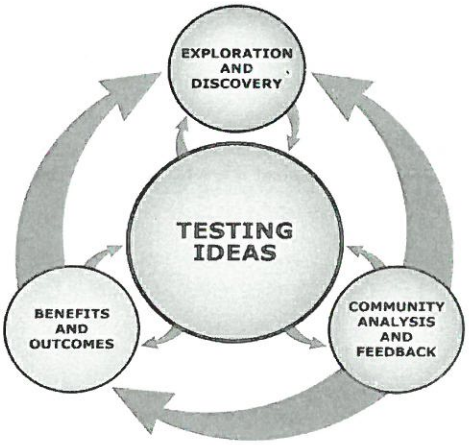
The Scientific Method

Name: _____

Date: _____

Science is a process, requiring skillful methods to gather, organize, and interpret information. It is a systemic approach to problem solving. At the heart of science is testing ideas.



Scientific Method

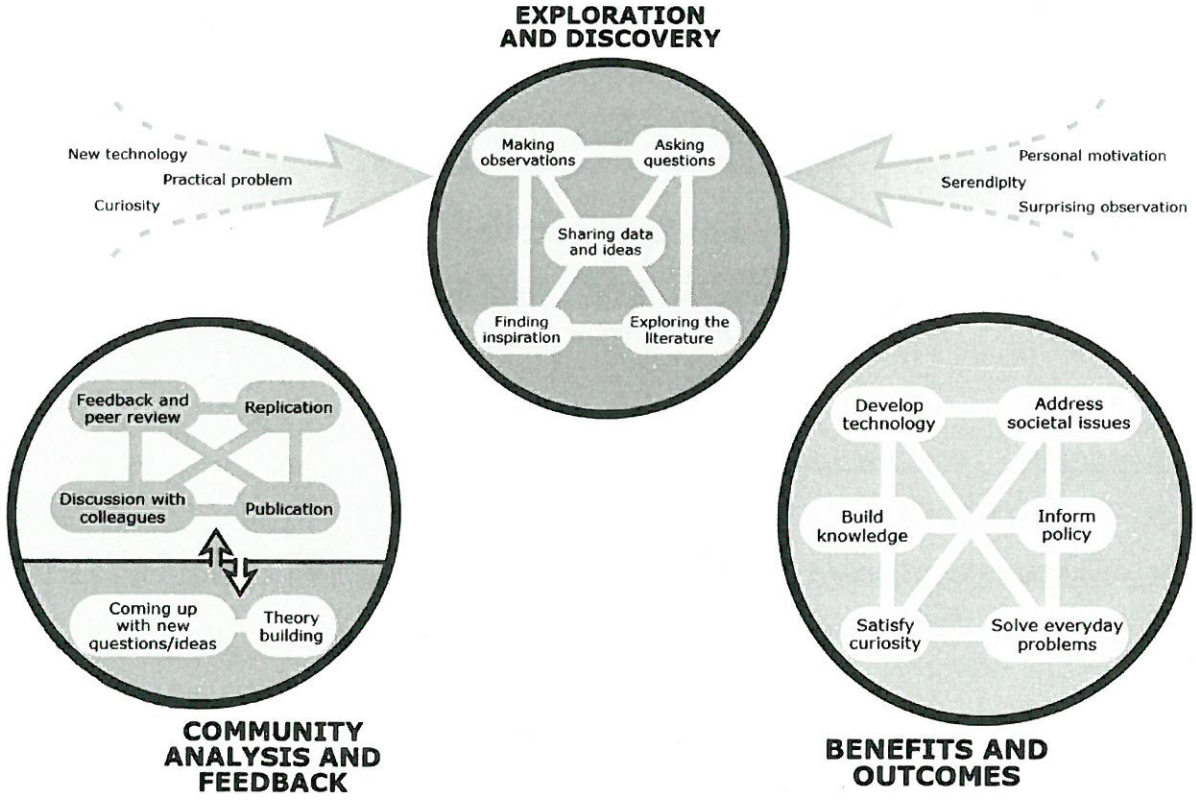
1. Observe and Record
2. Propose a Theory
3. Test a Theory

It is a systematic approach to problem-solving.

Reasons for Testing Ideas

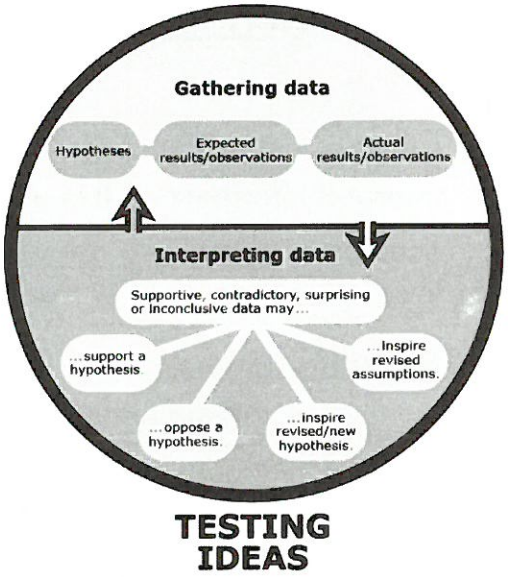
There may be many reasons why we might want to test ideas. They may include:

- curiosity
- personal motivation
- Addressing a societal issue or an everyday problem
- Testing someone else's idea
- A surprising observation



How Do We Test Ideas?

