

## SECTION 1

### **What is psychology?**

What is “psychology”? There is no easy definition. Its origins come from the words “logos” (the study) and “psyche” (the mind). Logically, therefore, psychology is the study of the mind, but this does not help much if we cannot define what we mean by the mind. Many claim that mental events take place within the mind. By mental events, we mean activities such as attention-consciousness, information processing, thought-language, memory, and decision-making. These labels are, however, still vague and abstract. If Psychology is a science, like any other science, we need to define and measure our terms. These vague terms are neither easily defined nor measured. Some claim that Psychology is (or should be) the study of overt (what we can “see”) behaviour. A scientist cannot directly observe “mental events” because they occur somewhere within your mind (or brain). A scientist can observe overt behaviour. For this course, we shall use a compromise definition of psychology – the study of mental events and behaviour.

Modern psychology consists of many different branches. These branches and divisions are somewhat arbitrary and are based on (1) whether the psychologist is a basic, fundamental researcher (an experimental psychologist), an applied psychologist using the applications of experimental psychology (thus an “applied” psychologist) or a clinical psychologist. The general public and many students first studying psychology assume that all psychologists are clinical psychologists (psychotherapists, counsellors). While many psychologists are clinical psychologists, many are not. Psychology really began as a branch of Physics (and was called Psychophysics). There is real physical energy in the universe. This is studied by physicists. Humans (and other animals), however, experience (or are conscious) of only a small portion of this energy. This is because our sensory receptors are sensitive to only a tiny fraction of the physical energy in the universe. Moreover, our information processing systems assure that we are conscious of only a small portion of all the energy that bombards our receptors, that which is most relevant for our survival. Our attentional systems thus filter stimulus input, only allowing a tiny portion of it “through”. Psychophysicists study the what and the why of consciousness.

- Original definition: The science of the study of the "mind"(psyche) or "mental process".
- transition from physical to non physical (symbol of psychological is the greek letter and butterfly
- psyche is the totality of the human mind, consciousness and unconsciousness
- historical roots of psychology and the study of the mind: Aristotle theorized about learning and memory, motivation and emotion, perception and personality

We shall first examine the three major divisions of Psychology. Within each of these branches, there are also several divisions or what I call “schools”.

### **Problems?**

- If we call psychological a science: science of objective, in any science we must all agree on certain aspects
  - Define our variables (things that change), problem objectifying definitions
- We have to be able to observe our variables: cannot observe that goes on in the mind
- We must measure (quantify) our variables

## What are mental processes?

- what are mental process: it is hard to define because they cannot be observed; however they can be inferred

## Behavior

- psychology is also the study of behavior aka why do we act (behave) the way we do?

- what is (define) behavior? :

- Behavior can be observed

- how do we measure quantify behavior

- what causes behavior

- in a true experiment we manipulate or change a variable

-this might cause another variable ( what we are measuring) to change

-physics, we manipulate the physical mind

## Major Divisions in Psychology

### Experimental Psychology:

- - Began in mid- to late-1800s. First experimental psychology lab considered to be that of Wilhelm Wundt in Leipzig, Germany. Wundt studied basic and simple concepts of consciousness.

- the exact description of consciousness is the sole aim of experimental psychological

- basic principles of experimental are used to explain psychological phenomena

- There are two early schools of psychology:

1-*structuralism*: developed by Edward Titchener in the U.S who attempted to isolate the basic elements of the mind. This was known as *structuralism*, the basic structures of the mind.

- -Our experience of the external world is probably also made up of a mixture of simpler elements. He used the analogy of chemistry; salt is made up of a “mixture” of sodium and chloride. Is human consciousness (the “mind”) similar? What we see and experience as a “yellow” light is not in fact a yellow light. The retina in our eyes has receptors for only 3 types of colour, red, green and blue. When the “red” receptor fires, we experience red light. But how can we experience “yellow”. There is no yellow receptor. It represents the firing of two receptor cells, those corresponding to red and green. We are conscious of yellow; we are not conscious of the fact that the red and green cells in the retina are simultaneously active which in turns activates very different, but highly specific areas of the visual “pathway” of the brain. The red-green signals are thus being translated by the brain-mind. Titchener asked his research participants to verbally state what they were “experiencing” when, for example, they smelled a flower, heard music, and so forth. This method of looking inward and reflecting on one’s own conscious experience was called *introspection*. It however proved to be very subjective and unreliable. What one individual might report following introspection might be very different from what another individual might report.

- Nevertheless, the initial studies indicated that the basic principles of experimentation can be used to explain psychological phenomena. The principles of experimental psychology had thus been initiated.

2- *functionalism* (pragmatism) developed by William James in the US. What is the function of our thoughts and emotions? Focused on how mental processes enable us to adapt, survive and flourish.

- - William James at Harvard University is considered to be the father of American psychology. James wrote a great deal about what we would now consider to be “cognitive” psychology (see section on Schools of Psychology). James did little actual experimentation. Thus, he did not experimentally test most of his theories. James is also considered by many to be an important (if not the most important) contributor to a branch of (an almost unique American) philosophy called pragmatism (following in the tradition of other American thinkers such as Benjamin Franklin). Philosophers had long debated whether human existence was mainly material or nonmaterial in nature (the materialism versus idealism debate). As an example, is the mind “strictly” material in nature? Is it simply part of the physical brain? We shall see more about this debate later when we discuss scientific methods. The James pragmatic approach declared, in essence, that the philosophical debate was really of no concern. What counted was the pragmatic end result. Pragmatism also forms the basis of another American philosophy, this one economic, capitalism. For many philosophers, pragmatism is an exceedingly empty principle. James is also credited with writing the first major textbook in psychology, a volume that is still often cited.
- James did not carry out experimental research, developed many theories:
- developed a number of theories about consciousness, attention, memory. Wrote a first textbook on psychology
- assumed that thinking, like smelling, developed because it was adaptive aka contributed to survival.

#### Applied Psychology:

- scientific study that aims to solve the practical problems such as social, developmental, education, industrial psychology

#### Clinical Psychology

- counseling psychotherapy: a branch of psychology that assist people with problems in living ( school , work, marriage) and in achieving a greater well-being
- Sigmund Freud, in Vienna, Austria is generally considered to be the founder of psychotherapy but Freud was not a psychologist. He was a psychoanalyst. Major roots of clinical psychology and therapy are recent – perhaps as late as the 1940s in the U.S. Now the major field in Psychology.
- major roots of clinical and psychology and therapy are recent- perhaps in the late 1949s in the Us
- first clinical psychology dept in Canada..U Ottawa
- now the major field in psychology

#### **Schools of psychology :**

- Each of the above divisions (experimental, clinical, applied) can also be sub-divided into a number of other branches, that we shall call “schools”. Again, these are somewhat arbitrary. Thus, many experimental, clinical and applied psychologists might take a so-called “cognitive” approach while others might take a more “biological” approach.

#### 1.Cognitive:

- Initially began in late 19th Century (William James). Fell into disrepute. Revival in 1950s. Now a “boom” field.
- Study of higher “mental functions” -- memory, attention, decision-making, language

- cognitive: attempt to infer hypothetical mental states of "information" processing based on current response behavior, patterns/performances. Major measures are how accurate and speed at which completed tasks. Note: that these mental states cannot directly be observed, only inferred. ex. Semantic (semantic memory) decision task: automatically search out words related to black. Semantic is the association of one word to another. This is permanent memory
- Cognitive short term memory: ex: series of letters. .
- Attempts to *infer* hypothetical mental states of "information" processing based on current response patterns/performance. The mental process and what behavior did we directly observe and measure.
- An example of an experiment in cognitive psychology: A group of participants is presented with 200 single words and 200 single pictures. They are asked to remember only the words. They are told that the pictures are there only to distract the participant from the task, remembering the words. The experimenter now presents a second series of words and pictures, some of which were presented before, some of which were not presented before. The participant recognizes perhaps 80% of the previously presented words, but surprisingly also recognizes about 80% of the pictures. The experimenter *infers* that images (or pictures) are stored in memory automatically even if the experimenter does not ask the participant to do so. But perhaps words are also stored automatically. The clever experimenter now changes the task. A second group of participants is tested again, being presented with the same long list of words and pictures. This time however they are told to remember all of the pictures and that the words are irrelevant. Again, they are shown another list of words and pictures and asked if they were previously presented. This time only 30% of the words are correctly recognized but 80% of the pictures are correctly recognized. The cognitive psychologist thus infers that pictures are processed automatically even if the subject is told to ignore them. Words are not however processed automatically.
- Note that the cognitive psychologist cannot directly observe the mental processes. In the example above, the psychologist cannot observe memory being stored. Nor can the psychologist observe how memories for words are stored differently than memory for pictures. The psychologist can infer however that the storage process **MUST** be different. To store words in memory requires effort (or attention) to the task. Thus is not the case for the storage of pictures. They are stored whether the intent of the participant is to actually store the pictures or not.
- experimenting with how we perceive, think and solve problems
- what we one call "cognitive" psychology was the major branch of experimental psychology in the late 1800s and early 1900s
- cognitive psychology provides an exceedingly elegant means of scientifically test various cognitive functions ("mental events"). Can we directly observe mental events? They must be inferred on the basis of performance (RT and accuracy)
- Subdivision of cognitive psychology :
  - Cognitive Psychology: has proven to be immensely powerful and popular
    - As outlined above, use measures such as performance and decision-time to *infer* about *hypothetical* brain functions
  - Cognitive Neuroscience
    - A problem with the usual methods employed in Cognitive Psychology is that the experimenter cannot directly *observe* the cognitive functions (for example, the automatic processing of pictures) that are of interest. Rather they are inferred on the basis of variance in performance. In science, we must be able to observe the measures of interest. How do we actually know that words and pictures are indeed processed differently in the brain? Recent innovations in neuroscience provide a method of overcoming this criticism. Modern brain imaging techniques permit the

experimenter to actually observe the changes in brain activity as the participant is engaged in some cognitive task. Thus, in the word-picture task above, certain brain regions will be activated when you are presented with a word and asked to remember it. Now, when you are asked to ignore the words (or at least not remember them), not all of the same brain regions will be activated. This may not be the case with pictures. When you are asked to remember the pictures, certain brain areas will be activated (and these will be different from words, because pictures are not words). Now you are asked to ignore the pictures. If you cannot, the same brain regions are again activated.

#### neural/cognitive modelling:

-use computers to mimic cognitive/information processing. How many "decision" must the computer need to make to arrive at a solution to a problem?

### 2.Biological: exploring links between the brain and the mind

- biological psychologists attempt to measure actual mental events by monitoring brain activity. They either: manipulate psychological state/mental events (attention, memory, decision making) and see the effect of this manipulation on brain activity, brain structure. Or we can manipulate brain (stimulate, lesion, drugs) and determine effect of psychological/mental decisions

-manipulate psychological state (attention, memory, decision making, emotions, motivation drives) and see effect of this manipulation on brain activity, brain structure. Engagement of frontal lobe is attention.

-manipulate brain (stimulate, lesion, drugs) and determine effects on psychology (mental processes)

### 3.Behavioral: focus on how we learn observable responses

- began 1920s with J.Watson and his criticism of cognitive psychology and psychoanalysis

- B.F Skinner (1935-1990) laid out much of the tenets of "behaviorism". Behaviorism: the view that psychology (1) should be objective science that (2) studies behavior without reference to mental processes. The study of unobservable, undefined, unmeasurable mental events (the field of study of cognitive psychology) is unscientific. The study of the mind is unscientific and this a waste of time.

-Psychology as an objective science (Because we infer). All psychological events must be directly observable. Cognitive events cannot be observed (only inferred). Only behavior that can be observed. The study of cognition is therefore unscientific according to behaviorists. Similarly, psychoanalytic principles cannot be observed. The existence of the unconscious, so critical to psychoanalytic principles, also cannot be observed

- why do we act the way we do? (motivation). All behaviour can be explained by consequences of behavior. We learn to repeat behaviour that has been "reinforced" We do not repeat behaviour that has not been reinforced.

- a strict environment (not inner "mind") explanation of behaviour. All behaviour is learned.

- no need to postulate about genetic influence, we learn to behave in certain ways. A criminal is criminal because of their past learning. They have been reinforced to act that way. No point in inferring about different types of memory, consciousness, etc

- determinism: all behaviour is determined by consequential events (reinforcement, punishment). All behaviour is learned. Behaviour that is reinforced will be repeated and that which is not will not be repeated. If behaviour is inappropriate it is because of poor learning (reinforcement was given inappropriately)

### 4.Social:

- Emphasis on social “behaviour”.
- Study of social environment and its effects.
- Social attitudes; social learning: how we learn to act the way we do
- Emphasis on social behavior influenced by parents, friends, media.etc
- Socialization: interactions with others that teaches social behavior
- There are certain social psychologists who believe that most of human behaviour can be explained through evolutionary/genetic principles. These are called socio-biologists. Emphasis on the study of animal behaviour (ethology). Deterministic theory. This is almost the opposite of behaviourists who believe that it is learning that determines our behaviour. Social biologists claim it is largely our biology and genetic endowment that determines our behaviour.
- A newer branch of social psychology is social neuroscience (not the same as sociobiology). Social neuroscientists use neuroscience methods to study social phenomena (social interaction, emotions, attitudes)

- small branch of social psychology: social(socio-biology; evolutionary)
- most human behaviour can be explained through evolutionary/genetic principles
- these are called socio-biologists
- emphasis on the study of animal behaviour (ethology)
- deterministic theory: you act the way you do not because of learning, but determined by the principles of evolution (survival of the species and more specifically survival of MY genes; E.O Wilson (1975-present)

### 5.Psychoanalytic/Psychodynamic

- S.Freud (late 19th, early 20th century) heavily influenced by first world war.
- much of behaviour and "emotions" is repressed (especially sexually) these emotions still influence our behaviour, but we are not aware of them because they are hidden away (also aggression)
- deterministic-behaviour is determined by unconscious "drives". We think we have rational thought and chose to act the way we do, but we do not.
- criticized as being unscientific : because how do we know the unconscious exists? How can we prove it? How do we know they don't resurface?

