., *A=B, B=C, therefore A=C,;*
  - *e.g.,* Men are animals;
    Socrates is a man;
    Therefore Socrates is an animal

- An *invalid* syllogism (and technically therefore not a syllogism at all) may use invalid or unrelated premises to reach an inaccurate conclusion
  - e.g., Worms are animals;
    Socrates is an animal;
    Therefore Socrates is a worm

Tautology:
- In logic, a tautology is a proposition that is already true by definition, not because of any logical deduction. Usually, it is a non-sensical statement. For instance, "*All triangles have three sides*" is an inherently true proposition, but it doesn't tell us anything new.

apply to sasquatch/yetis, UFOs and the Loch Ness Monster or Ogopogo.

• Communication/Publication

- Once completed and repeated, results of an experiment may be submitted for publication
  - Before publication the results are vetted by the journal editors for apparent veracity
    - Once published other "scientist" are able to repeat, review, falsify, test and question the results

4a. Theory

- is a hypothesis that has been repeatedly and extensively tested and always found—so far—to be the/a **best explanation** for some phenomena.
  - It is supported by the facts and helps to order and explain those facts.

- Parsimony: Without unnecessary elements; simple. The most elegant theory fully explains the phenomena in the simplest possible way (e.g., with the fewest number of rules).
  - c.f. Occam's Razor

Theory – is a well substantiated (factual, observable, predictable) **explanation**

Law - is a general **description** of a pattern or a relationship.

Principle - a basic generalization that is accepted as accurate and **that can be used as a basis for reasoning**.

No theory is an absolute truth, or immutable, as technology changes, as instrument sensitivity increases, or as more research is conducted a long held theory might be altered/updated or displaced by new information.

If scientific theories keep changing, where is the Truth?

In 1686 Isaac Newton proposed his theory of gravitation. This was one of the greatest intellectual feats of all time. The theory explained all the observed facts, and made predictions that were later tested and found to be correct within the accuracy of the instruments being used. As far as anyone could see, Newton's theory was the **Truth**.

During the nineteenth century, more accurate instruments were used to test Newton's theory, and found some slight discrepancies (for instance, the orbit of Mercury wasn't quite right). Albert Einstein proposed his theories of Relativity, which explained

Theory (in the scientific sense)

Having said all this, please realize that a theory is based in known facts, it is not likely to be abandoned so much as revised, refined, and clarified .

Examples of theories,
Astronomy
Heliocentric Theory - the sun is at the centre of our solar system
Biology
Theory of Evolution - change over time
Physics
Theory of Gravity - why things fall
Circuit Theory - electronics, pneumatics, hydraulics
Chemistry
Atomic Theory - electrons, protons, neutrons...
Mathematics
Number Theory - arithmetic
Chaos Theory - fractals
Geology
Plate tectonic Theory - volcanoes, earthquakes...

the newly observed facts and made more predictions. Those predictions have now been tested and found to be correct within the accuracy of the instruments being used. As far as anyone can see, Einstein's theory is the Truth…*so far as we know it*.

So how can the Truth change? Well the answer is that it hasn't. The Universe is still the same as it ever was, and Newton's theory is as true as it ever was. If you take a course in physics today, you will be taught Newton's Laws. They can be used to make predictions, and those predictions are still correct. Only if you are dealing with things that move close to the speed of light do you need to use Einstein's theories. If you are working at ordinary speeds outside of very strong gravitational fields and use Einstein, you will get (almost) exactly the same answer as you would with Newton. It just takes longer because using Einstein involves rather more maths.

One other note about truth: science does not make moral judgments. Anyone who tries to draw moral lessons from the laws of nature is on very dangerous ground. Evolution in particular seems to suffer from this. At one time or another it seems to have been used to justify Nazism, Communism, and every other *-ism* in between. These justifications are all completely bogus. Similarly, anyone who says "evolution theory is evil because it is used to support Communism" (or any other *-ism*) has also strayed from the path of Logic.

Source: http://mtrsn.burtcom.homeip.net/sfaq_idx.htm#science (Sci.Skeptic FAQ)

4b. Law

- Laws ***describe*** rather than ***explain*** (theory).