After you get an idea, coming up with a testable hypothesis is important. There are two main parts: Gathering Data and Interpreting Data. The key is to come up with a good question.



TESTING IDEAS

Experiment Types

There are generally three types of experiments:

1. A controlled Experiment
2. A quasi-Experiment
3. An observational Study

All experiments have some parts in common:

- Hypothesis or a research question
- Identification of variables
- Observations
- Interpretation of data

Variables

A variable is any factor that could affect what it is you are studying. Some variables you can control or change, some you cannot. The types of experiments vary in terms of the amount of control over variables the experimenter has.

1. Controlled Experiments

- Experimenter is able to control or account for all aspects of the experiment.
- Allows us to establish cause-effect relationships. Can claim causation.
- Example: Does sunlight affect plant growth?

2. **Quasi-Experiments**

- Variable tested without any pre-selection process or control. Other factors could affect result.
- We cannot control all variables since it could lead to ethical issues or is logistically difficult.
- Examples: Does smoking cause cancer?
  Does campus crime affect applicants to university?

3. **Observational Study**

- Experimenter cannot control any variables. They simply observe and analyze the data.
- Examples: What traits produce the best hockey players?

Practice:

Classify the studies below as either a contolled experiment, a quasi-experiment, or an observational study.

1. A random selection of adults were surveyed in a study on what time they go to bed and how much coffee they drink per day. The study found people that drank more coffee tend to sleep later at night.

   Observational study (no variables controlled)

2. A group of adults were split into two groups. One group drank a moderate amount of coffee per day and the other drank no coffee. Both groups recorded their bedtime.

   Quasi-experiment
   ↳ can't control all variables
   (diet, exercise, etc.)

Types of Experiment Worksheet

List the experiments below as either an experiment (controlled or quasi) or an observational study.

1. Jonathan wanted to see the effectiveness of social media on product advertisement. To do this, he collected data on the most popular users on Twitter and tracked the sales of the products they endorsed.

   Observational study

2. In a study of the effectiveness of a particular drug, two groups of people were created. One group was assigned the real drug while the other was assigned a placebo (a sugar pill). Neither of the groups were told what they got.

   Quasi-experiment

3. In an effort to see the relationship between happiness and technology use, a random sample of people were monitored in their use of social media and how happy they tended to be.

   Observational study

4. In order to examine whether the migration patterns of birds have changed over the past 20 years due to climate change, a large flock of a bird species were electronically tagged and their location was monitored throughout the year. This migration data was then compared to previous migration patterns 10 and 20 years ago.

   Observational study

5. A well-known social media company wants to test how their redesigned app will affect user engagement. To do this, they assigned one large group to use the new app and second large group to the older version of the app. Both groups' app use was monitored and compared.

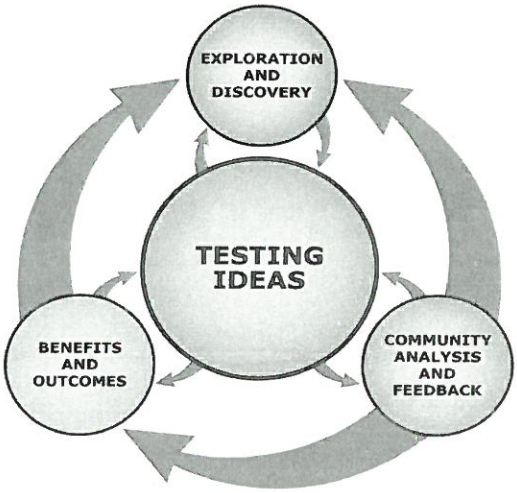
   Quasi-experiment

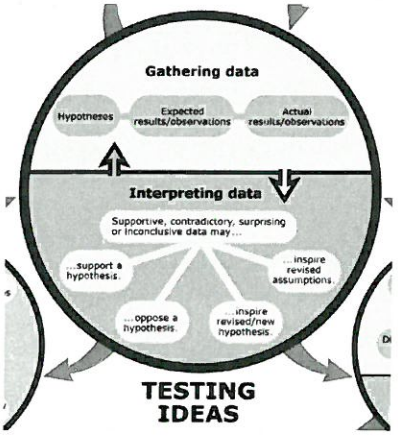
6. A study was conducted at a university to determine whether sleep has any relationship to a student's grades. A large group of randomly chosen students were surveyed on how much sleep they get a night on average. Their grades were compared to their reported average sleep time.