### **Differences among psychoanalysis, psychiatry, clinical psychology, experimental psychology**

- Psychoanalysis-trained in psychoanalysis
- May or may not be a psychiatrist. Emphasis on Freud and post-Freudian (e.g Jung) theory
- Psychiatrist: a branch of medicine dealing with psychological disorders practiced by physicians who sometimes provide medical treatment as well as psychological treatment. Residency in "psychiatry". Must have a medical degree. 2-3
- Psychiatrists employ a medical model
- Theory that psychiatric disorders are a mental illness. Treatment methods can include psychotherapy and drug therapy. Diagnosis first, then depending on results the treatment will vary. Just like any other in the medical field.
- In Canada, only psychiatrists can prescribe medication
- Clinical psychologist- a branch of psychology that studies, assesses and treats people with psychological disorders. in Canada and US you must have research degree, a Ph.D
- Is trained in both research and clinical psychology
- In some regions in the US, a D.Ps ( not trained in research) will suffice

- Clinical PSY emphasis on abnormal behavior and not necessarily illness
- Emphasis on change through counseling/psychotherapy
- Experimental psychologist: trained ONLY in research (in one of several different areas) degree is Ph.D
- Not trained in clinical psychology
- Legally cannot provide psychotherapy or counselling (cannot claim to be psychologist to the public)
- Anyone can call themselves a “counselor” or a “therapist”. A counselor or therapist does not have to be a trained clinical psychologist. This does not mean that the non-psychologist “counselor” is a poor counselor. It simply means they do not have a Ph.D. in clinical psychology

### **Phenomenological/ humanistic** (Clinical Psychology)

- humanistic theories: historically significant perspective that emphasized the growth potential of healthy people and the individuals’ potential for personal growth. They drew attention to the ways that current environmental influences can nurture or limit our growth potential and our importance of having our needs for love and acceptance satisfied (Maslow)
- Emphasis on unique human quality of behavior
- concerned with individuals unique personal experience, their phenomenology (sometimes called experiential psychology: asking about experiences and altering how you look at them)
- Focus on subjective experience (subjective because we all look at things differently)
- concern with developing theories of inner life rather than explaining behaviour
- criticized as being unscientific because it focuses in subjective, not the objective. Science can only study that which is objective and that which can be observed.

### **Psychologies Biggest Questions**

- Stability VS change: are we capable of change or do we stay the same throughout our lifetime? are traits present at birth or do they develop through experience?
- Rationality VS irrationality:
- Nature VS nurture: the longstanding controversy over the relative contributions that genes and experience make to the development of psychological traits and behaviors. Today’s science sees traits and behaviors arising from the interaction of nature and nurture. Contemporary view of this is that psychological events often stem from the interaction of the two
- natural selection: the principle that among the range of inherited traits variation, those contributing to reproduction and survival will most likely be passed on to succeeding generations

### **Epistemology** (method of obtaining knowledge)

Philosophers have identified at least three methods by which we can gain knowledge, “truth”. These are:

- Divine (non-physical) insight : We gain knowledge through communication with a higher, non physical being/ existence who knows everything and somehow relays that in a non physical way.
- Pure logic and thought (Aristotle ): If we are logical in our reasoning, we should be able to deduce all knowledge
- Scientific manipulation. This is the only method of gaining knowledge that we shall study in this course. A biologist might want to know if water affects plant growth. The biologist then manipulates a variable, the amount of water that is given to a specific plant. The biologist *varies* (thus the word “variable”) the amount of water given to the plant. He/she gives the plant more or less water. He/she then observes the *effect* of this variable (the amount of water that is given) on

plant growth. The result might well be that plants that are given more water grow higher. We now have *knowledge*. We *know* that water will *cause* plants to grow

- scientific method: self correcting process for evaluating ideas with observation and analysis

### **Idealism VS materialism**

- For many centuries, philosophers and scientists debated about the nature of human experience (consciousness).
- A pure materialist assumes that all that exists must exist in some physical form. This material existence is subject to the laws of the physical universe. There is thus no room in this model of the universe for non-material (non-physical) existence. A pure materialist is thus an atheist. He or she does not believe in any higher non-physical, existence, in god(s) or in the non-physical soul/mind.
- By contrast, a pure idealist does not believe in the physical reality of our existence. This is best exemplified by the Greek philosopher, Plato. How do we know that physical reality exists at all? How do I know that I am not simply experiencing dream-like existence? It was not until several centuries after Plato that a compromise solution was made by the French philosopher and mathematician, Descartes, who found room for a nonphysical existence (the mind or soul) and physical existence (the body). The laws of science operate *only* on a physical, material existence.
- Nevertheless, philosophers point out that we do have concepts such as love, hate, free will and in psychology we have concepts such as the mind, consciousness-unconsciousness. Are these entirely physical in nature?
- Is all that exists material in form? -laws of physical universe
- Psychology "concepts": love, hate, liberty, free will, the "mind", consciousness-unconsciousness

### **Scientific Process**

- *Observation of universe*: There are many things we do not understand, for which we do not have an explanation ( aka variables that change) so..
- *Define a problem*: what is the problem that needs explanation? What questions are you asking? Let's take an example from psychology. We know that a drug, alcohol, affects performance on many tasks. Why does it affect performance on these tasks? You might *speculate* (or have an "opinion" more about this later) that alcohol mainly affects tasks that are very complex. Simple tasks are thus spared. Even if this was true, it does not explain why alcohol affects complex tasks more than simple ones. Furthermore, you need to define what you mean by a "complex" and an "easy" task. What is complex about a complex task? As you can see, we now have many problems that need to be solved.
- *Search the literature*. Go to the library. Read the scientific periodicals (called "journals"). Search the internet. Has anyone already asked the same questions? Many scientists have already done many, many studies on the effects of alcohol. While you might speculate that alcohol only affects complex tasks, you would be wrong. The fact is that we *know* (that word again) that alcohol may not affect all complex tasks. Speaking is a very complex cognitive function. Yet we manage to speak and to understand speech quite well under the influence of alcohol. Driving a car is also a relatively complex task. It takes several months (if not years) to master this task. Yet under the influence of alcohol, we seem to manage quite well. We can (unfortunately) get into the car, turn on the ignition, put the car in gear, accelerate, turn, navigate. Identifying red lights should be an easy task. Very young children can, after all, discriminate red from green. But, under the influence of alcohol, we sometimes do not do this task well. We sometimes miss the red light.

- *Development of a theory*: a possible "answer". a summary (synthesis of what we already know). Based on a complete review of existing studies (the "literature"), you might arrive at the conclusion that alcohol appears to mainly affect tasks that require short-term memory. Tasks that require long-term (or permanent) memory are not affected. Now you have developed a *theory* based on a thorough review of the literature. This is no longer speculation. Based on theory, scientists form an *hypothesis* (or prediction). In the example above, you would hypothesize that alcohol affects any task that requires short-term memory. It should not however affect tasks that require long-term memory.
- *Testing of hypothesis* (unbiased, objective). This involves the design of a study to answer the questions & resolve the controversy. Obviously you would need to include in your "design" certain tasks that require the use of short-term memory and others that do not.
- *Data collection*. Run the study.
- *Analyses of the data*. Does alcohol cause a *variation* in performance? Do the results *differ* (or vary) depending on which task was run?
- *Interpretation of the results*. Was the hypothesis supported by the results? Are there alternate explanations (theories) that might also explain the results?

### Theories/Hypotheses

- A theory: predicts behavior or events. Theories are formed after a review and synthesis of the relevant literature. It is based on existing facts. It is an explanation using an integrated set of principles that organizes observations and predicts behavior or events. (based on a synthesis of previous facts) makes a testable prediction called a *hypothesis*
- hypothesis: a testable prediction often implied by a theory
- Theory vs speculation (opinions). A theory is only formed after an objective review and synthesis of already published research. It is not formed on the basis of guesswork or subjective opinion. We can all speculate about why things are the way they are. The problem with this is that your opinion is as good as mine. Which opinion is correct? Again, theory is based on fact. You may have an opinion that humans can get by on 2 hours of sleep. Your theory is wrong. It is a fact that humans require more sleep (a subject we will study in this course) and if they do not get, will suffer grave consequences.
- All hypotheses must be testable. (See next section). We must be able to design a study to test the hypotheses. Hypotheses make predictions. The results of the study will allow us to say whether your theory is true or false.
- A GOOD theory is one that potentially can be proven to be WRONG. There is no point in simply stating that alcohol affects performance. Even if I find that it does not affect certain tasks, you can always claim that I was not using the right tasks (the ones that would be affected by alcohol).
- Replication - Others should be able to exactly replicate what you have done and what you have found. This is why science is said to be "objective" and "universal". If we repeat the experiment anywhere in the universe, the results should be the same. We thus obtain "universal" knowledge.

-*FACT*: men are more aggressive than women

-hypothesis: if this is the case, one would predict that there should be more men in prison for violent -offended

-Note: that this does not tell us WHY men are more aggressive

-We will need a theory that proposes why this is so

-We then test this theory

FACT: testosterone plays a significant role in aggression

Fact: men have more testosterone than woman

The results of the study will allow us to say whether the theory is true or false

## Hypothesis Testing

There are many, many problems that remain unsolved. Different theories can, however, be developed, each of which might potentially explain a fact. Fact: men perform slightly better in math than women (to balance matters, women perform slightly better than men on verbal tasks). One theory to explain why men do better on math is that it is a result of evolution, and more specifically, hormonal differences. Another theory, however, maintains that the differences can be explained on the basis of social learning. Women learn that math skills are not admired. Men learn that they are admired. Both theories cannot be correct. We thus have a *controversy*.

- Scientists state an hypothesis. This is an expectation based on previous scientific research (fact). “If theory X is correct, we would expect that...” On the other hand, if theory Y is correct, we would expect that...”
- The hypothesis must be stated in a specific enough manner that we can prove it to be wrong
- Define variables of interest. *Operational definition*. If you claim alcohol affects performance, how do you define “performance”? If your hypothesis is that alcohol causes you to “feel good”, how will you define “feeling good”?
- Means of measuring (quantifying) variables of interest. This is often an extremely difficult step in Psychology. Recall that science operates on the basis of material existence. There must be more or less of it. This implies that you must be able to *quantify* your variable of interest. You need to attach a number to it (to “measure” it). Logically, a variable must “vary”. Even if alcohol does make one feel good, how would you measure “feelings” and in particular, “feeling good”?
- According to many philosophers of science, we should assume that all hypotheses are false unless proven otherwise. This is what is meant by the *null* hypothesis. The onus is thus on the researcher to prove their theory true. In this sense, science is very cynical and pessimistic. We assume god(s) does (do) not exist until proven otherwise. We assume there are no aliens on other planets. We assume there are no tigers roaming the campus of the University of Ottawa. If we come upon a tiger, then we have positive evidence. Our null hypothesis is wrong. If we do not find any tigers, it can always be claimed that we have not looked in the right places. In the example of alcohol, we assume that it does not affect performance. If it does, the null hypothesis is wrong. (Incidentally, this is exactly the same logic that we use in British-based “common law” legal systems. We assume that a suspect is not guilty... The *null* hypothesis is that the suspect is *not* guilty. Note we do not assume that they are innocent... it is philosophically difficult (if not impossible) to prove innocence. The onus is on the government (the courts) to prove the suspect to be guilty. There is enough positive evidence to judge the null hypothesis... the assumption that the suspect is not guilty... to be wrong. If there is not enough evidence to find the suspect guilty, they are not judged to be “innocent”; rather they are judged to be “not guilty”.

## Problems in Psychology

Often many of the questions we ask are exceedingly difficult to test. Frequently, we cannot easily define psychological concepts. We may not agree on a way of measuring the concept. Let’s use the example of aggression. We know that certain children are more aggressive than others. As good scientists we need to ask the question, why? Why are some children more aggressive while other children are less aggressive? What is the cause of aggression? Perhaps it is because the very aggressive children have inherited a gene for aggressiveness. But perhaps certain children have also learned to become very aggressive. We go to the library/internet and do a search. We find that there

are wide differences across the world. In particular, countries that do not censor very violent computer games, television and movies (the “action thrillers”) appear to be much more violent than those that do. A “learning-modelling” theory claims that aggression is learned and indeed it is rewarded (reinforced). Those children that watch the most violence on television (or play the most violent computer games) tend to become the most aggressive.

- Theory: Watching violence on television *causes* children to become more aggressive. Biology has nothing to do with it.
- Alternate theory: It is biology (too much activity in certain “aggression” areas of the brain)) that cause certain children (and boys in particular) to be aggressive. Learning has nothing to do with it.
- Both theories cannot be correct.
- *Operational definition*: Define *variables* of interest: Children? Violence? Aggression?
- Manipulate extent of violence to which children are exposed in the experiment? How will this be done?
- Measure/quantification: How does one quantify violence? Aggression?
- Ideally we would also manipulate the brain. We remove the aggression areas of the brain. Now are the aggressive children less aggressive? Obviously, we could not ethically do this type of study. But perhaps we could identify those who are the most and least aggressive and then scan their brains using an MRI. Are the brains of the most aggressive different from those who are the least aggressive? Note that this is not a true experiment (because we have not manipulated anything; see next section). Further, even if the experimenter does find a difference in the brains, this does not tell us why the brains are different. We would not know the *cause* of the aggressive behaviour. Perhaps the brains are different because children who are aggressive have different upbringings. Perhaps their diets are different. In short, the differences in the brain structures might have nothing to do with aggression.