- A physical law or a law of nature is a scientific generalization based on empirical observations.
- Laws of nature are conclusions drawn from, or hypotheses confirmed by scientific experiments.

    - e.g., The geologic **Law of Superposition**, which states that in an undisturbed pile of sediments those on the bottom were deposited first,

followed in succession by the layers above them ending with the youngest on top.

B. Experimentation

There are basically two approaches to the empirical method, both of which a simply methods of collecting scientific data to uncover knowledge.

1. Types of Experiments

a. Directed Experimentation

- is a contrived event in which an investigator attempts to observe the effects of a deliberate act, performed in order to create an observable informative event. An experiment is deliberate act through which some effect or result can be observed.

b. Informed Observation

- the observer goes to wherever such an event is likely to occur, equipped with tools appropriate to observing the expected event, and performs whatever actions are needed to increase the probability that an informative event will occur.

All experiments are designed to either prove of falsify something. Experiments are designed to prove something actually happens and can be observed. It cannot prove a negative — i.e., the experiment cannot be designed to prove that something won't happen.

Also, no scientific experiment can either prove of disprove something that cannot be observed. The design of an experiment should lead to a clear and unambiguous answer.

2. How To Design An Experiment

Rule #1

The problem must be clearly formulated in words.

- the theme of your research, your problem, should be summarized within a paragraph.

- the problem must be **testable/ falsifiable**, resulting

is some sort of quantifiable, measurable data.

- Falsification: When a hypothesis has been proved incorrect.

- If an hypothesis is not falsifiable, it is not testable.

- For example, the hypothesis "ghosts exists" is not falsifiable but "ghosts do not exist" is. "ghost exists" is not falsifiable because even if you never find evidence of ghosts, you may just not be performing the appropriate tests. According to most philosophers of science, well-formed hypotheses can be supported or proved incorrect, but never proved correct. Thus, if you perform numerous tests and do not find evidence of ghosts, you have supported the hypothesis that "ghosts do not exist" but you have not proven it.

Rule #2
The problem must be such that useful empirical data can be identified and collected: and wherever possible that data should be numerical in nature.

Rule #3
The events on which data are collected must be accessible and observable, either directly or indirectly, through whatever means are appropriate for the case at hand

3. Steps in Experimentation

Step #1
Clearly define the problem or **hypothesis**.

Step #2
Describe the design of the experiment in writing.

- what apparatus and materials you will use.
- how will the experiment be set up.

Step #3
Describe the method of data collection in writing.

Hypothesis:
- The prediction that the *independent variable* will have **an effect** on the *dependent variable* in an experiment
- **e.g,** in a clinical trial of a new drug, the hypothesis might be that the new drug is better, on average, than the current drug.

H_1 is our simplified hypothesis: that there is a difference, the new drug is more efficacious (better)

Null Hypothesis:
- Is primarily a statistical test, a **null hypotheses** is a hypothesis that is presumed true until statistical evidence in the form of a hypothesis test indicates otherwise.
- The prediction that the *independent variable* will have **no effect** on the *dependent variable* in an experiment.
- e.g., in a clinical trial of a new drug, the null hypothesis might be that the new drug is no better, on average, than the current drug.

H_0 is our simplified null hypothesis: there is no difference in effect between the new drug and the old drug

The null hypothesis, represents a theory that has been put forward, either because it is believed to be true or because it is to be used as a basis for argument, but has not been proved.

The final conclusion once the test has been carried out is always given in terms of the null hypothesis. We either "Reject H_0 in favour of H_1" or "Do not reject H_0"; we *never* conclude "Reject H_1", or even "Accept H_1".

- the procedure you will follow.

Step #4
Perform the experiment and collect data. To ensure the experiment is valid there must be a *control*. A control is a standard against which experimental variables are compared. Controls are often conducted as parallel experiments.

Step #5
Analyze the resulting data.

- analysis of the data is done to draw conclusions from the results of the experiment. Was the hypothesis accepted or rejected?