   Observational study

Hypotheses and Controlled Experiments

Date:_____





At the heart of science is the process of testing ideas.

Before testing ideas…

- Find a problem or something you want to figure out.

- What kind of background knowledge do you think you might need? (exploring literature, discussion with colleagues)
- Identify something specific you want to test and come up with a hypothesis…

Narrowing Down the Initial Question…

What is the effect of acid rain on plants?

- What background knowledge might you have to research before tackling this question?
  - Acidity and acid rain
  - How plants grow
  - Types of plants?
- Try to be more specific in your question:

What is the effect of acid rain on the growth rate of sunflower plants?

A Hypothesis…

- Is a possible explanation or a prediction based on limited evidence.
- Is the starting point for further investigation.
- Is developed from the original question in the inquiry/investigation
- Is based on prior knowledge
- Oftentimes an "if… then… because" statement.

Controlled Experiments

- For certain questions, you may be able to conduct a controlled experiment.
- The factors that might influence the data are called variables.
- In controlled experiments, all the variables are under control of the experimenter.

Types of Variables…

- The variable that the investigator changes is called the independent variable.
- The variable that changes due to the change in the independent variable is called the dependent variable.
- All other variables that are kept the same are called controlled variables.
- The experiment should be repeated multiple times ("trials")
- It is important to always have a controlled trial in this type of experiment, where one trial mimics "normal" conditions

Example #1:

Question: How does temperature (heat energy) affect the rate at which water boils?

Hypothesis: ***If*** more heat energy is added to water, ***then*** the water will come to a boil faster ***because*** the water particles will be moving faster.

Example #2:

Question: How does the amount of time a student spends studying affect their grades?

Hypothesis: ***If*** a student studies more, ***then*** their marks will improve ***because*** they have a better understanding of the material.

Try #1: How does acid rain affect the growth of sunflowers?

A. What could our hypothesis be?

If sunflowers are watered with acidic water, then they will grow less because the acid would damage the plant's cells.

B. How could we conduct the experiment?

- Water 5 plants with highly acidic water
- Water 5 plants with slightly acidic water
- Water 5 plants with neutral water

C. What would be our independent and dependent variables?

- Independent: acidity of the water
- Dependent: plant growth

D. What are some controlled variables?

- amount of water/frequency
- type of plant, soil, pot.
- light exposure

E. What is our control trial?

- Watering with neutral water

Try #2: We want to know whether seeds germinate faster if fertilizer is applied.

A. What could our hypothesis be?

If fertilizer is added to seeds, then they will germinate faster, as the seeds will have more nutrients available to them.

B. How could we conduct the experiment?

Place 10 seeds in cotton soaked with water and fertilizer and 10 seeds in cotton soaked in plain water. Time how long it takes each seed to germinate.

C. What would be our independent and dependent variables?

Independent: amount of fertilizer in the water
Dependent: time it takes for seeds to germinate

D. What are some controlled variables?

Amount of water, type of cotton used, exposure to sun, temperature

E. What is our control trial?

Seeds with plain water

Variable Practice

Scientists use experiments to search for the cause and effect relationships in nature. In other words, they design an experiment so that changes to one item cause something else to vary in a predictable way. These changing quantities are called variables.

Question	Independent Variable (manipulated variable)	Dependent Variable (responding variable)	Controlled Variables (what is kept the same)
How much water flows through a faucet at different openings?	Water faucet openings (closed, half open, fully open)	Amount of water flowing measured in liters per minute	• same faucet • amount of water pressure
Does heating a cup of water allow it to dissolve more sugar?	Temperature of water	Amount of sugar dissolved	• Volume of water • type of sugar • stirring rate • size of cup • type of cup
Does an electric motor turn faster if you increase the voltage?	Voltage	Rate at which the motor turns	• type of motor • Same wire connections • Same room conditions

Identifying Variables - Practice

Target: I will be able to: Identify manipulated (independent), responding (dependent), and controlled variables in a scientific investigation.

Smithers thinks that a special juice will increase the productivity of workers. He creates two groups of 50 workers each and assigns each group the same task (in this case, they're supposed to staple a set of papers). Group A is given the special juice to drink while they work. Group B is not given the special juice. After an hour, Smithers counts how many stacks of papers each group has made. Group A made 1,587 stacks, Group B made 2,113 stacks.

Topic or problem you wish to investigate: Smithers thinks that a special juice will increase the productivity of workers.

Specific Question: Will the special juice that Smithers has increase the productivity of workers?

What is the manipulated (independent) variable for this problem?

- Special juice consumption

What is the responding (dependent) variable for this problem?