## TYPES OF STUDIES

**True Experiment:** carried out in the natural sciences, and if often not possible in humanities, medicine and social sciences

### **Case studies**

- Study one or more individuals in detail to obtain data that be true for all of us. For example: we might study brilliant mathematicians and analysis of special individuals is the hope of revealing things true to all, usually used in descriptive methods
- can suggest hypothesis for further testing
- limitation is that case studies do not allow us to learn about general principles that apply to all of us because it only involves one individual so we cannot generalize

### **Sampling:**

When we study groups of individuals, we obviously cannot study all members of the group. If we wish to compare males and females, we cannot study every single member of the Canadian population. We therefore need to select certain individuals who are representative of the population.

- Population - the whole group you wish to study
- Sample - a smaller *random* (every member of the population has an equal likelihood of participating in the study) selection of individuals in the population

The sample must be *representative*. It is better to have a small but representative sample than a large, unrepresentative sample

#### Size of the sample

- We are much confident with results from larger than smaller samples
- If a very large sample is used very small differences might be statistically significant
- On standard high school exams in Canada, males score minutely higher than females on math, but this is statistically significant.

#### **Group studies**

- Sample a small number of individuals from a population
- Randomization:
- Representative?
- It's better to have a small but representative sample than one that is large and unrepresentative

#### **True experiment studies**

- In a true experiment, the factor (or *variable*) of interest is *manipulated*. This variable is called the *independent variable*. Let's return to the study of the influence of alcohol. We might manipulate the dosage of alcohol. The scientist will give more or less alcohol. One group gets a large dosage (say 200 ml of vodka... that's about 7 or so oz!). A second group gets a smaller dosage (say 50 ml). A third group gets no alcohol (0 ml of vodka). We mix the alcohol with a mint drink. None of the participants in the experiment can tell which drink they are getting.
- Our hypothesis is that alcohol will affect performance (we obviously need to define "performance". What task will the participants perform? Larger dosages will affect performance more than small dosages.
- We assume our expectation to be wrong! Again, this is the null hypothesis. We thus assume that alcohol does not affect performance until proven otherwise.
- If our theory is true, the manipulation of the independent variable *causes* another variable to change. This is a cause-and-effect relationship. In the example, alcohol might cause performance to worsen. The variable that is affected by manipulation of the independent variable is called the *dependent variable*. In this example, our dependent variable is performance on a task. We need to define a task. Let us assume that the participant is asked to push one button if a red light is presented and another button if a green light is presented. We will measure how long it takes to respond to each of the lights. (The delay in responding is called the "reaction time" (RT)).
- The dependent variable is that which we measure. Thus, the dependent measure in this example is RT. The dependent variable, RT, might vary because of the independent variable, the dosage of alcohol. If the theory is correct, RT should be slower when a high dosage is given compared to when a low dosage is given.
- While certain variables are manipulated, others are held *constant*. Everything in the alcohol experiment is held constant, except for the dosage of alcohol. All participants, regardless of the amount they drink, see exactly the same lights. They all do exactly the same thing in the lab.
- Note that there are two things that vary. The dosage of alcohol that our three groups receive is varied (or manipulated). Performance (measured by RT) may also vary. We thus have an independent variable (it varies) and a dependent variable (it will vary if the independent variable causes it to vary; it will not vary if the independent variable does not cause it to vary). If alcohol does indeed affect performance (RT becomes slower with higher dosages), we *reject* the null hypothesis as being *false*. Our conclusion is thus that it is not true that alcohol does not affect

performance. In other words, alcohol does affect performance. Alcohol *causes* RT to vary. If RT is not influenced by alcohol, it will not vary. RT will be the same whether participants drink alcohol or not. In this case, we fail to reject the null hypothesis. We do not have evidence that alcohol affects performance.

- Note that if RT does vary, we will know why. We have obtained *knowledge* about the *effects* of alcohol. It *causes* RT to slow. Assuming this is the first time the experiment has ever been run, we now know something we did not know before. This is called scientific *progress*. When scientists do not know why certain variables vary, they are said to be *ignorant*. Ignorance is the absence of knowledge. Variance that cannot be explained is called *error*. A “mystery” is something we cannot explain (for which we do not have knowledge of why it varies). It is assumed that scientists can potentially explain everything in the universe. If, at the moment, they cannot, they must be making an error. Please note that contrary to popular belief, scientists can, in fact, only explain a very few things. We remain, therefore, very ignorant about most of the mysteries of the universe.
- There is also another very important source of variance in our experiment. We have a certain number of participants in the experiment. Their reaction times will not be identical. Some will be faster. Some will be slower. In other words, there are individual differences (or variance) within each group. What is the cause of this variance? The only variance we can explain is that which we manipulated. We do not know why individual participants’ RTs vary. Variance as a result of individual differences is thus called error variance. We can speculate about why individual RTs vary. Perhaps some individuals were more interested in the study. Perhaps certain individuals are simply faster while others are slower. Perhaps some react to alcohol more than others, but we are only guessing. We do not really know any of this. To gain this knowledge, we need to manipulate these variables. So, if you think “interest in the study” explains RT, you now need to design another experiment. You need to define “interest” (and how would you do this?). You need to manipulate “interest”. Then, you examine if “interest” in the task does indeed cause RT to vary.
- Our dependent variable (RT in this example) therefore varies for two reasons – because of the effects of the independent variable (that which we manipulated) and individual differences. We can explain the effects of the independent variable. Alcohol causes RT to vary. We cannot explain variation among individual participants. In any experiment, there are thus two sources of variance: one that we can explain, and one that we cannot explain. As we shall later see, this becomes crucial when we attempt to determine if differences due to the independent variable are *statistically significant*.

### **Experimental "designs"** (experimental control)

- Researchers employ different designs to test their theories. Studies are designed to assure that the results that are obtained cannot be explained by “confounds”
  - One design uses *control* and *experimental* conditions or groups: experiments enable researchers to isolate the effects of one or more factors by (1) manipulating the factors of interest and (2) holding constant other factors
  - experiment is a research method in which an investigator manipulates one or more factors (independent variables) to observe the effect on some behavior or mental process (dependent variable)
  - create an experimental group: the group in an experimental manipulation is carried out. It is the group that is exposed to the treatment; to one version of the independent variable. In the example above it is the group that received the alcohol.

- The other group is the control group. Why? because the control group in an experiment is not exposed to the treatment; serves as a comparison for evaluating the effect of the treatment. Provides a baseline to which the experimental condition can be compared. No experimental manipulation is carried out with control group. In the alcohol example above, the control group is the group that receives no alcohol.
- Again, an example will be used. We want to know the effects of sleep deprivation on RT. We will manipulate the amount of sleep that participants will have and then examine the effects on performance (on the speed of responding or RT). The independent variable is thus the amount of sleep. The dependent variable is thus RT. Twenty individuals will participate in the study. Half (10) of them are assigned *at random* to the experimental group. The other half are assigned to the control group. The experimental group is tested following 24 hours of sleep deprivation. The control group is not sleep deprived. The amount of sleep is thus manipulated between the two groups.
- Random assignment: participants will be randomly assigned to either the control or experimental groups, this minimizing pre existing differences between those assigned to the different groups
- unlike correlation studies which uncover naturally occurring relationships, an experiment manipulates a factor to determine its effect
- Problems with use of control group: one group might be different from another by chance probability alone
  - Solution: use same group of participants repeated conditions
- *Pre-post designs*. A problem with the use of 2 different groups (experimental and control) is that whatever differences we find in our independent variable might be due to chance. Let us assume that RT is much slower in the experimental than the control group. Can we then conclude that sleep deprivation causes a slowing of decision-making? Not necessarily. Perhaps the experimental group was simply a very slow group. Had this group not been sleep deprived, the participants would still have had slow RTs. The fact that we randomly assigned participants to one group or the other should control for this finding, but it is possible that just by chance the slow responders were randomly assigned to the experimental group (just as it is possible to sometimes flip a coin and get 5 heads in a row).
  - The solution to this dilemma is to use the same group of participants in both *conditions*. The group is then tested prior to sleep deprivation and again following it. They are thus tested pre- and post-deprivation. The *pre-post design* thus controls for possible random differences in the selection of different groups. But... there are also problems with the pre-post design. Differences between pre- and post- conditions might be due to a “confound” such as practice (with repetition of a task performance might be better), or perhaps participants become bored of having to do the same task a second time, in which case, performance deteriorates.
- Placebo effect: A special design is used to examine the effects of “treatment”. Let us assume that I have a theory that suggests that a new drug I have discovered will be effective in the treatment of cancer. I give the pill to a group of cancer patients. After 3 weeks, it is found that the pill is quite effective. More than 40% of the patients’ symptoms are reduced.
  - Does this necessarily mean my drug was effective? No! It is entirely possible that the reductions in the symptoms might have happened even if there were no drug treatment. Or, perhaps the fact that patients knew they were being treated for cancer caused the change in their symptoms. These types of improvements are called the “*placebo*” effect.
  - A treatment is given to a patient. The patient improves over time. Was treatment effective? Perhaps not. The “placebo” effect. Placebo: not the real treatment

- To control for this, one group of patients is given the actual drug ( or any other treatment) and the other half is given what they think is valid treatment . This control condition is called the placebo condition
- Double blind design: neither the two groups nor the administrator will know which groups is receiving the treatment to ensure all patients have the same expectations
- Placebo effects can be extremely powerful and is a good explanation of the supposed benefits of psychotherapy and counseling
- No medical treatment that is approved by the minister of healthy and be used with the general public before a placebo study is carried out
- 20% of Canadian doctors prescribed placebos to unknowing patients
- 35% of psychiatrists PWRs rives medications in sub-therapeutic doses or below minimal recommended therapeutic levels
- Psycho therapy actually a placebo effect?

### Problems with True experiments

- Often the sample size is small. Can we generalize to the population as a whole from such small samples?
- Experiment must be carried out in a controlled setting (often in a laboratory). Is this typical of the real world? Let us suppose we are studying changes in personality as a result of alcohol. We hypothesize that alcohol will make participants less inhibited. They will socialize more and perhaps be more aggressive. Lab results indicate, however, that the participants are not more aggressive or sociable. Perhaps this can be explained by the fact that they are in a lab environment, and do not act as they would in a more normal, social bar-type situation. Is it possible to generalize from the results of a lab-based study to the real world?

### Quasi-experiments

- In the social (human) environment, the scientist cannot always manipulate the independent variable
- As an example, a scientist has done an extensive search of the literature and observed that there is good evidence that that men do perform slightly better in math than women. The scientist then develops a theory that men are better at math because of their male hormones. A study is designed. We arrange to test a sample of undergraduate students on a math test. The results do indeed indicate that the men do better than the women. Why? (Again, in science we want to know the cause of variation. The scores on our math test vary and we do know that sex or gender will cause the scores to vary, but why?). Recall in a true experiment, we manipulate the independent variable. But in this experiment, nothing was manipulated. We know that men did better than women at math and we might develop a theory that claims this is due to differences between male and female hormones. To prove that the *cause* of the difference is due to hormones, we need to *manipulate* the quantity of male and female hormones in our participants. (Recall how we gain knowledge in science). In a true experiment, women would be given massive dosages of male hormones (and thus become male-like) and men would be given massive dosages of female hormones (and thus become female-like). If the differences in math were due to hormones, then the women should now do better in math than the men. How many humans would however volunteer to participate in this study?
- Several other examples could be given – differences between younger and older participants; differences between normal controls and patients.

- In a quasi-experiment, it is not possible to manipulate the independent variable (example, sex, age, race...)

It is however assumed that the differences that are found are *caused* by the independent variable. This can be a very questionable and controversial assumption.

### Natural Observation

Not all studies in the humanities are carried out in a laboratory. As we noted above, it may be difficult to generalize from a lab to true life situations. Human participants may act differently in a lab situation than they would in their natural environment. For example, a participant may be able to compensate for the effects of sleep deprivation in a lab context. However, put them on a real highway and they fall asleep. In the alcohol studies described above, very few participants ever become violent or aggressive. Does this mean that alcohol has no effect on aggression or other emotions? Go to a real bar and there are only too many examples of violence.

- Studies carried out in the field or “natural” environments attempt to overcome the limitation of generalization that is imposed on lab studies.
- But, there are problems with studies in the natural environment. It is exceedingly difficult to implement the control of other variables that might affect the results (confounding variables) afforded by the lab context. Thus, while there might be considerably more violence in a real bar, what accounts for the violence? Is it only alcohol? How can these confounding variables be controlled?

Again, it is very difficult to carry out true experiments in the natural environment. As such, the researcher cannot easily know why differences occur

### Surveys

In the social sciences and in particular in social psychology, we often gain knowledge of human beliefs and attitudes by directly asking about them with *surveys*.

- Participants are asked to report their behaviour, attitudes or beliefs
- The participant is asked a question with which they can either agree or disagree.
- Wording of questions can be crucial.

Example of survey questions: *Do you agree or disagree that:*

- Canada should not allow pornography.
  - Canada should forbid pornography.
- 
- Canada should not put marijuana users in prison.
  - Canada should legalize marijuana usage.

The phrasing about your opinions about pornography and drug usage varies (“should not allow” and “should forbid”) but in essence, the two statements are identical (“should not allow” = “should forbid”; “Should not put... in prison” = “legalize”). Yet we might find that the proportions of respondents that answer “Yes” will vary depending on whether they are given question a or b.

- Survey studies are often quasi-experiments. If a researcher determines that 65% of men and only 35% of women are opposed to gun control in Canada, this would be an example of a quasi-experiment. The sex (or gender) of the participant could not be manipulated. Therefore, we do not know why males and females answered the way they did.