- if the data seems "wrong" or "funny," consider:

  • an unaccounted experimental artifact or error

  • there was some variable not properly isolated

  • the design of the experiment was flawed

Step #6
Submit to others for review to double check your work.

Reliability and Validity: What's the Difference?

- **Reliability** is the **consistency of your measurement**, or the degree to which an instrument measures the same way each time it is used under the same condition with the same subjects.
  - In short, it is the repeatability of your measurement.
  - A measure is considered reliable if a person's score on the same test given twice is similar.
  - It is important to remember that reliability is not measured, it is *estimated*.

  - **Reliability** is the extent to which an experiment, test, or any measuring procedure yields the same result on repeated trials.

  - Without the agreement of independent observers

Reliability:
- consistency of your measurement

Validity:
- the degree to which a test actually measures what it purports to measure.

able to replicate research procedures, or the ability to use research tools and procedures that yield consistent measurements, researchers would be unable to satisfactorily draw conclusions, formulate theories, or make claims about the **generalizability** of their research.

- **Validity** is the strength of our conclusions, inferences or propositions.
    - More formally, Cook and Campbell (1979) define it as the "best available approximation to the truth or falsity of a given inference, proposition or conclusion."
    - In short, **were we right**?

    e.g., Say we are studying the effect of strict attendance policies on class participation. In our case, we saw that class participation did increase after the policy was established. Each type of validity would highlight a different aspect of the relationship between our treatment (strict attendance policy) and our observed outcome (increased class participation).

- **Validity** is the most important characteristic of a data collection process. It deals with the question of whether or not the data collection process is really measuring what it purports to measure.

- While **reliability** is concerned with the **accuracy** of the actual measuring instrument or procedure, **validity** is concerned with **the study's success at measuring what the researchers set out to measure**.

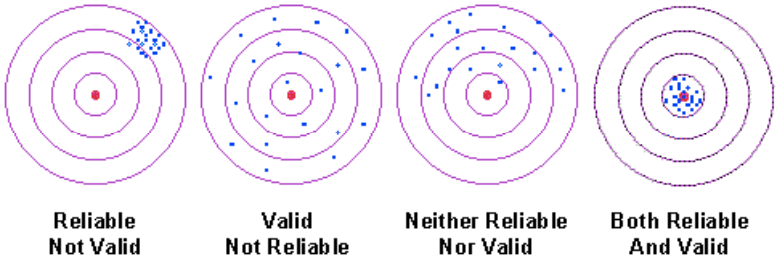
- A metaphor for the relationship ***between reliability and validity*** is that of the **target**.

- Think of the centre of the target as the concept that you are trying to measure. Imagine that for each thing you are measuring, you are taking a shot at the target.

- If you measure the concept perfectly for an item, you are hitting the centre of the target.

- If you don't, you are missing the centre. The more you are off for that item, the further you are from the

centre.



The figure above shows four possible situations.

- In the first one, you are hitting the target consistently, but you are missing the centre of the target. That is, you are consistently and systematically measuring the wrong value for all respondents. This measure is reliable, but no valid (that is, it's consistent but wrong).

- The second, shows hits that are randomly spread across the target. You seldom hit the centre of the target but, on average, you are getting the right answer for the group (but not very well for individuals). In this case, you get a valid group estimate, but you are inconsistent. Here, you can clearly see that reliability is directly related to the variability of your measure.

- The third scenario shows a case where your hits are spread across the target and you are consistently missing the centre. Your measure in this case is neither reliable nor valid.

- Finally, we see the "Robin Hood" scenario -- you consistently hit the centre of the target. ***Your measure is both reliable and valid***.

- Researchers should be concerned with both *external* and *internal* validity.

  - *External validity* refers to the extent to which the results of a study are generalizable or transferable.