- Number of stacks of paper made

List at least three (3) variables that should be controlled.

- Same size stacks, same type of staplers, same type of paper

Homer notices that his shower is covered in a strange green slime. His friend Barney tells him that coconut juice will get rid of the green slime. Homer decides to check this out by spraying half of the shower with coconut juice. He sprays the other half of the shower with water. After 3 days of "treatment" there is no change in the appearance of the green slime on either side of the shower.

Topic or problem you wish to investigate: Homers shower is covered in a strange green slime.

Specific Question: Will coconut juice remove the strange green slime that is covering Homer's shower?

What is the manipulated (independent) variable for this problem?

- Exposure to coconut juice

What is the responding (dependent) variable for this problem?

- Removal of slime

List at least three (3) variables that should be controlled.

- Same shower stall, same shower use, same temperature, same length of time

Experimental Variables Worksheet

Directions: Determine the Independent Variables (IV), Dependent Variables (DV), Constants, and Controls from the following science experiments.

- **Independent Variable (IV)**: What the experimenter changes during the experiment.
- **Dependent Variable (DV)**: What the experimenter measures.
- Controlled (CV) Variables: Things that are kept the same. Controlled Variables (CV)
- Controlled Trial: Used to see if Independent Variable has any affect.

1) The number of flowers on different breeds of bushes in a greenhouse is recorded every week for two months.

IV:	Breed of bush
DV:	Number of flowers
CV:	Growing time, same soil, same amount of light, same temperature
Controlled Trial:	none

2) You give four sunflowers different watering with either pure water or different concentrations of salt solutions. After a two-week period, the height is measured.

IV:	Concentration of salt solution used for watering
DV:	Height of sunflower plant
CV:	Growing time, amount of light, soil used, temperature, etc.
Controlled Trial:	Pure water trial

3) Three redwood trees are kept at different humidity levels inside a greenhouse for 12 weeks. One tree is left outside in normal conditions. Height of the tree is measured once a week.

IV:	Humidity level
DV:	Height of redwood tree
CV:	same type of tree, length of time, temperature, sunlight
Controlled Trial:	Tree left outside

4) Pea plant clones are given different amounts of water for a three-week period. First pea plant receives 400 milliliters. Second pea plant receives 200 milliliters. Third pea plant receives 100 milliliters. Fourth pea plant does not receive any extra water; the plant only receives natural ways of receiving water. The height of the pea plants is recorded daily.

IV:	Amount of extra water
DV:	Height of pea plant
CV:	Type of plant, amount of sun, size of plant at start, soil type
Controlled trial:	Plant which receives only natural ways of watering

5) One tank of goldfish is fed the normal amount which is once a day; a second tank is fed twice a day; and a third tank is fed four times a day during a six-week study. The fishes' body fat is recorded daily.

IV:	Number of feedings a day
DV:	Amount of fishes' body fat
CV:	type of fish, size of tank, type of food, water quality
Controlled trial:	Fish fed normal amount

Hypothesis Practice

A hypothesis is a possible explanation or a prediction for an observed cause-effect relationship. A hypothesis is developed from the original question in the inquiry/investigation and it is based on **prior** knowledge. Often it is worded "If...then...because" OR "as...then...because". The "If" part of the statement is the cause variable (independent variable), and the "THEN" part of the statement is the effect variable (dependent variable).

Example #1

Question: How does temperature (heat energy) affect the rate at which water boils?

Hypothesis: **If** more heat energy is added to the water, **then** the water will come to a boil faster **because** the water particles will be moving faster.

Example #2

Question: How does the amount of time a student spends studying affect their grades?

Hypothesis: **As** a student studies more, **then** their marks will improve **because** they have a better understanding of the material.

Suggest a hypothesis for each of the following problems:

1. Why do people who smoke put more salt on their food?

If a person smokes, then they put more salt on their food because smoking damages their tastebuds

2. How does the amount of sunlight affect the growth of a plant?

If a plant receives more sunlight, then it will grow faster because it receives more energy

3. Why does water evaporate faster when its surface area is increased?

If the surface area of a pan of water increases, then it will evaporate faster, since more of the water molecules are at the air-water boundary

4. Why do plastic lids no longer fit their containers after going through the dishwasher?

If a plastic lid is run through a dishwasher, then it will shrink because plastic will deform when it is exposed to heat.

Making Observations

1. Are you a good observer? Can you spot the 12 differences?

2. Quantitative vs. Qualitative Observations

Quantitative observations are those which contain a measurement of some kind. This means that the observation will also have a **NUMBER** associated with it. For example, John has a mass of **70 kg** is a quantitative observation. The volume of the liquid was **250 mL** is another exam
ple.

On the other hand, **Qualitative** observations DO NOT contain any numbers and are collected by your **SENSES**. For example, Susan has red hair, is a qualitative observation. Bob is tall, is another qualitative observation.