Surveys can also be used in a true experiment. Suppose we do the same survey on gun control and obtain the same results. Now, the participants are shown a film depicting just how many people are murdered by guns. Now, the results change. Most men might now no longer be opposed to gun control. This study carried out a true manipulation. As a result, it is possible to say that we now *know* that attitudes toward gun control will vary depending on prior learning

**Measures of central tendency:** single score that represents a whole set of scores

- There are usually individual differences in the dependent measure. Some individuals score high some score low
- measure of central tendency neatly summarizes data
- Statisticians typically employ three different measures of central tendency (the typical score)
- Mode: most frequently occurring scores in a distribution
- Mean: average of scores of a distribution, obtained by adding the scores and then dividing by the number of score
- Median: middle score in a distribution, half the score are above and half are below

Problems with the Mean

- At times. Our measures are not normally distributed. Extremely high (or low) scores might distort the average (or mean). Most university students are in their late teens or early 20s. However, some are in their 70s. The older students would tend to pull up the mean

**The Normal Curve**

- A *distribution of scores* is a graphic representation of how many individuals have a particular score.
- If I ask the age of students in this class, perhaps 40 are 17, 120 are 18, 50 are 19, 30 are 20, 12 are 21, and perhaps 5 more than 21.
- Many psychological measures are distributed according to a bell-shaped “*normal*” curve.
- In the example above (age of students in this class), the age of students would not be distributed normally, but if we survey your grade point average (GPA) in high school, we should obtain a normal curve. Let us suppose the mean (or average) is 83%. Most students have a GPA that is about 83%. A small percentage might have a GPA that is above 95% and a small percentage below 71%.
- The image below represents the SAT scores in the U.S. in 2010. This example can be found on the web (<http://introductorystats.wordpress.com/2011/09/24/an-example-of-a-normal-curve/>). In the U.S., the SAT is a test taken by all high students who hope to go on to universities. In 2010, about 1.5 million (that is not a typo) students wrote the exam. The minimum mark on the exam is 0 (theoretically) and the maximum mark is 2400. The mean on the SAT for the 1.5 million students is about 1450. Figure 1 presents the “frequency distribution” of the students. There are 181 bars in this histogram, corresponding to the 181 distinct possible scores in the data (the scores come with an increment of 10, ranging from 600, 610, 620, and all the way to 2390, and 2400). Because of many bars crammed into a small graph, each bar appears as a thin vertical line. The histogram is symmetrical around a single peak, the actual mean of all the students (around 1500) and it tapers down smoothly on each side. Most of the data are clustered in the middle. The bars around the middle are very tall (i.e. most students score in the middle range). On the other hand, the bars at either the extreme left side or the right side are very short (very few students have extremely low or extremely high scores). As a result, the histogram has a “bell” shape. This is the shape of a *normal* curve.

- Note that the normal curve is balanced. Half of the individuals score at or above the mean and half score at or below the mean. Again, this is the definition of the *median*. Most score around the mean. Again, this is the definition of the *mode*. Only a small percentage will score well above or well below the mean.
- In a perfectly normal curve (as in the example above), the mean, the median and the mode are therefore identical.
- In Figure 3b below, we isolate the top 5% of the scores (shaded in green). This is a score of 2050 or higher.
- Thus, 95% of the students score below a score of 1509.
- In this sense, the top 5% of the students (those scoring 2050 or above) are said to be statistically “abnormal”. It is critical to realize that what we mean by statistical abnormality is *arbitrary*. Is it the top (or on the other side of the curve, the bottom) 1%, 5%, 10%, 25% of individuals?
- As we shall see, the concept of statistical “significance” does require an understanding of the normal curve.
- In a true experiment, we manipulate the independent variable. Let’s assume that prior to the SAT, we give one group of students a memory drug. In principle, memory should improve. We give this drug to 50 students. We then compare their scores on the SAT with 50 students who did not take the drug. If we look at the normal curve in Figure 1, we would predict that the mean SAT score for the non-drug group would be about 1500. However, it is possible (but unlikely) that the nondrug group could have a mean of 2050 or above. By chance, we might have selected out 50 of the best students in the U.S. What is the probability that we would have selected out the top students by random selection alone? .05. Thus, if we ran our study 100 times, we might have selected out a group that has a mean of 2050 or higher 5 times. Now, let’s look at our drug group. After ingesting the drug, their mean score is 2050. This is highly “abnormal”. It might happen “by chance” alone (we just happened to have chosen 50 very bright students). Thus, there is 5% chance that the drug did not work at all. But, on the other hand, there is 95% likelihood that the drug did indeed work.

### Statistical significance

- Statistical significance : a statistical statement of how likely it is that an obtained result occurred by chance. Divide explained variance by unexplained variance
- Research must indicate what is the probability of finding a difference this large by chance alone
- A statistician might claim that differences this large could only occur by chance on 5% of occasions. This means that if we would run the experiment 100 times, we would find differences this large just by chance on 5% of occasions (i.e., 5 times).
- Let’s use the example of alcohol and reaction time. The experimenter chooses 10 individuals at random to be in the control group and 10 individuals to be in the experimental group. The experimental group is asked to drink the equivalent of 10 beers. Subjects (also called “participants”) are asked to push a button whenever a red light is flashed on a monitor. The overall (or “grand”) mean of all 20 subjects is 390 but this varies. Some individuals are above the mean; others below. The mean RT of the control group is 320 ms (milliseconds) while that of the experimental group is much slower, 460 ms. In short, the experimental manipulation appears to have caused the RT to increase. However, we might randomly select 10 subjects and place them in a group and select another 10 subjects and place them in a second group. We do not give any of the subjects alcohol. The two groups should thus, on average, have the same reaction times, but just by chance (by the luck of random selection), they might not. What is the probability that the difference in means of the two groups will vary by 140 ms (exactly the same

as in our experiment)? Statisticians will always provide a measure of chance probability. They might thus indicate that a difference of this magnitude could be found by chance (by random chance selection) only on 5% of occasions. In short, if we chose two groups at random (and did not give them any alcohol) and we did this 100 times, we would obtain differences of this magnitude 5 times. This is what we mean by a *chance* finding. There is no reason to expect that the mean RT of the two groups should vary, other than pure chance. Indeed, we have 95% likelihood that these differences could NOT be due to chance. *Statistical significance* thus provides a measure of how often a difference could be found purely by chance.

- Note that statistical significance and practical significance are not the same thing. A result can be statistically significant but have no practical significance.
- There are two sources of variance in any experiment. One we can explain (because of the experimental manipulation); one we cannot (individual differences).
- How do we determine if our experimental effect is statistically significant?
- The explained variance is divided by the unexplained variance (knowledge is divided by what we do not know).
- But how do we measure variance? We need to compute explained variance and unexplained variance. As the name implies, variance is computed by examining the extent to which scores deviate from the mean. You need to think about the following concepts. They are the essence of ALL science, whether you study Psychology, Physics, Biology, Sociology, Criminology, Medicine or Business. Note that if the experimental manipulation has a large effect, the explained variance will be very large. On the other hand, if the experimental manipulation has no effect at all, the explained variance would be zero (0). Unexplained variance examines the extent of individual differences. If all individuals scored exactly the same, there would be no individual differences. Thus unexplained variance would be zero. On the other hand, if individuals have very different scores, there would be large unexplained variance.
- Unexplained variance is computed by subtracting the mean from each individual's score, telling us how much an individual varies from the mean. (Note that we do not know why these individuals deviate from the mean... this is "unexplained"). As would be expected from the normal curve, some individuals will be above the mean, and some below the mean, giving negative and positive *deviance*. We square these scores (to eliminate the sign), sum up these squared deviances, and then divide by the number of individuals in the group (thus we have a mean or average deviance). This provides a measure called (not surprisingly) "variance". However, recall that we initially subtracted each individual's score from the overall mean, then we squared this difference. Thus, the variance is actually a measure of the squared difference. We still therefore need to take the square root of variance. The square root of variance provides another measure, the standard deviation (SD).
- In an experiment, there is an overall (or "grand") mean. In the example above, the grand mean was 390 ms (320 for one condition + 460 ms in another condition, divided by 2). We then subtract this grand mean from the group means (320-390 and 460-390), square the differences, and sum these squares, then divide this sum by the number of groups to give a mean or average explained variance.
- If the ratio of explained to unexplained variance is large enough, the result is probably statistically significant. It is not likely that this difference could be due to chance.

### Significant Differences

- an observed difference reliable when
  - representative sample are better than biased samples

- less variable observations are more reliable than those that are more variable
- more cases are better than fewer
- $F = \frac{\text{explained variance}}{\text{unexplained variance}}$
- Ensure explained variance is large and unexplained variance is small
- (The size of the experimental effect)
- Larger differences are more likely to be significant

### Factors that affect statistical significance

- Recall that significance is a reflection that differences this size are not likely to be found by random chance.
- Explained variance (knowledge) is divided by unexplained variance (individual differences or ignorance).
- Thus, the likelihood of finding statistical significance increases according to the size of the experimental effect. Larger differences are more likely to be significant. The likelihood of finding significance decreases when the size of the experimental effect is small.
- The likelihood of finding significance increases when unexplained (individual) variance is small, and decreases when individual variation (individual differences) is large. In a pre-test, if all individuals score the same, and then in a post-test, they score only slightly higher, this is not due to chance. If the experimental manipulation has a highly consistent effect across all individuals, the effect is likely to be significant. In the alcohol study, we noted that the drug might slow reaction time. If only 10 participants are sampled, the experimental effect of the drug (alcohol) will probably be significant if all 10 participants show slow reaction times following ingestion of alcohol. It would be quite unlikely to flip a coin 10 times, and get heads on each flip.
- The size of the sample. If a very large sample is used, very small differences might be statistically significant. On college entrance exams in the U.S., men score minutely higher than women on math, but this is statistically significant. This reflects the representation of the sample. Large samples, because they are composed of so many members of the population, are much more likely to be representative of the population. In this case, many women actually score higher than men, but on average men score just slightly higher than women. Again, statistical significance does not imply practical significance.

### Observation and correlations studies

Many studies that are carried out in the social and medical sciences are not experiments at all. Rather, they are best described as “correlational” studies. As an example, it is known that poorer people commit more crime than richer people. Does this mean that poverty causes people to commit more crime? Perhaps; perhaps not. Also, the more one smokes, the more likely it is that they will get cancer. Does this mean smoking causes cancer? It might, but there may be other factors that cause cancer. Why do people smoke to begin with? Maybe what causes people to smoke is what also causes the cancer. In these examples, a change in one variable is associated with a change in another. There is thus a co-relationship (or a *correlation*) between smoking and cancer and between poverty and crime.

- A correlation means that a change in one variable is also associated with a change in another
- Example: geese and leave; smoking and cancer; testosterone and violence; punishment and crime
- Correlation: a statistical measure of the extent of a relationship between two variables
- The correlation allows one to predict scores on one variable if the scores on both variables are known

- Correlations vary between -1.0 to +1.0. A negative correlation indicates that as the scores on one variable increase, the scores on another decrease. The more alcohol one drinks, the less able one is to drive a car. A positive correlation indicates that as one score increases, the other score increases as well. The more one studies, the higher the marks; the more calories one eats, the heavier one becomes.
- the larger the correlation, the stronger the association. (ability to predict) notes that the sign is not important
- A correlation permits a prediction. If there is a high correlation between eating calories and weight gain, knowing how much you eat, I can predict how much weight you will gain. Knowing how much alcohol you have consumed allows me to predict how well you can drive a car. Both positive and negative correlations allow the researcher to predict. The sign (+ or -) is thus incidental. It is the size of the correlation that is important. With a correlation of 1.0, there is perfect predictability. The closer the correlation is to 1.0, the closer the association between the two variables.
- On the other hand, if there is no relationship, the correlation is 0.0. Knowing the scores on one variable does not help predict the scores on another. Height is a very poor predictor of marks in Intro Psychology. The correlation between height and marks is thus close to 0.
- correlation coefficient: a statistical index of the relationship between two things
- Scatterplots: a graphed cluster of dots, each of which represents the values of two variables. The slope of the points suggest the direction of the relationship between two variables, the amount of scatter suggests the strength of the correlation (little scatter indicates high correlation)
- If there'd is no relationship, the correlation is 0.0
- Correlation does not prove causality
- Ex smoking and lung cancer. Does this necessarily mean smoking causes cancer?

### **Correlation and Causation:**

- correlation helps us predict causation. Correlation does not prove causality.
- While there might be a high correlation between smoking and the incidence of cancer, this does not mean smoking *causes* cancer. Perhaps smokers are under more stress than nonsmokers, and it is the stress that causes cancer, not smoking. There is a strong negative correlation between age and memory. The older we become, the more we forget. This does not mean however that ageing *causes* memory loss. Because the elderly have lived so long, they have stored much more than younger adults. They thus have a more difficult time searching through all these memories. Perhaps if a younger adult could be identified that also has stored a tremendous amount, they could have difficulty retrieving these memories. In Criminology in certain countries, it is hypothesized that capital punishment should reduce the incidence of murder. However, countries that have capital punishment also have very high murder rates. Often, countries that do not have capital punishment do not have high rates of murder. Does the fact that the sentence for murder is capital punishment actually *cause* more murders to be committed?
- Again, in order to prove causality, the researcher must carry out a true experiment. In the correlational studies, no manipulation is carried out.
- association does not. Correlation indicates the possibility of cause-effect relationships but does not prove such

### **Logical positivism**

- Every scientific theory must be potentially falsifiable
- We cannot prove something does not exist (ex. syria)

- We can prove something exists
- Based on theory, scientists form a hypothesis (or prediction). Stress; smoking; cancer
- According to many philosophers of science, we assume all hypotheses are false under proven otherwise
- Thus we assume the negative. We assume the hypothesis is false
- The null hypothesis

### **Scientific process**

- Design the study. Testing of hypothesis (unbiased, objective) this involves the design of a study to answer the questions and resolve the controversy
- Experimental *manipulation* the experiment manipulates the independent variable
- This might cause the dependent variable (that which he/she is measuring) to vary
- If the theory is true, the manipulation of the independent variable causes another variable to change
- The variable that might change is called the dependent variable
- The dependent variable is that which we measure

### **Sources of variance**

- Explained variance: measures the proportion to which a mathematical model accounts for the variation (dispersion) of a given data set. Often, variation is quantified as variance; then, the more specific term explained variance can be used.
- Unexplained variance : opposite to  $\hat{\quad}$
- Individual differences: not everyone respond in same way

Violence cause (!!!) aggression?