  - *Internal validity* refers to
    - the rigor with which the study was conducted

(e.g., the study's design, the care taken to conduct measurements, and decisions concerning what was and wasn't measured) and
- the extent to which the designers of a study have taken into account alternative explanations for any causal relationships they explore (Huitt, 1998). In studies that do not explore causal relationships, only the first of these definitions should be considered when assessing internal validity

Sources:
http://writing.colostate.edu/references/research/relval/
http://www.socialresearchmethods.net/tutorial/Colosi/lcolosi2.htm
http://www.socialresearchmethods.net/kb/rel&val.htm

Definitions of Commonly Used Research Terms (source: University of Washington Health Sciences)

Blinded studies
Blinded studies are done so that neither the researchers' nor the participants' expectations about the experimental treatment can influence the study results. Ordinarily, in a "single-blinded" study, the participants do not know whether they are in an experimental group or a control group . In a "double-blinded" study, neither the participants nor the researchers know which participants are in which group. (see the aside on the Hawthorne Effect)

A clinical trial is a research study designed to test the safety and/or effectiveness of drugs, devices, treatments, or preventive measures in humans. Clinical trials can usually be divided into four categories or " phases ".

Control group
Participants in a control group are used as a standard for comparison. For example, a particular study may divide participants into two groups - an "experimental group" and a "control group." The experimental group is given the experimental treatment under study, while the control group may be given either the standard treatment for the illness or a placebo . At the end of the study, the results of the two groups are compared.

Experimental group
Study participants in the experimental group receive the drug, device, treatment, or intervention under study. In some studies, all participants are in the experimental group. In "controlled studies," participants will be assigned either to an experimental group or to a control group .

Health Canada
Health Canada is a government ministry that enforces laws on the manufacturing, testing, and use of drugs and medical devices. The HC must approve a drug for marketing before it is made commercially available to the public.

Human subject
A human subject is a volunteer participant in a research study.

Informed consent
Informed consent is the participant's agreement to be in a study after being fully informed about what participating will involve. Informed consent begins with a

The **Hawthorne Effect** originally referred to the increase in worker productivity observed when a worker is singled out and made to feel important. The phenomenon was first observed at the Hawthorne plant of the Western Electric company in Cicero, Illinois from 1927 to 1932 by researchers from Harvard Business School. Researchers discovered that productivity increased regardless of which environmental factors were manipulated. They concluded that giving employees any sort of attention improved productivity. These studies, called the **Hawthorne studies**, were early examples of industrial psychology.

The Hawthorne Effect more generally refers to the tendency of subjects to attempt to please researchers.

Source:
http://en.wikipedia.org/wiki/Hawthorne_effect

discussion between the researchers and the prospective participants. The discussion includes important information about the research study such as:

- The purpose of the study
- The procedures involved
- The risks of participating in the study
- The benefits of participating in the study
- How long the study will last
- How the participant's confidentiality will be protected
- What will happen if the study causes harm to the participants
- That participation is voluntary
- That participants are free to withdraw from the study at any time.
-

Based on this discussion with the researcher, participants are asked to sign a consent form that includes this same important information in writing. Prospective study participants can take the consent form home to discuss it with family and friends before signing it. Once the form is signed, participants are given a copy of the signed consent form so that they can review it at any time. Participants should feel free to ask the researchers questions before, during, and after the study. Informed consent is an ongoing process.

Institutional Review Board (IRB)
An IRB is the group or committee that is given the responsibility by an institution to review that institution's research projects involving human subjects. The primary purpose of the IRB review is to assure the protection of the safety, rights and welfare of the human subjects . The IRB may have other names such as, "Human Subjects Review Committee."

Investigational or experimental device
An investigational or experimental device is a medical device (such as an artificial heart valve or a screw used to hold bones together) that has not yet received approval from the Health Canada for marketing.

Investigational or experimental drug
An investigational or experimental drug is a drug that is not yet approved for marketing - it is not commercially available.

Placebo
A placebo is an inactive substance, which may look like medicine but contains no medicine - a "sugar pill" with no treatment value. In some studies, the participants in a control group may be given a placebo.