Indicate whether each of the following is a quantitative or qualitative observation:

a. The concert was very loud.	Qualitative
b. The water was cold.	Qualitative
c. The reaction took 48 seconds to occur.	Quantitative
d. The grass was green.	Qualitative
e. The volume of the object was 4.9L.	Quantitative
f. The length of the trop was 675km.	Quantitative
g. The sandpaper was rough.	Qualitative
h. The sugar plus sulfuric acid turned black, then grew to a height of 20cm.	Qualitative, Quantitative

Recording Results and Observations

Observations (both quantitative and qualitative) are best recorded in table. Examine the observation table below.

Question: How does adding a mass to the end of an elastic affect its length?

Table 1: How the mass of an object affects the length of an elastic band

Mass of object (g)	Length of elastic (cm)
0	20
200	22
400	25
750	27
1000	30

What makes this a good observation table?

- has independent + dependent variables
- multiple data points
- Includes units
- Appropriate title + headings

How else could you show these results in a meaningful way?

- Scatter plot

Read the question below and design your own observation (data) table.

Question: How does the amount of time stirring affect the amount of salt that dissolves in a glass of water?

Table 2: How does stirring time affect dissolving of salt?

Stirring Time (s)	Mass of Dissolved Salt (g)
0	
60	
120	
180	

Representations of Data

When we represent data graphically, there are a few things that are important to include.

1) **Title** – A descriptive title can help guide the reader to understand what the data means.

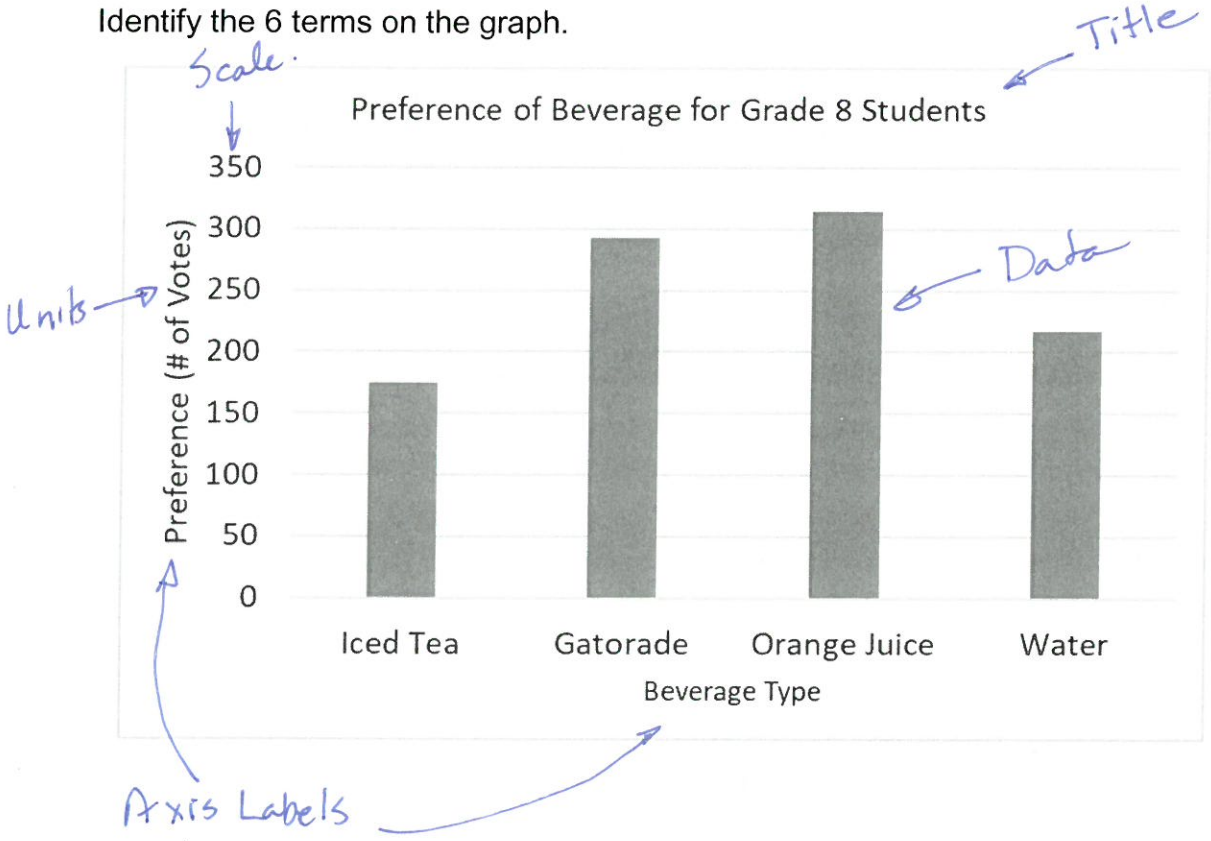
2) **Axis Labels** – Labelling the axis allows the reader to see which variables are being compared. The independent variable is placed on the x-axis (the bottom), and the dependent variable is placed on the y-axis (the left).