- The social modeling theory: framework for why people behave the way they do and learning
- If children watch violent mass media they will mean that violence is acceptable
- Those who watch more mass media will be more aggressive (is this causality or a correlation)
- Freudian catharsis theory- exposure to (experiencing ) a drive ( or repressed urge) will decrease the "drive"
- Freudian hypothesis : if children watch mass media, the aggression drive will be released

## SECTION 2

Imaging techniques

- Anatomical techniques
- slicing the human brain
- viewing macro structures with the human eye or micro structure with a micro scope
- appropriate for cadavers

MRI (magnetic resonance imaging)

- Advantages: provides higher resolution images of the human brain
- Problems :
- Static: provides an image of the structure

### **Structure of Neurons**

- All cells surrounded from a membrane that is semi permeable

- **Dendrites:** branches going off the nucleus of the neurone, and they make communication with other neurone
- **Axon:** long slender tubes that grows out of dendrites and masses messages through its branches to other neurons or to muscles or glands
  - The axons of longer neurons are surrounded by a *myelin sheath*: This causes them to appear white. Axons of shorter neurons are not surrounded by a myelin sheath. They thus appear to be grey.
  - The myelin sheath is made up of a lipid (fat) material that may surround long axons. They serve to (1) protect the axon (2) insulate the axon ... this thus preventing axonal “cross-talk” (3) speed up transmission
- **Terminal endings:** (bouton endings) As the name indicates, this is the terminal ending of the axon. At this ending, there is a swelling (the “bouton”). This is caused by the storage of neurotransmitter substance here. A physical gap (called the “synaptic gap” or simply the “synapse”) separates the terminal ending and the dendrites of the next neuron.
- **Synapse:** the junction between the axon tip of the sending neuron and the dendrite or cell body of the receiving neuron. The tiny gap at this junction is called the synaptic gap or synaptic cleft (meeting point between neurons). Pre and post synapse gap. Excitation or inhibitions (prevent the post synaptic cell from doing anything)
- When (and if) the neurotransmitters are released, they must travel across this gap. Embedded in the walls of the dendrites of the postsynaptic neuron are highly specialized receptors that can “recognize” the chemical code of the neurotransmitters. The neurotransmitters can then attach themselves (or “bind”) to the receptor site. The neurotransmitter may excite or may inhibit the activity of the second neuron (more about this later) secrete brute transmitter substance. There connect to other dendrites and that's how neurones communication. Nerve transmitters are stored here.
- reut

The nobel prize 1906: C.Golgi And S. Cajal

- Must have a chemical reaction from one neurone to another (neurones don't come into physical contact)

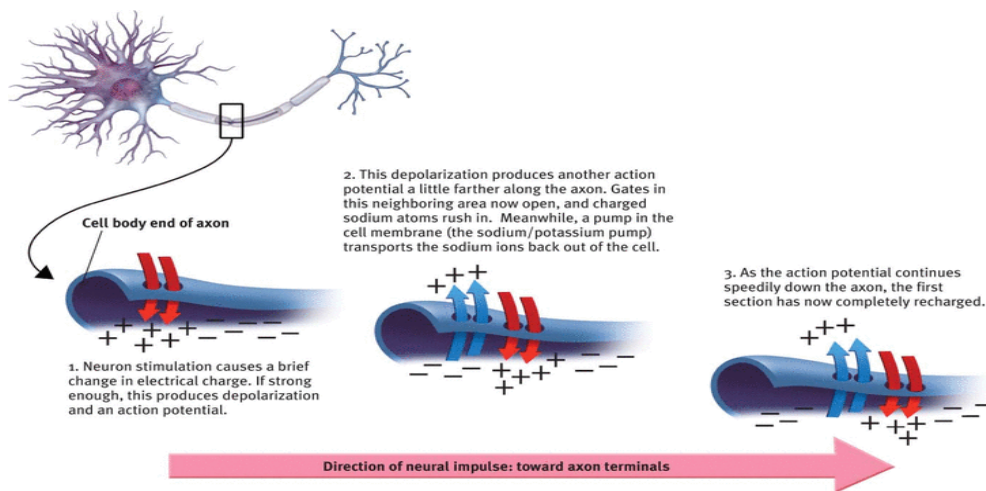
## Different Types of Neurons

3 categories of Neurones

- **Sensory neurons:** transmit impulses received by sensory receptors to central nervous system . *Afferents (white matter, long axons)*. Neurons that carry information from the sensory receptors to the brain and spinal cord for processing
- **Motor neurones:** carry outgoing signals/information from CNS (brain and spinal cord) to muscles and glands. *Efferents (long axons)*
- **Interneurons:** don't communicate with outside world, they communicate with other neurons through complex interactions. (internal communication and intervene between the sensory input and motor output). This is the grey matter, short axons less than 1mm) . Often, far removed from either sensory or motor neurons. Communicate can be excitatory or inhibitory. This allows for flexibility of behavior. This is the route to memory, learning and complex behaviour. Some receive signals from sensory neurons and send impulses to other motor neurons. Much more often, the interneuron is far removed from either sensory or motor neurons. One interneuron communicates with another. This is the route to memory, learning and complex behavior
- Nerve fibre( a nerve is not w single fibre) a nerve is a collection of axons

## Resting potential

- All cells carry an electrical charge (potential)
- The charge of the neurones can change
- This allows one neurone to communicate to another ( or perhaps a muscle)
- An inactive neurone contains an excess of *negatively* charges ions *inside* the cell membrane (surplus of positively charges outside the cell)
- The charge inside the human neurone is about -70mV(mV) This is called the *resting potential* of the neurone
- We can change this charge in the lab, the influence of neurotransmission is what changes charges in the body



## Depolarization (Excitation of the Neuron)

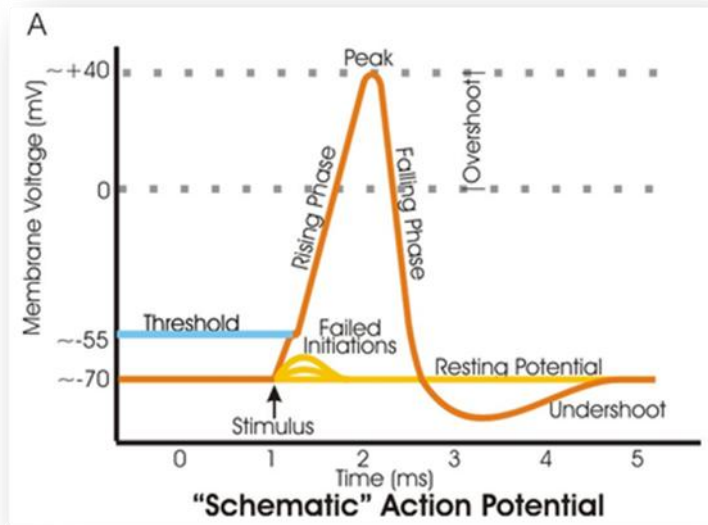
- Inside the neuron there is a surplus of negatively charged molecules (ions)
- Mainly because of the buildup of chloride (Cl<sup>-</sup>) aka salt
- The sodium-chloride balance is critical for the proper functioning of the neuron. Where does the sodium-chloride come from? The salt balance within the body.
- Sodium cannot easily pass through the cell wall (the membrane) of the neuron. Sodium is a relatively large molecule. Moreover, other molecules easily bind to the sodium molecule making it even larger.
- When the dendrite is stimulated by another neuron through the release of an excitatory neurotransmitter (or artificially by electrical stimulation), the cell membrane's "channels" (or "gates") open, allowing *positively* charged ions to flow in (point 1 in the figure above).
- This change in the charge of the neuron (less negativity or more positivity) is called *depolarization*

## Action potentials:

- action potential: neural impulse; a brief electrical charge that travels down the axon, measures in milliseconds
- When the flows of positively charged ions reaches a certain critical threshold (the threshold of excitation), the neuron fires ( doors open). The cell us now less negatively charged (depolarization)

- This causes the cell's electrical potential; to change. The extent of change is dependent on the intensity of stimulation. If it is a small stimulation (low intensity stimulation), the change in the electrical potential of the nerve cell might now be -65 mV (see yellow lines, "failed initiations" in the Figure). If the intensity of the stimulation increases, the electrical potential of the cell may now change to -60 mV (also in yellow).

- When the flow of positively charged ions reaches a certain critical threshold (the "*threshold of excitation*"), the neuron fires. In the Figure on the right, the "threshold" is about -54 mV. Once the change in electrical potential reaches this -54 mV threshold, a dramatic change is observed.



- This is called the *action potential*. The action potential (the rushing in of the sodium and other positively charged molecules) continues inevitably down the entire length of the axon. This is called *propagation* of the action potential. (point 2 and 3 in Figure above)
- If the level of excitation is not enough (the critical threshold is not reached), the electrical charge of the neuron will return to its resting potential ("failed initiations" in the Figure).
- The likelihood of reaching the critical threshold is increased by either having a single (or a few) neurons excite the post-synaptic neuron rapidly (the effects of one excitation summates with the consequent excitation). Alternately, the effects of the excitation of several neurons can summate together.
- Once the action potential is initiated, it will travel down the length of the axon. It may then subsequently influence the firing of another neuron
- This is called action potential (travels down axon)
- Once the action potential is initiated, it will travel down the length of the axon
- It may then subsequently influence the firing of another neuron
- If the level of excitation is not enough (the critical threshold is not reached), depolarization will reverse and return to resting potential, and will not travel down length of axon) charge will fade away

### All or none law

- The action potential will travel down ( will be propagated) the length of the axon
- The amplitude of the axon potential does not vary. This is the all or none law. In the Figure, the change in the electrical potential is now +40 mV. This amplitude will not vary as the charge moves down the length of the axon. This is inevitable (no variation here). This is the *all-or-none law*. We either get the action potential or we do not. Increasing the intensity of stimulation will not cause the action potential to get larger.

- Increasing the intensity of stimulation will not cause the action potential to get large.
- This has important consequences for coding in the nervous system.
- For example, we cannot code the intensity of the stimulus by the size (or amplitude) of the action potential. Its amplitude cannot vary. Intensity could be coded by how often the neuron fires or perhaps by how many neurons carry the message.
- The all-or-none law, however, more or less ensures that once the action potential is initiated, it will travel the length of the axon and its amplitude will not vary. There is little room for “freedom” or “flexibility” in the well-protected world of the axon. The response (the action potential) cannot easily be altered (unless there is a fault with the chemical or nutritional balance). This will not be the case for the synapse. Learning will involve changing how the nervous system responds (we’ll see this when we study learning and memory).

### **Propagation of action potential** (how signal does down length of axon )

- Axon with no myelin sheath and axons with
- Action potentials will travel down the length of the axon sheath (faster in shorter axons )
- This is a slow process in unmyelinated axons. The membrane gates initially open upon excitation. This depolarization causes the neighbouring membrane gates to also open, and then this neighbour’s gates also open and so forth until the action potential reaches the end of the axon at the terminal ending.
- Long axons are myelinated, they have a myelin sheath) faster
- the myelin sheath is not continuous. because the myelin is made of lipid material, the charged molecules cannot penetrate into the axon. At places, the bare axon is exposed. These places are called the nodes At places the axons (called the "nodes") is exposed
- This allows the action potential go "jump" from nodes to node
- Thus, transmission is much faster in myelinated axons. Because long axons tend to be myelinated, while short axons are not, transmission is much faster in long axons.