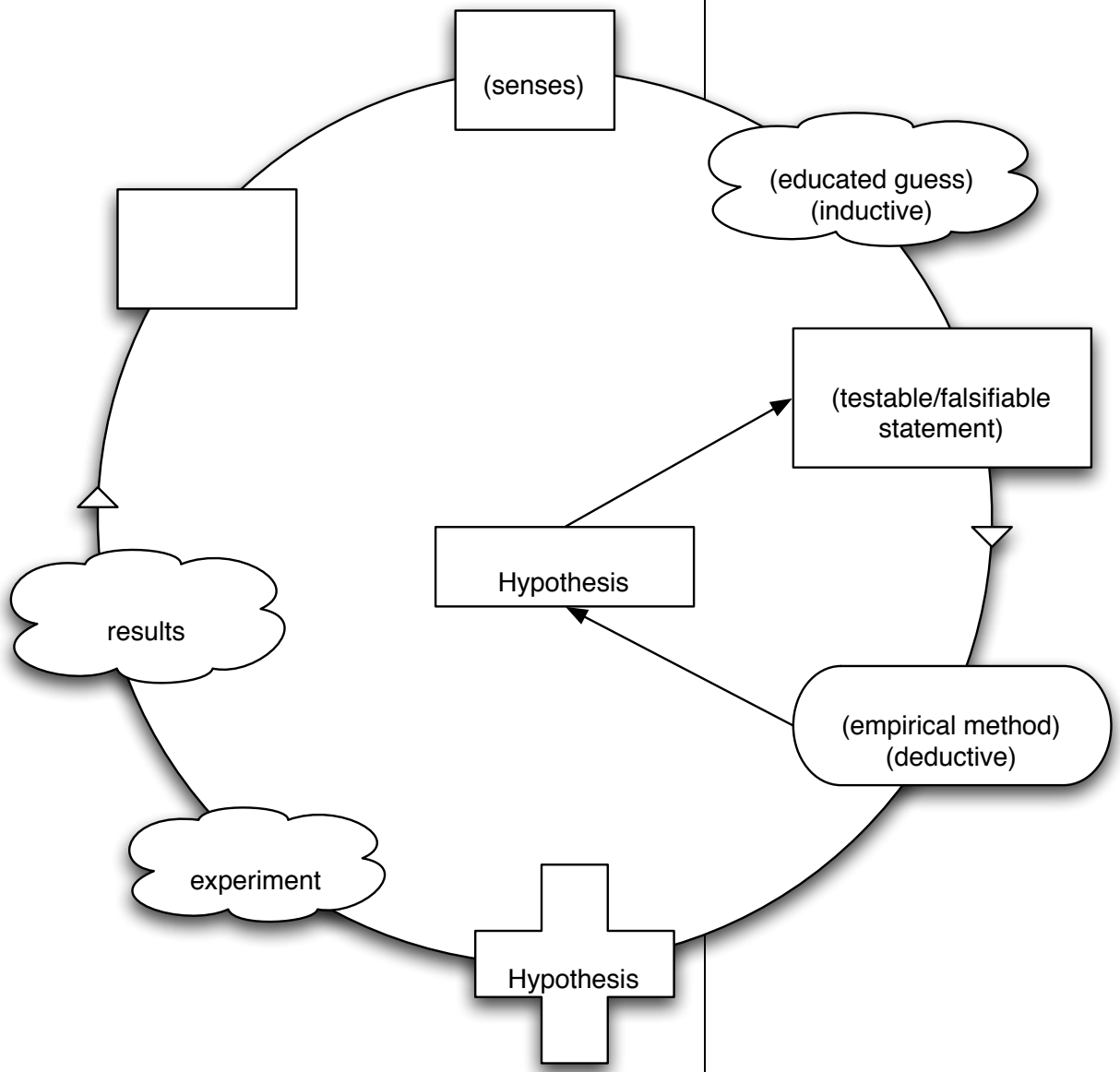
Principal investigator
The principal investigator is the chief researcher - the person in charge of carrying out a study.

Protocol
The protocol is the formal design or action plan of a research study. The protocol explains what will be done, when, how, and why. A particular study may be done by several researchers around the nation or around the world. Each researcher follows the same protocol so that at the end of the study information from all of the researchers can be combined and compared.

Random assignment
Random assignment is assignment by chance, like flipping a coin or pulling numbers out of a hat. This method is sometimes used to determine who is in the experimental group and who is in the control group . For example, in a study with random assignment to one of two groups, participants have a 50% chance of being assigned to either group.