3) **Units** – All quantitative data needs to have units. These are often included with the axis labels.

4) **Scale** – An appropriate scale has a range of values to include all data. Scales are divided into equal **intervals** to make the graph easier to read.

5) **Data** – The information you are including needs to be place clearly and accurately on the graph.

Identify the 6 terms on the graph.



How to Choose Which Type of Graph to Use?

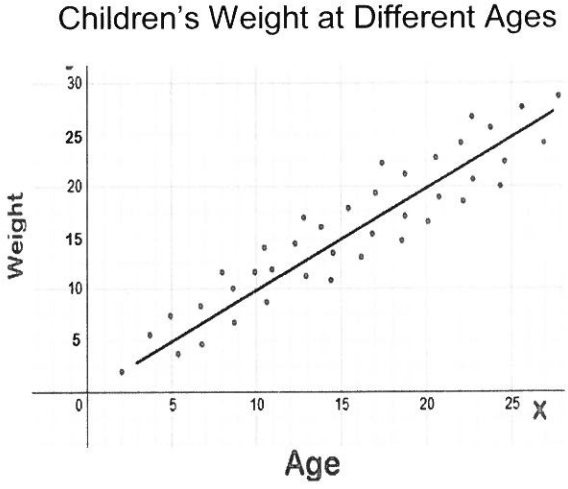
Scatter Plots

Scatter plots are used to determine relationships between two different things.

Plot the points on the graph. If you are plotting more than one set of data on the graph, use different shapes or colours.

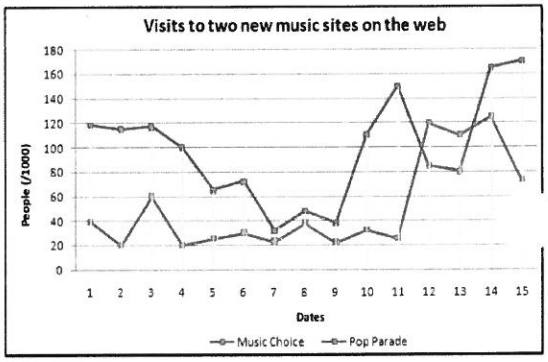
Do not draw a straight line from one point to the next. Instead, draw a smooth line or curve through the points, as close to each point as you can. This is called a "**line of best fit**." This shows the trend of the data.

The line of best fit can be used to show relationships and make predictions.



Line graph.

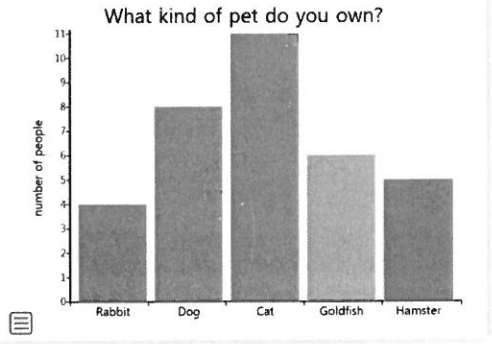
Line graphs are used to track changes over time.
More than one data set can be placed on the same graph.



Bar Graph.

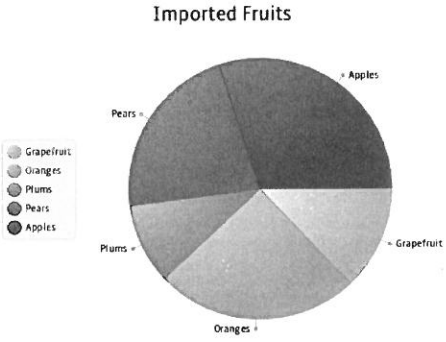
Bar graphs are used to make comparisons between different groups.

Bar graphs are useful when one of the variables is qualitative (no numbers).



. . . a Pie Chart.

Pie charts are best to use when you are trying to compare parts of a whole. This means the parts add up to 100%. They do not show changes over time.