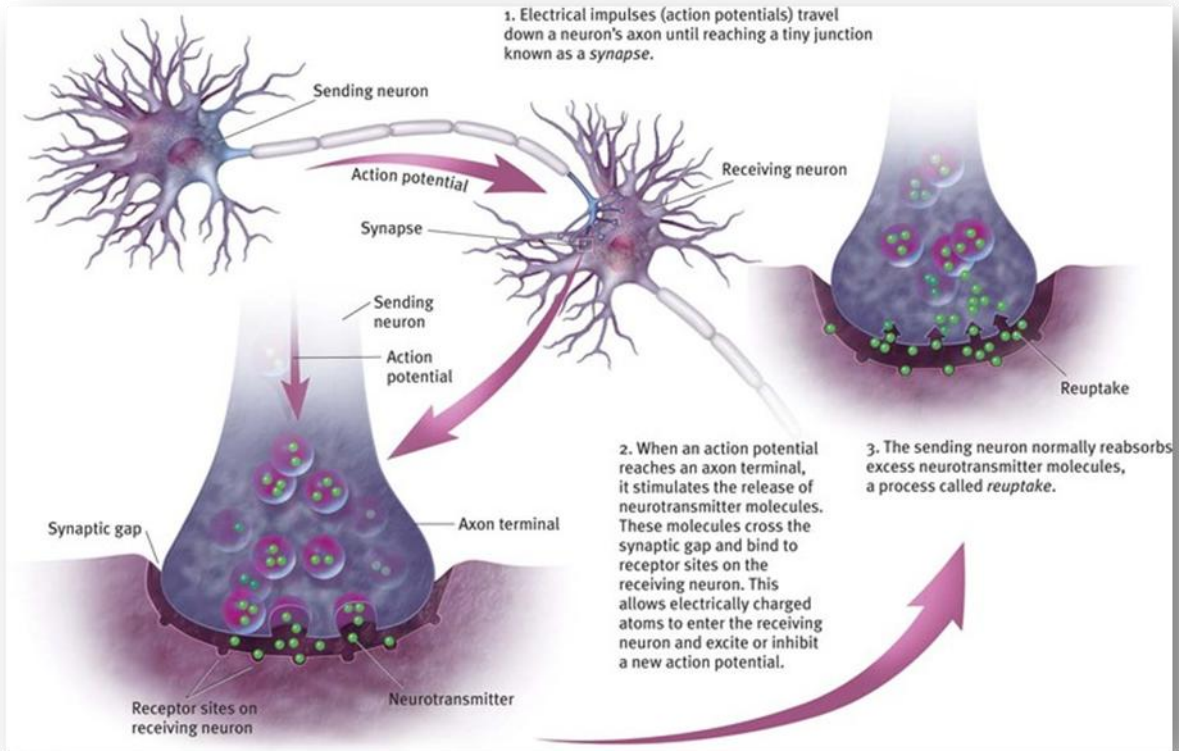
### **Synaptic transmission**

- Under the influence of action potential, neurotransmitters are released into the synaptic gap
- The synaptic gap is the intercellular space
- The neurotransmitters are no longer "protected" by the cell membrane
- Neurotransmitters travel, to post-synaptic neurones or muscle cells
- Specialized receptors can economize the chemical code of the neurotransmitter
- neurotransmitters: chemical messengers that cross the synaptic gaps between neurons. when released by the sending neuron, neurotransmitters travel across the synapse and bind to receptor sites on the receiving neuron, thereby influencing whether that neuron will generate a neural impulse. The neurotransmitter unlocks tiny channels at the receiving site, and electrically charged atoms flow in, exciting or inhibiting the receiving neurons readiness to fire
- The neurotransmitter binds to the post synaptic receptor. Excitatory or inhibitory effects
- The neurotransmitter will have a long term effect until it's actions are terminated
- Enzymes: break down molecule into simpler elements ex will stop contracting muscle
- Reuptake : neurotransmitters re-absorption by the sending neuron

### **Release of Neurotransmitter**

- Under influence of action potential, neurotransmitters are released into the synaptic gap.
- Neurotransmitters may travel across this gap to the post-synaptic neuron.

- Keep in mind that this gap is the “real” world outside of the well-protected neuron. The neurotransmitters are subject to attack by poisons (toxic agents). They might not be released. They might not reach the post-synaptic site.



- Specialized receptors can “recognize” the chemical code of the neurotransmitter (similar to a lock and key mechanism).
- The neurotransmitter binds to the post-synaptic receptor. It is here that the neurotransmitter has an effect on the post-synaptic neuron. It may have an excitatory or an inhibitory effect (see next section).
- The neurotransmitter will have a long-term effect unless its actions are terminated. Enzymes break down the neurotransmitter so that its effect is not continuous. The molecule is “broken apart”. Often the more basic elements of the neurotransmitter are then recycled back into the pre-synaptic neuron to be used again. This is the reuptake process step 3 in the figure above).
- Each and every one of these steps can be altered. “Drugs” that are similar in chemical structure to a true neurotransmitter may also bind with the receptor site. They may block the site. When the true neurotransmitter arrives, it will find the receptor site already occupied. Thus, the neurotransmitter will have no effect. Drugs can also mimic the effect of a neurotransmitter. The reuptake process may be ineffective. Perhaps the enzymes are in short supply. Perhaps drugs “attack” the enzymes. Thus, the effect of the neurotransmitter will be prolonged. And, the reuptake mechanism will be delayed. This will leave a short-supply of neurotransmitters in the pre-synaptic site.

- The cozy protected environment of the axon is not the rule at the synapse. While transmission in the axon was highly inflexible, obeying an all-or-none law, this is not the case at the level of the synapse. If we wish to design a nervous system in which flexibility of behaviour (altering past behaviour), learning, memory and complexity are desired, the synapse is the place to do it. It should come as no surprise that in evolution, complex behaviour comes about as a result of expansion of the grey matter, where tiny, unmyelinated neurons are tightly packed, forming billions and trillions of synapses, and permitting exceedingly complex inter-neuronal communication. Unfortunately, these exceedingly complex interactions are also exceedingly complex to understand. The end result is that we, in fact, poorly understand the functioning of the higher centres (the grey matter of the cortex) of the brain, even in very simple animals (those that are not well-cortically endowed). This should however be good news for students... lots of information yet to be discovered.

### **Actions of neurotransmitters**

Recall: the all or none law of the action potential. No flexibility here. This is not the case with the neurotransmitters

- Neurotransmitters are either excitatory or inhibitory. Thus it is possible either to increase or to decrease the likelihood that a post synaptic neuron will fire.
- An *excitatory* neurotransmitter will increase the likelihood that the post synaptic cell will fire. An excitatory neurotransmitter depolarizes the neuron. The resting potential becomes less negatively charged than normal. How? Depolarization. Possibility of action potential
- An inhibitory neurotransmitter will decrease the likelihood that the post synaptic cell will fire. How? An inhibitory neurotransmitter hyperpolarizes the neuron. The resting potential becomes more negatively charged than normal.
- Increase in the critical threshold for the firing the action potential of the post synaptic neuron
- Why is it necessary to have both excitatory and inhibitory neurotransmitters? Imagine trying to walk. Certain muscles in your leg must be excited (an excited muscle contracts). Others, however, must not contract. If all muscles were contracted, you could not walk (incidentally, this lack of motor “coordination” is often a problem in various dystrophies and in Parkinson’s-like diseases). Another example: Your sensory receptors are constantly bombarded with incoming stimuli. Your brain cannot possibly process all this input because of its limited capacity (even though you have a massive amount of grey matter). Only the most relevant of sensory input should reach the very busy cortex. The vast majority of sensory input is irrelevant, thus processing of what in the end is irrelevant, needs to be inhibited. Another example: A good deal of the frontal regions of your brain is involved with the inhibition of inappropriate action. This is the essence of the saying: reason over passion... the need to inhibit the passions.

•

### **Drug Interaction**

As already mentioned, drugs can wreak havoc on neurotransmitters. There are at least : 6 ways drugs may affect synaptic transition

0. Block release of neurotransmitter
1. Block storage of neurotransmitter in pre synaptic membrane
2. Cause release of excessive neurotransmitter
3. Stimulate or block receptor on post synaptic membrane
4. May attack enzymes that break down neurotransmitter

## 5. Block re uptake of neurotransmitter

### Neurotransmitters

- Acetylcholine (muscle), we can observe these actions we know the most about this )
  - ACh generally excitatory on membrane of skeletal fibres. It causes muscles to contract
  - muscle paralysis : curare blocks ACh receptor, botulinum blocks ACh release, nerve gas, many pesticides/insecticides (may block receptor site or interfere with enzyme reuptake)
  - muscle convulsion , ex spider and snake venom stimulates ACh)
  - in CNS role in memory, ACh depleted in Alzheimer's disease
- Norepinephrine, NA (brain)
  - synthesized from epinephrine ( or adrenaline), a hormone release by the adrenal gland: a pair of endocrine glands that sit just above the kidneys and secrete hormones ^ that help rouse the body in times of stress. It is called the master gland because it responds to signals from the hypothalamus, and releases hormones that trigger other endocrine glands to secrete hormones that in turn influence the brain and behaviour
  - important role in alertness and mood
  - increase alertness in the brain; increase heart rate
  - fight or flight
  - cocaine and amphetamines (bupropion, Dexedrine , prolong action of NA, stimulant effects)
- Gamma Amino butyric Acid (GABA)
  - major inhibitory neurotransmitter of the brain
  - sedative, sleep and anti anxiety
- Dopamine
  - predominately inhibitory
  - implicated in movement in the periphery, attention and learning
  - might involve ADHD
  - Insufficient quantity s related to Parkinson's disease (tremors and paralysis) , too much is psychosis
  - too much DA: psychosis
- Serotonin 5HT
  - plays a role in sleep (dreaming?) perhaps control of eating mood and pain regulation
  - drugs that are mimic in their chemical structures to 5HT ,AU result in bizarre hallucinations.
  - certain drugs cause over release of 5HT, increase energy and deplete stores leading to withdrawal like symptoms
- Endorphins
  - so called natural "opiates" of the brain
  - Chemical structure similar to opiates (heroin, morphine)
  - Inhibited sensation of pain
  - Increase mood and pleasure

## THE NERVOUS SYSTEM

### Orientation

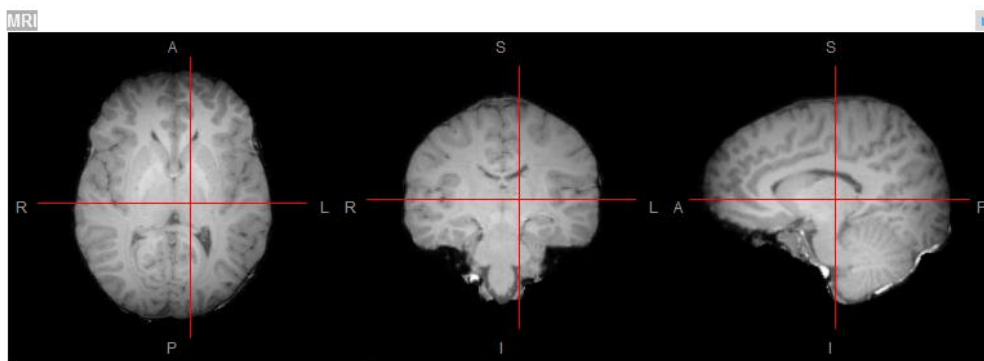
- medial-lateral: middle of the body/ side of the body

- anterior posterior aspects of the brain (front of the head-back of the head)
- superior-inferior aspects of the brain (upper portion of head-lower portion of head)

**Slices** (viewing the brain in 2-dimensional images)

- *Horizontal* (parallel to the floor) slice. Permits visualisation of anterior-posterior and lateral-medial aspects of brain. One cannot see the superior-inferior aspect. The MRI images on the right show examples of various horizontal “slices” at various levels of the brain (going from an inferior at the bottom to a superior position at the top).
- *Coronal* (from ear-to-ear) slice. Permits visualisation of superior-inferior and lateral-medial aspects of brain. One cannot see the anterior-posterior aspect.
- *Sagittal* (from nose to back of head) slice. Permits visualisation of anterior-posterior and superior-inferior aspects of brain. One cannot see the lateral-medial aspect.
- *Mid-sagittal slice*: sagittal slice that splits the brain into two equal halves.

In the image below, a view is shown of a horizontal, coronal and mid-sagittal slice (A=anterior, P=posterior; R=Right, L=Left; S=superior, I=Inferior). The crosshairs are located on a part of the brain called the thalamus (see discussion below).



## Imaging Techniques

Function techniques (observing the active brain)

- What areas of the brain are responsible for our different functions?
- In the clinical setting: observe functions lost because of brain injury (trauma, stroke, tumours, etc)
- Problem: human brain injuries are often widespread and not highly specific
- In the experimental setting: lesion (remove) a specific part of animal brains to determine it's function
- Stimulate a specific area of the brain to observe the function it controls
- Problems: in many cases, it is difficult to know just what an animal is experiencing
- Higher mental states may well differ across species. Now applicable are these stories to humans?
- lesion: naturally or experimentally caused destruction of brain tissue

Functional techniques

MRI: magnetic resonance imaging

- Provides a high resolution image of the human brain. Static: does not indicate which areas of the brain are active during a specific task. Expensive.

Problems with MRI

- Very expensive

#### fMRI: Functional MRI

- Uses MRI scan
- Indicates which areas are active (and require oxygen) for a task to be complex
- High resolution image of brain structures (unlike PET)
- Disadvantages: slow. Can be as fast as 200-500 ms to obtain image, but the brain makes decisions much more rapidly than this. It is also expensive
- The image on the cover shows a real tennis player and an fMRI image from a supposed vegetative patient (who should not be conscious) told to “think about” playing tennis. The “hot” (in yellow) indicates the area of the cortex that is most active, the motor cortex and more specifically the hand area.

#### PET: Positron Emission Tomography

- Advantages: provides an image of the function of various structures of the brain. Indicates which areas are active (and require glucose) for a task to be complete
- disadvantages: invasive-> requires deoxyglucose to be injected into the blood. It is very slow because bloods circulate slowly. The brain makes rapid decisions. The PET provides an image of all the brain areas that were active within the last 1-2 minutes. It is also very expensive

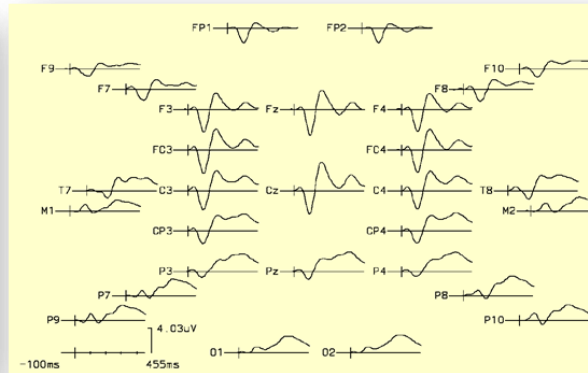
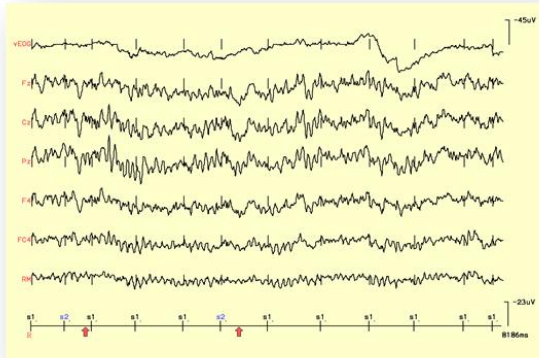
#### Anatomical dissection.