Sponsor
The sponsor is the company, research institution, group, foundation, or government agency that funds a research study.

Review: Dynamic and Cyclic Model of Scientific Method



Fill in the missing Vocab: communicate, experiment, hypothesis, inference. observe, refute, repeat, support, theory.

Experimental Design Questions

← **Excerpt from the Provincial Exam Specifications.**

Past provincial examinations have included items which require students to "*collect, display and interpret data*" such

as plotting a graph and interpreting the results. The learning outcome "*devise an experiment using the scientific method*," may also now be examined.

The K–12 Science Curriculum implicitly assumes that most modern scientific knowledge has been obtained through empirical experimentation. The scientific method assumes the following sequential steps:

1. Observing natural phenomena which leads to the clear statement of a question.
2. Researching information related to the question.
3. Using knowledge, experience, insight and imagination to formulate a hypothesis to serve a testable answer to the question.
4. Designing and carrying out a controlled, repeatable experiment to test the hypothesis.
5. Determining whether the data obtained support or reject the hypothesis.
6. Reporting the results to others.
   - communicating information and results (e.g., graphs, diagrams, models, formulae)

In order to demonstrate comprehension of learning outcome "*Devise an experiment using the scientific method*," students should be able to:

1. Indicate how the above steps are applied to a scientific inquiry.
2. Design a controlled experiment where:
   - a hypothesis is produced (given a question)
   - procedures are implemented to test the hypothesis
   - a control is included which will serve as a known comparison to the resulting data.

Below is an example of an experimental design question, based on content covered in the Digestive system. It is an "understanding" level item and appears as five written-response questions. These questions cover all of the expectations of experimental design, only some of which may be examined on any specific examination as a multiple-choice or written-response question. Students who practice this example should be successful on similar questions.

1. State a **hypothesis** that could be used to design an experiment determining whether trypsin is the enzyme responsible for protein hydrolysis in the small intestine.

Response:

- ✓ Trypsin ***may*** be more effective at hydrolyzing proteins than other enzymes found in the small intestine.

or

- ✓ **If** protein hydrolysis in the small intestine **is related** to the presence of trypsin, **then** trypsin will more effectively "digest" proteins than other intestinal enzymes.

or

- ✓ **If** trypsin in the small intestine **is related** to the effective hydrolysis of proteins, **then** trypsin will more effectively "digest" proteins than other intestinal enzymes.

An acceptable response:

*Trypsin **is** more effective at hydrolyzing proteins than other enzymes found in the small intestine.*

Independent variable = Trypsin (are unknown, the variable we have selected to manipulate)

Dependent variable = hydrolyzing proteins (a measureable quantity, we can measure how effective trypsin was vs some other enzyme from the small intestine.

2. Using any of the materials listed below, **design an experimental procedure** that could be used to test the hypothesis.
   - Seven bottles each containing a different enzyme. The enzymes trypsin, pancreatic amylase, maltase, peptidase, lipase, nuclease and nucleosidase are at the same concentration and at a basic pH.
   - A bottle containing a protein solution of known concentration.
   - Test tubes and a test tube rack.
   - A device capable of measuring the concentration of protein in a solution.
   - A water bath capable of maintaining the bottles and test tubes at a constant temperature.

Response:

1) Fill seven of the test tubes with an equal amount of protein solution.
2) Add a different enzyme to each of the test tubes.
3) Maintain the test tubes at 37°C for one hour (times may vary).
4) Measure the resulting concentrations of protein in each of the tubes.

Your response here should match your hypothesis, if your hypothesis above does not jibe with your experimental procedure, you may not receive full marks.

3. In order for the hypothesis to be supported, what substance should be found in the tube containing

trypsin but not in the other tubes at the conclusion of the experiment?

Response:

- ✓ peptide molecules

4. What could be used as a **control** in this experiment?

Response:

- ✓ Apply the procedure above to a second set of seven tubes without the enzymes.