Graphing Practice

A. Draw a line graph for the following data:

# of Days	# of Bacteria
1	2
2	4
3	9
4	16
5	33
6	65
7	128

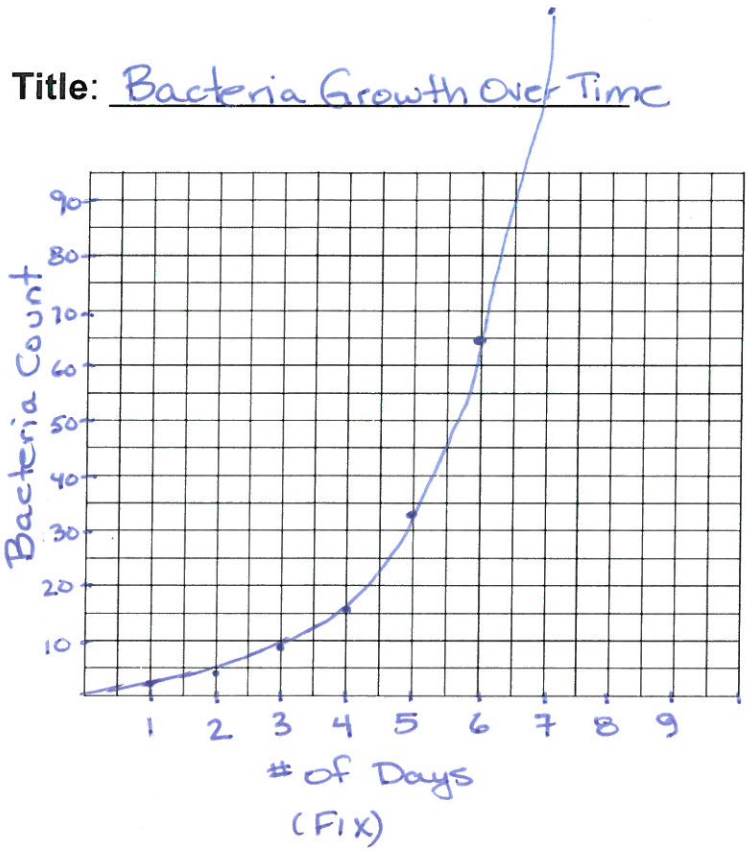
1. What is the independent variable?

   Time (Days)

2. What is the dependent variable?

   Bacteria Count

Title: Bacteria Growth Over Time



B. Draw a bar graph for the following data:

Material	Flow Rate (cm/s)
Water	6
Cooking oil	4
Molasses	0.5
Ethanol	5
Ketchup	2

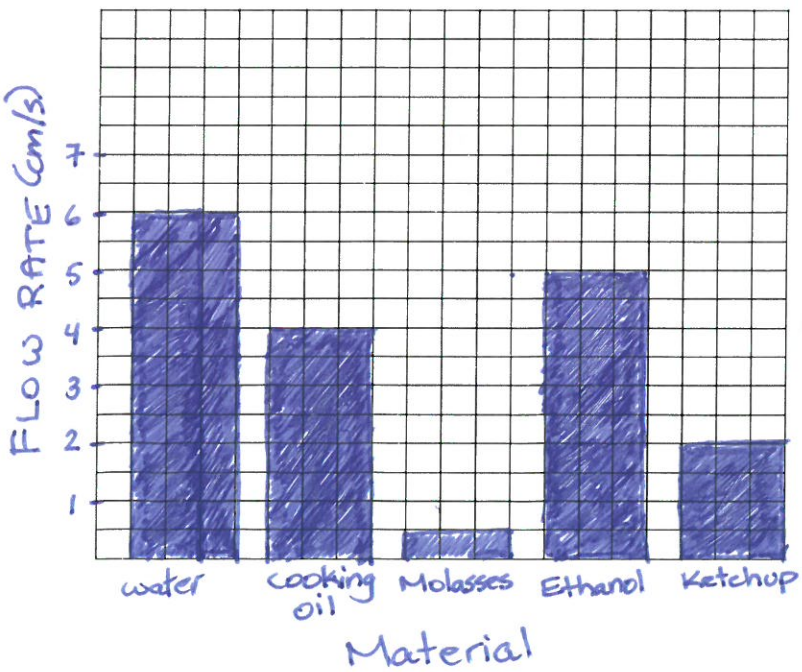
1. What is the independent variable?