- Slicing the human brain.

#### EEG: Electroencephalogram/Evoked Potentials.

- Electrodes attached to the surface of the scalp. Provides an indication of the electrical activity of the brain (EEG). When a stimulus is presented, evoked potentials can be used to measure the brain's response to these stimuli.
- Advantages of EEG and evoked potentials:
  - the advantage of evoked potentials can be rapidly recorded and determined every 1msec the changes of the of the electrical activity of the brain when it must process information contained in a stimulus.
  - It is also very inexpensive.
  - measure direct changes
- Disadvantages of EEG:
  - Poor resolution in comparison to fMRI; we cannot tell easily where the electrical activity is being generated
  - Electrical activate from the scalp provides a poor indication of the actual underlying structures of the brain
- The image below on the left shows the electrical activity of the brain (EEG) recorded from 6 different locations on the scalp. The EEG was recorded for 8.186 sec. At various times, an auditory stimulus was presented. The stimulus is labelled as either S1 or S2 (a low or a high pitched tone). The actual responses (called “evoked potentials”) of the brain are very difficult to see in the EEG. This is because the evoked potentials are very small (often measuring only a few  $\mu\text{V}$ , or millionths of a Volt). Through computer extraction techniques, the evoked potentials can be made visible. In the figure on the right, evoked potentials are displayed from 32 different scalp locations (the front of the head being on the top, the back of the head at the bottom). A large downward deflection that measures about  $4 \mu\text{V}$  is seen at and it occurs at about 100 msec

(thousandths of a sec). The fMRI because it ultimately relies on changes in blood flow (very slow) would not be able to display changes in processing within the brain this rapidly. There are 32 different electrodes on the scalp and it is possible to see that the amplitude of the large downward deflection varies across the scalp (remember the statistical concept of “variance”). But where is this activity actually coming from within the brain?



## DIVISIONS OF THE NERVOUS SYSTEM

- nervous system: the body’s speeds, electrical communication network, consisting of all the nerve cells of the peripheral and central nervous system
- central nervous system (CNS): the brain and spinal cord. This is body’s decision maker
- Peripheral nervous system (PNS): the sensory and motor neurones that connect the central nervous system to the rest of the body
- Nerves: are bundled axons that form neural "cables" connecting the central nervous system with muscles, glands and sense organs ex. Optic nerve is bundle of axons that form a cable carrying the message of each eye to the brain

### 1. Peripheral Nervous System (PNS):

1. **Autonomic nervous system:** controls self regulated actions of internal organs and glands such as the heart. We do not have control over this. The autonomic nervous system performs two functions:

1. **Sympathetic nervous system:** the division of the autonomic nervous system that *arouses* the body, mobilizing its energy in stressful situations ex. Acceleration of heart when excited arousing

2. **Parasympathetic nervous system:** the division of the autonomic nervous system that calms the body conserving it's energy ex. Calming you down to preserve energy  
the two work together to keep our bodies in a steady internal state

2. **Somantic nervous system:** controls the body's skeletal muscles. It is also called the skeletal nervous system. We can control out semantic nervous system. ex. brain will report to current state of skeletal muscles that carrying back instructions triggers my hand to turn the page at the end

- Sensory receptors
    - in the body and also specialized receptors in the head
  - Sensory "nerves"
    - afferent input from the sensory receptors to the CNS
    - In the body (soma)
    - In the head (specialized "senses")
  - Motor nerves: efferent output from the CNS to the muscles; motor actions
  - Muscles:
    - in the body and head (movement of the head, face, eyes, ear, tongue, lips)
    - heart, lungs, stomach, gut
2. **Central Nervous System: controls**
- 1. **The spinal cord:** a two-way information highway connecting the peripheral nervous system and the brain.
    - ascending neural fibres send up sensory information
    - descending fibres send back motor-control information
  - Central grey region: Central region (looks like an "H") takes on a greyish colour because of densely-packed neurons in this region are not surrounded by a myelin sheath. The neurons are very short. There is very elaborate inter-neuronal communication. Inter-neuronal communication permits flexibility in behaviour. It is this complexity of inter-neuronal communication that will lead in evolution to complex behaviour such as learning, memory and so forth.
  - White surround region: Surrounding the central grey region is the white "surround". This consists of ascending "sensory" pathways that ascend from the spinal cord to the brain and the descending "motor" pathways that descend from the brain to the spinal cord. These ascending sensory pathways are located in the dorsal region of the spinal cord. The descending motor pathways are located in the ventral portion of the spinal cord. The sensory and motor pathways can be very long, up to 5 metres in animals such as the giraffe and whale. Because of their length, the pathways need a means to communicate rapidly. The addition of the myelin sheath to the axons permits very rapid neuronal transmission. Since myelin is lipid (i.e., fat) material, it takes on a white colour. Thus, the long ascending and descending pathways appear white to the eye.
  - Flexibility of behaviour is also called "plasticity" (it can be moulded). It is also called soft-wiring.
  - The opposite of flexibility is the hard-wiring. Many connections in the nervous system as "wired" genetically. This forms the basis of a reflex (inevitable sensory input-motor output that cannot be altered through learning).
  - Monosynaptic reflex. Sensory input -> motor output (see image below of withdrawal reflex)

#### Monosynaptic reflex

- Step 1: arrival of stimulus and activation of receptor
  - Step 2: activation of a sensory neurone
  - Step 3: Information processing in CNS
  - Step 4: Activation of a motor neurone
  - Step 5: Response by effector
  - Spinal cord does not have enough grey matter to store information
- Polysynaptic reflex

- Explanation examples : finger is placed of a candle flame, hear information is carried from the skin receptors along a sensory neurone to the spinal cord. From there it is passed via interneurons to motor neurones that lead to the muscles in the hand and arm moving. Pain-reflex occurs in spinal cord because information travels to and from the brain via the spinal cord.
- Explanation examples : finger is placed of a candle flame, hear information is carried from the skin receptors along a sensory neurone to the spinal cord. From there it is passed via interneurons to motor neurones that lead to the muscles in the hand and arm moving. Pain-reflex occurs in spinal cord because information travels to and from the brain via the spinal cord.

## 2. The brain

- Information travels through 3 types of neurones
  - Sensory neurones: neurones that carry incoming information from the sensory receptors to the brain and spinal cord for processing
  - Motor neurones: neurones that carry outgoing information from the brain and spinal cord to the muscles and glands
  - Interneurones: neurones within the brain and spinal cord that communicate internally and intervene between the sensory input and motor outputs. This is the major type neurone

## Divisions of the Brain

- Hindbrain
  - medulla: slight swelling; the base of the brainstem, controls hearbeat and breathing
  - pons: above the medulla, which help coordinate movement
- Midbrain: collectively, the medulla, pons and midbrain form what is called the *brainstem*
- Forebrain
  - diencephalon
  - cerebrum

**The Brainstem:** the crosspoint where most nerves to and from each side of the brain connect

1. Medulla, pons, midbrain
  2. Specialized senses of the head (vision, heaing, taste, smell)
  3. Head "muscles" eye, ear movement, facial muscles
  4. Life "support" systems- temperature, heart, respiration
  5. Sleep-wake cycle
  6. Reticular activating system: : a nerve network that travels through the brainstem and plays an important role in controlling arousal (location between ears). Looks like a spider's web or net (rete in Latin means net). Stimulate any part of the reticular formation and eventually all parts will be stimulated. This does not allow for specific communication. But it is a good means of assuring a generalized reaction. This system allows for general arousal of the brain.
  7. The cerebellum: the "little brain" at the rear of the brainstem; functions include processing sensory input and coordinating movement output and balance. It enables non verbal learning and memory, judge time, modulate emotions, balance, etc. It coordinates our voluntary movements.
- Older brain structure are the structures that make up the brainstem and functions of the brainstem, thalamus and cerebellum

## The Diencephalon

### Thalamus:

- the brain's sensory switchboard, located on top of the brainstem; it directs messages to the sensory receiving areas in the cortex and transmits replies to the cerebellum and medulla (everything except smell)
- located immediately superior to the brainstem and inferior to the massive cortices. (middle of the brain on top of brainstem)
- this is the first place where all sensory systems merge
- Receives input from all sensory systems (exception olfaction) forms when life forms semi permanently exit water
- Massive grey area (because it serves complex roles)
- Has specific sensory nuclei
- Has many "association" areas
- Acts as a type of receptionists / filter for the neocortex

### Hypothalamus

- a neural structure lying below (hypo) the thalamus; it monitors and directs several maintenance activities (eating, drinking, body temperature), helps govern the endocrine system via the pituitary gland, and is linked to emotion. Located inferior to the thalamus at the base of the brain
- Reward centres located in the hypothalamus, it affects behaviour because rewards teach learning and direct behaviours (hippocampus: processes memory)
- Many sub divisions, each of which controls the basic needs and drives of the organisms: eating.
- Monitors blood levels that circulate at the base of the brain: levels of nutrients, water, oxygen, temperature, hormones. ex. if we do not have enough glucose a signal goes out and we feel hungry. If blood pressure is low we feel thirsty.
- It is part of the Autonomic nervous systems (ANS) and operates independently of our consciousness
- Is connected at its base to the pituitary gland and ultimately controls it.
- Control of the endocrine system via the pituitary gland

### Pituitary Gland

- Located at the base of the brain; inferior to the hypothalamus (circled in red in the MRI scan).
- The pituitary gland, properly speaking is not part of the brain at all. It is the "master" gland of another system of communication, the endocrine system. Pituitary gland is therefore the endocrine system's most influential gland.
- The pituitary gland regulates growth and controls other endocrine glands.
- Ultimately, the pituitary is under the control of the brain and more specifically, under the control of the hypothalamus.
- Thus, it is the hypothalamus that controls the endocrine system.
- This is a feedback system: brain -> pituitary-> other glands->hormones-> body and brain).

### **Endocrine System**

- The endocrine glands release hormones that circulate in the blood. This is believed to be an older system of communication in the body.
- The neuronal means of communication is very rapid and can be very specific (it is possible to lift only the left index finger) or can be quite general (generalized sleep, wakefulness).

- Hormonal communication by contrast is very slow (because hormones circulate in the blood is slower than neurotransmitter), long-lasting, and generalized. As a result, hormones produce a generalized “drive” that appears to haunt and invade consciousness.
- The hypothalamus closely monitors the endocrine levels that are circulating in the blood. It can then command the pituitary to increase or decrease the output of hormones in other glands.
- hormones: : chemical messengers that are manufactured by the endocrine glands, travel through the bloodstream and affect other tissues. When these act on the brain they influence interests of food, sex, aggression.
- Hormones produce molecules that act on receptors, but they take a longer time to travel to their location which is why endocrine messages tend to outlast the effects of neural messages ex. Feelings of being upset linger.
- This can be seen in moments of crisis where the ANS orders adrenal glands to release epinephrine, norepinephrine aka adrenaline and Noradrenaline

### **Cerebral Cortex**

- Newer neural networks: enable perceiving, thinking and speaking.
  - Cerebral hemisphere come as a pair
  - Cerebral cortex: the intricate fabric of interconnected neural cells covering the cerebral hemispheres; the body's ultimate control and information processing centre
  - What makes us distinctly human is arise of complex social structure : expansion of cerebral cortex, relaxing of tight genetic controls and increase in adaptability organisms
  - Structure of the cortex
    - hemispheres filled with axons connecting the cortex to the brains other regions
    - cerebral cortex contains 20billion nerve cells
    - supporting these nerve cells are 9 times as many spidery glial cells
- also play a role in learning and thinking
- more complex brains have an increase in glial cells
  - each hemisphere cortex is subdivided into 4 *lobes*, separated by prominent *fissures*, or folds.

### **The Cerebrum (Neocortex)**

1. Sulci and gyri
2. Architecture (6-layered)
3. Central white (more or less) and grey surround
4. Complex interconnections
5. Sub-divided into the frontal, parietal, temporal, occipital lobes
6. Longitudinal fissure separates the left and right hemispheres
7. Central fissure separates the frontal and parietal lobes
8. Lateral fissure separates the frontal/parietal lobes from the temporal lobe.

9. Corpus callosum. A thick band of white matter that connects the left and right hemispheres so that one knows what the other is doing.