5. What is the purpose of the **control**?

Response:

- ✓ to provide a baseline to compare with the activity of the enzymes
- ✓ to make sure no other variables are responsible for the hydrolysis of the protein

C. Homeostasis

Homeo = similar, same
Stasis = not moving, not changing

- Is the *maintenance*, by an *organism*, of a *relatively stable internal physiological environment*.

    - Such a response is generally chemically driven and will **not be immediate** or **spontaneous** but will demonstrate some amount of lag between some extreme (e.g., too hot) and a return to normalcy

i.e., constant temp (37°C), stable composition (blood glucose 0.1%), level and pressure of body fluids , constant metabolic rate....

Blood glucose level is the amount of glucose (sugar) in the blood. It is also known as serum glucose level. The amount of glucose in the blood is expressed as millimoles per litre (mmol/l).

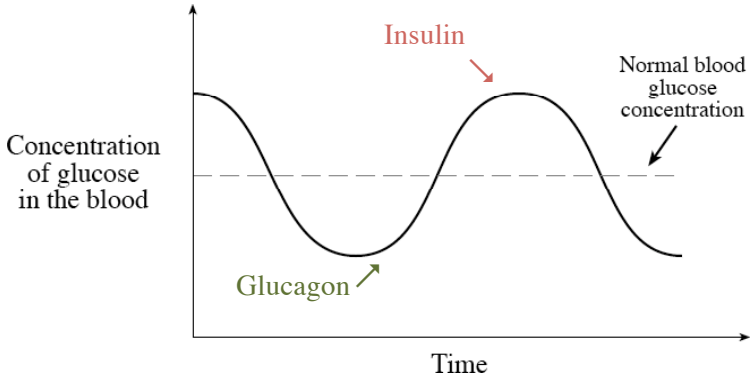
Normally, blood glucose levels stay within narrow limits throughout the day (4 to 8mmol/l). But they are higher after meals and usually lowest in the morning.

Normal values are:

- 4 to 7mmol/l before meals.
- less than 10mmol/l one-and-a-half hours after meals.
- around 8 (7-10) mmol/l at bedtime.

Diabetes is the failure to keep within these safe limits (homeostatic range).

Source:
http://www.netdoctor.co.uk/health_advice/facts/diabetesbloodsugar.htm



Insulin
- lowers blood glucose levels
  - converts excess glucose to glycogen for storage

Glucagon
- raises blood glucose levels
  - converts glycogen back into glucose

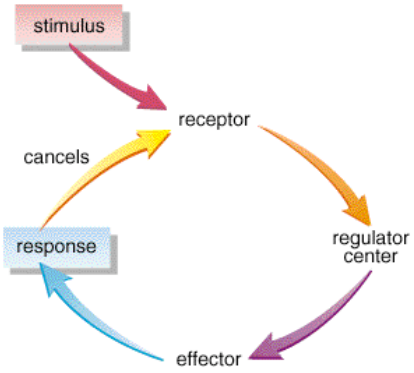
This is vital if the organism is to function properly, e.g., fever, associated with temperature well above the homeostatic norm

It requires the detection of any deviation from the norm and the means to correct such deviations.

Their detection of deviations is achieved by the **feedback** of information to controlling organs.

1. Negative Feedback
- A homeostatic control mechanism (*see text fig 21.8 Hormonal control of ovaries*)

  - whereby *an increase in some substance or activity inhibits the process leading to the increase.*



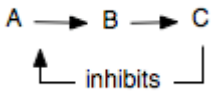
e.g., the pancreas receives "feedback" concerning its production of insulin. When blood concentration of insulin is too high, it is detected by the pancreas and insulin production is stopped.

Many homeostatic controls are hormone controlled.