   Type of Material

2. What is the dependent variable?

   flow rate

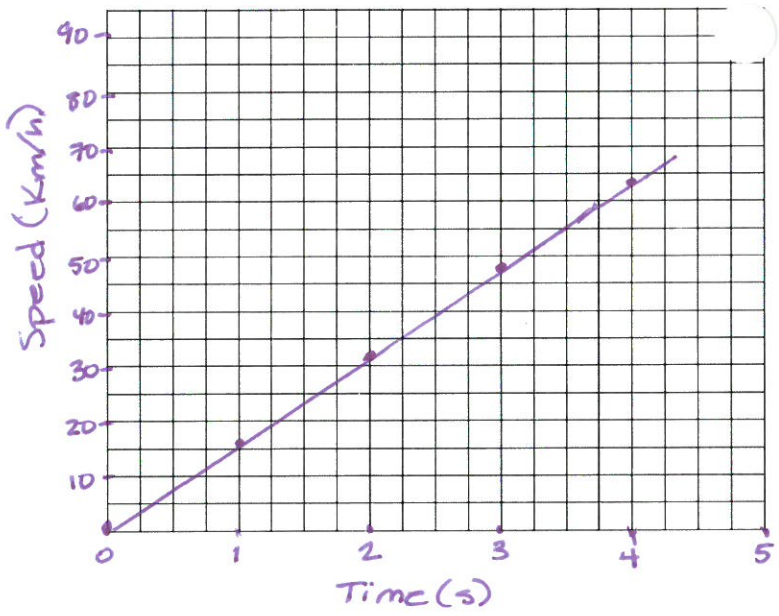
Title: Flow Rate of Different Materials



C. Draw a line graph for the following data of the acceleration of a car.

Time (s)	Speed (km/h)
0	0
1	16
2	32
3	48
4	64

Title: Acceleration of a Car



1. What is the independent variable?

   Time

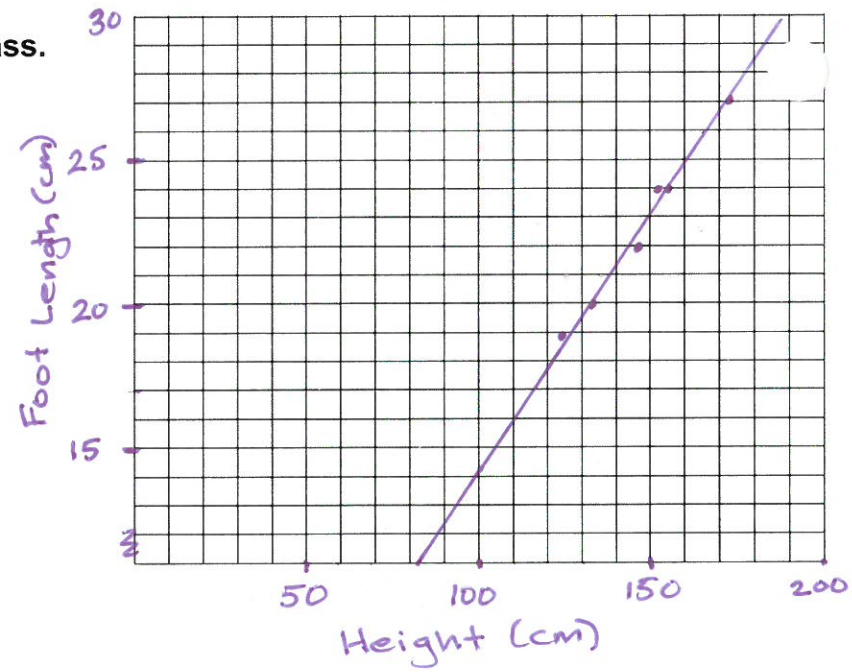
2. What is the dependent variable?

   Speed of Car

D. Draw a scatter plot for the following data for foot length vs. height for students in the class.

Height (cm)	Foot Length (cm)
126	~~21~~ 19
153	24
148	22
172	27
155	24
133	20

Title: Foot Length vs. Height for Students



1. What is the independent variable?

2. What is the dependent variable?

3. Based on the data above, how tall would you expect someone to be if their feet were 30cm long? 190cm

4. How foot length would you expect for a student who is 120 cm tall?

   16cm

Conclusions

A good conclusion should include:

- A statement of the purpose
- Whether the hypothesis was supported or rejected
- A sentence or two summarizing your results, with data
- What may have impacted the reliability of your results?
- A future experiment that can build on your results

*Remember, in a formal conclusion, never use I, we, you, they, she, he…etc.

Example:
The purpose of this experiment was to test the new fertilizer, Brand A, on plant growth. The hypothesis that Brand A would cause plants to grow taller than plants treated with store bought fertilizers was rejected. Plants treated with Brand A grew 1.5 cm in one week, whereas plants treated with store-bought fertilizer grew 1.9 cm in one week. One problem that occurred was that Brand A appeared to oxidize when exposed to sunlight, reducing its efficacy. In the future, it would be interesting to apply Brand A at night time to see if application without sunlight results in more effective plant growth.

Now your turn…

Purpose: to determine if moisture affects the growth of bacteria

Hypothesis: If bacteria plates are exposed to higher levels of moisture, then more bacteria will grow.

Results:

Plate Number	Amount of Water Added (mL)	Number of Bacteria Colonies
1	0	5
2	10	7
3	20	20

Conclusion:

The purpose of this experiment was to determine if moisture affects the growth of bacteria. The hypothesis, that adding more water to bacteria causes the number of bacteria colonies to increase, was supported. When no water was added, only 5 colonies grew, while 20 colonies grew when 20mL of water was added. One problem that occurred was that not all the colonies were the same size, so it may have affected the results. In the future, it would be interesting to see if the number of colonies would continue to increase as more water is added.