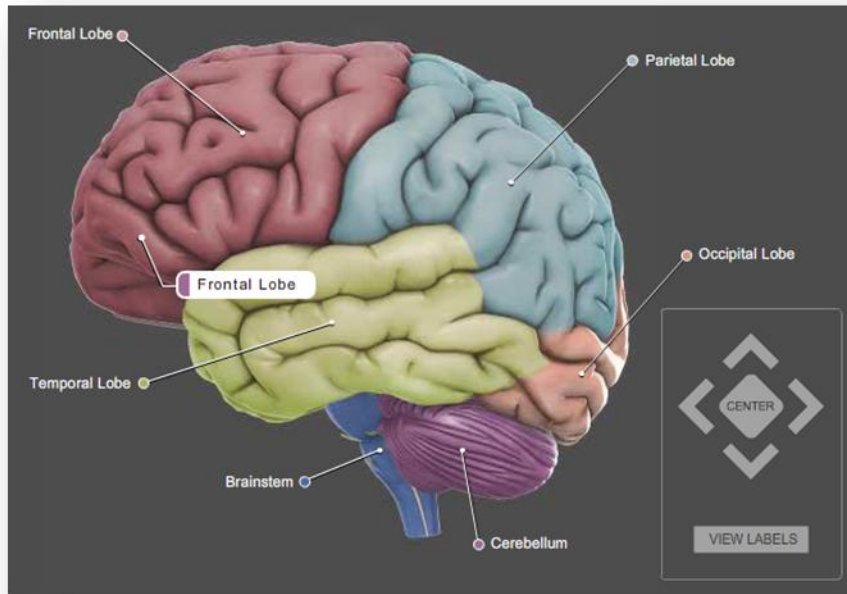
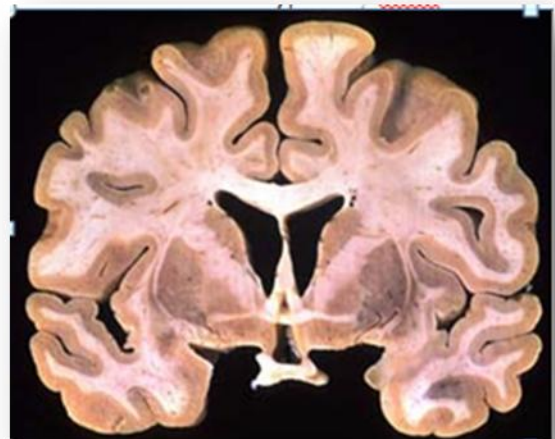


Image courtesy of [www.g2conline.org](http://www.g2conline.org)

### Architecture of the Cortex

- Neocortex: 6 layered grey matter. In evolution, as the behavioural complexity of the animal increases, the amount of grey cortical matter must also increase.
- Behavioural complexity-flexibility (learning, memory) requires the complex interaction that is only possible with massive interneuronal communication.
- The formation of new memories requires a physical change in the structure of the brain! New synapses must develop, or at the very least, the nature of existing synapses must alter. Note the significance of this statement.
- It implies that a good deal of the neocortex is not genetically determined. The connections that are made in the cortex are largely not genetically laid out. However, other researchers would say that this statement is too strong. They would claim that while some of the neocortex is not genetically laid out, most of it is. Some (if not large) portions of the neocortex develop with learning (i.e., “experience” with the environment).
- The image on the right is a coronal slice showing the left and right hemispheres. The dark areas are grey matter and the light areas, white matter. The neocortex consists of sulci (the various crevices) and six layers of grey matter (the gyri). The left and right



hemispheres are connected by a thick layer of white matter, the corpus callosum.

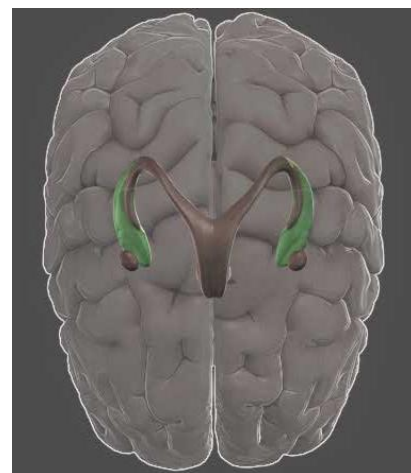
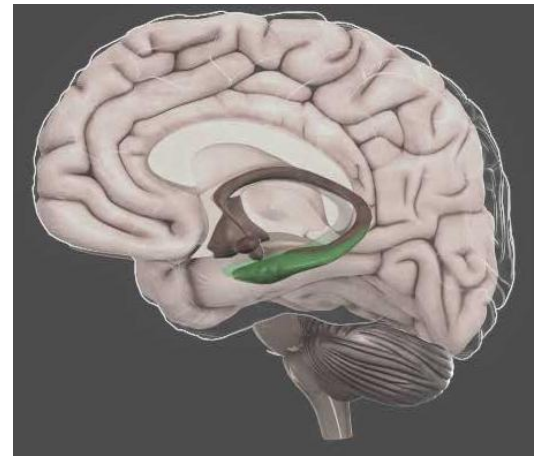
- Fissures: separate hemispheres and lobes
  - longitudinal fissures: separate left and right hemispheres
  - frontal lobe is separated from the parietal lobe by central fissures
  - temporo-parietal lobe is separated from frontal lobe by lateral fissure

### Frontal Lobe

- portion of the cerebral cortex lying just behind the forehead; involved in speaking and muscle movements and in making plans and judgements . Voluntary movements.
  1. Motor functions: direct muscle output
    1. Primary motor cortex in the pre-central gyrus
    2. Broca's area and speech
  2. Psychological function - highly complex "higher mental" functions. Selective attention, concentration; "will"; initiative (initiator of appropriate action); social norms; insight, logic, feedback (ability to learn from error); consciousness (awareness of the external world/ awareness of one's own thoughts and actions); self-consciousness (awareness that I am aware that I am aware); personality. The essence of human existence is probably a result of the development of the frontal lobe.

### Temporal Lobe

- portion of the cerebral cortex lying roughly above the ears; includes the auditory areas, each receiving information primarily from the opposite ear.
- Primary auditory cortex in the superior portion of the temporal lobe (Gyrus of Heschl)
- Wernicke's area (receptive speech)
- Short-term memory systems -- hippocampus; amygdala (?) .
- The hippocampus (in green in image on right) is located in the infero-medial portion of the temporal lobe and then loops (like a ram's horns) toward the hypothalamus. The next image shows a view from a superior location. The hippocampus (in green) is located in an inferior location in the temporal lobe and then loops upward and toward the middle (medial) portion of the diencephalon.
- The *hippocampus* appears to be specialized for the storage of short-term memories. If the information is relevant enough, the hippocampus can allow for the transfer of short-term memories into permanent memory. If the hippocampi (the hippocampus is embedded in both the left and right hemispheres) is severed, the patient will not be able to learn anything new. This is because



the patient will be unable to transfer information from the short-term to permanent, long-term memory. (Images courtesy of genes to cognition online (www.g2conline.org))

- Amygdala: two Lima bean sized neural clusters in the Limbic system; linked to *emotion*. Ex. when electrical stimulation of a cats amygdala provoke angry reactions, this is because the ANS division is activated by the sympathetic nervous system
- limbic system ( see later)

### **Parietal Lobe**

- portion of the cerebral cortex lying at the top of the head and toward the rear; receives sensory input for touch and body position
  1. *Permanent memory* (or "long-term" memory) systems
  2. *Switching of attention*. While the frontal lobe appears to be specialized for the focussing or "maintenance" of attention (this is called "vigilance" or "concentration"), when something novel occurs, we need to switch attention. This is a role of the parietal lobes.
  3. *Hemi-neglect*. Patients who have damage to the right parietal lobe fail to attend to information arising on their left side. They thus "neglect" half of their universe. This tendency to neglect the left side occurs only when there is also information on the right side. Thus, if there is information on the left side and none on the other, the right parietal lobe patient will detect it. Thus, there is nothing wrong with the sensory systems. The patient can hear, see or feel information on the left side of their bodies. But if there is information on both the left and the right side, the patient will not see (or hear or feel) the information on the left. They thus attend to the information on the right side (that therefore is transmitted to the left hemisphere) and neglect information on the left side. This can lead to very bizarre behaviour. Patients may only dress half of their bodies and be completely unaware of it. They may claim that there is nothing at all wrong with them and can thus be very difficult to treat. If you are on the patient's left side and speak to them, she/he will hear you (since there are no sounds entering the right ear) but not see you (since they will also be seeing objects in the room on the right side). Patients may thus complain that they are hearing voices. At times, these patients are misdiagnosed as being "psychotic".
  4. *difficulty naming objects*

### **Occipital Lobes:**

- portion of the cerebral cortex lying at the back of the head, includes areas that receive information from the visual field

### **Sensory/motor/ Association cortices**

- There are 3 major types of cortices within the brain
1. Sensory cortex: cortex receives input about sensory information via relays from the thalamus (although there are direct inputs from the olfactory system that bypass the thalamus).
    - Visual cortex:(almost 50% of the occipital lobe) , receives input from your eyes
    - Auditory cortex: (the gyrus of Heschl, embedded in the superior part of the temporal lobe), receive information from your ears
    - Somatosensory (post-central gyrus - immediately posterior(behind) to the central fissure; thus in the parietal lobe.). Touch, temperature
    - more sensitive a body region, the larger the sensory cortex area devoted to it.

2. Motor cortex in turn sends motor output into the peripheral via the efferent

- motor: (pre central gyrus – immediately in front to the central fissure)
- Speech Areas
  1. Motor (communicate) aspects: Broca's area in the inferior region of the frontal lobe
  2. Sensory (receptive) aspects: Wernicke's area at the junction of the parietal and temporal lobes.
  3. Hemispheric differences. In 95-99% of right-handed individuals, the "dominant" (dominant means the centre for speech) hemisphere is the left hemisphere. In left-handers, it is not quite this simple. For about 50%, the left hemisphere is still dominant but for perhaps as many as 40%, the right is dominant. For some left-handers (from 10-25%), both hemispheres are dominant. Assuming that the left hemisphere is dominant, damage to Broca's area in the left hemisphere will result in an inability to speak. Damage to the Wernicke's area in the left hemisphere will result in an inability to understand speech. But there are also important language roles in the right hemisphere. Damage to Broca's area in the right hemisphere will result in monotone speech. Speech lacks "tonality". Damage to Wernicke's area in the right hemisphere will result in an inability to understand the emotional aspects of speech

3. Association cortex: has no direct contact with the outside world. The association cortex has very elaborate inter-neuronal communication. One neuron communicates with perhaps several other neurons. It is the association cortex that permits the complex behaviour, learning and memory that is associated with "intelligent" species. It is the association cortex that allows for considerable behavioural flexibility.

- Includes very large areas of the frontal lobe, parietal lobe, temporal lobe and portions of the occipital lobe
- Association areas have no direct contact with the outside world. They are neither sensory nor motor cortices. Rather they are involved in higher mental functions such as learning, remembering thinking, speaking. They receive information only after considerable processing by the sensory (or motor) cortices.
- Their architecture consists of small interneurons with very elaborate and complex interconnections. Their function is exceedingly complex.
- The size of the association cortices massively expands with evolution. A monkey thus has much more of its cortex devoted to association functions than a horse. A human has much more association cortex than a monkey. One should not be terribly impressed by the size of the human brain. Whales and elephants also have large brains. A good deal of the elephant's brain is, however, devoted to motor activity (there is a good deal of muscle to control). Sharks, who are considered to be simple animals, actually have a fairly large brain, at least with respect to fish. However, most of this is devoted to sensory (smell) and motor functions (the exquisitely fine and rapid motion associated with swimming).
- the surface of the cortex is non dormant, these areas interpret, integrate and act on sensory information and link with stored memories
- include movement, recognition, behavior

## **Hemisphere difference**

- Dominant (left) hemisphere
  - language ( or at least consciousness of language, ex, video of the guys who's hemispheres (corpus callosum) are severed from each other )
  - math operations?
  - Logic?
- Non dominant hemisphere
  - spatial construction/ block design
  - Face recognition
  - Tonality/ emotional expression/ music
- Corpus callosum : This is the major commissure of the brain. A commissure connects the left hemisphere to the right hemisphere and the right to the left allowing the left hemisphere to communicate to the right and vice versa.
- What happens if the callosum is severed?: The brains plasticity( to what extent can a damaged brain reorganize itself and what is it's neurogenesis)
  - brains are sculpted not only by our genes but by our experiences
  - plasticity: the brains ability to change, especially during childhood, by reorganizing after damage or by building new pathways based on experience
  - effects of damaged brain are caused by discrete neurones (which do not regenerate) and some brain functions seem preassigned to specific areas
  - some neural tissues can reorganize in response to damage. One way is by constraint induced therapy
  - plasticity explains why for example deaf people have enhanced peripheral vision. sometimes the brain tries to repair itself by producing new brain cells instead of reorganizing existing tissue. This process is known as neurogenesis
  - neurogenesis: the formation of new neurones. Same thing that occurs in an embryo

### **Limbic System**

- between the oldest and newest is the limbic system
- the anatomy of the limbic system is quite complex. The word limbic means circle or loop. The loop within the brain includes: the cingulate cortex –hippocampus/amygdala-hypothalamus circuit. The amygdala is located immediately in front and somewhat superior to the hypothalamus
- The limbic system plays an intimate role in the maintenance and expression of emotions. The role of the limbic system has been summarized as consisting of the 4 F's: feeding, fighting, fleeing, undertaking making behaviors
- Olfactory nerve, amygdala, hippocampus, septum, frontal lobe, hypothalamus

### Frontal control of emotion

- Control of emotions is carried out by the central executive
- It is the frontal lobe
- The frontal lobes are inhibitors of inappropriate actions

### **Autonomic nervous system**

- The autonomic nervous system appears to function "autonomously" from the cortex. The cortex may not be aware ("conscious") of what the autonomic nervous system is doing. The cortex may have only limited control or no control at all over the autonomic nervous system.
  - Controlled by the hypothalamus. It (the autonomic nervous system) consists of two branches, the sympathetic and parasympathetic
    - sympathetic branch
      - provide energy: increase heart beat, respiration, dilate of skeletal muscles; contract affirmed of skin; inhibit digestive system.
    - Parasympathetic branch
      - conserve energy- slow heart beat
- 

#### Definition of consciousness

- Consciousness as a process
  - the process of becoming conscious
  - Selective attention process
- Consciousness as a state
  - sleep-wake states
  - conscious waking state
  - unconscious sleeping state

#### Natural sleep: the loss of consciousness

- What is sleep?
- How is sleep defined
- Sleep is not unique
- It consists of at least two divisions; NREM and REM
- What is the purpose of sleep? What is the purpose of each stage?
- Sleep is rhythmic. What "clock" controls this
- Do all animals sleep? Do all mammals sleep?

#### Recording sleep in humans

- Electroencephalogram (EEG)
- Electromyogram (EMG)
- Electrooculogram (EOG)
- Other activities
  - respiration
  - Heart beat/ pressure
  - Temperature

#### How is consciousness measured?

- Overt behaviour: subject signals awareness
- Physiology:
  - EEG

-brain response to stimuli (evoked potentials)