A = is some external stimulus
B = promotes C

2. Positive Feedback
- Usually adds to the rate at which a change is occurring which does not maintain a steady state.

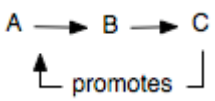
Negative Feedback



C = inhibits B, and therefore itself

e.g., if the blood contains high levels of estrogen, this will have a positive effect on the hypothalamus, triggering it to produce even more estrogen. (affecting the female secondary sexual characteristics, estrus, and menstrual cycle)

Positive Feedback



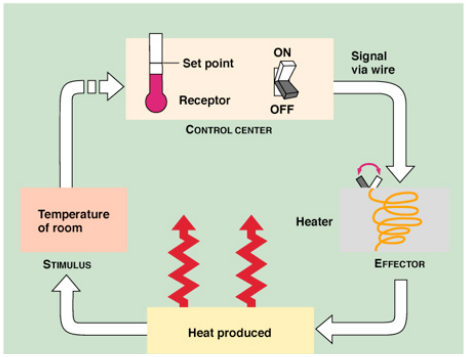
C = promotes B, and therefore itself

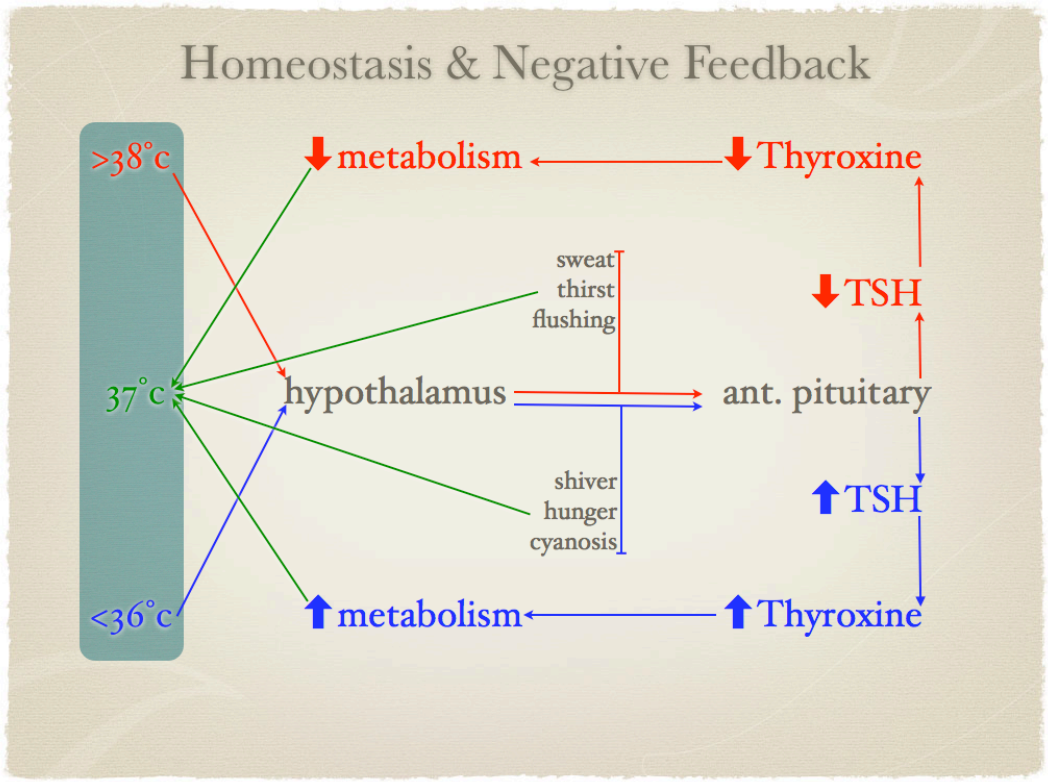
Summary

- Positive feedback loops bring about rapid change. This is what happens during labour and childbirth. The contraction of the uterus causes the release of the hormone oxytocin from the hypothalamus of the brain, which causes additional contractions, which in turn causes the release of more oxytocin until the foetus is expelled from the uterus.

- Most of the body's homeostatic systems rely on negative feedback loops to resist change by sensing a stimulus and then activating mechanisms that counteract the impending change. In other words, the information provided by the feedback reverses (is negative to) the direction of the response. The process of temperature regulation is prime example, i.e., too hot, then the body response is to sweat and cool the body (negate the extreme).

Negative feedback





TSH – Thyroid Stimulating Hormone, stimulates thyroxine release from the thyroid gland
Thyroxine – regulates oxidative metabolism, "body's gas pedal"