Adv H Biology Learning Outcome checklist **<u>Unit 3: Investigative Biology</u>**

3.1: Scientific Principles and Process

	I can state or explain the following
(a) Scientific method	
	the **scientific cycle** is made up of observation, construction of a testable hypothesis, experimental design, gathering, recording, analysis of data, and evaluation of results, conclusions and the formation of new hypotheses where necessary.
	the '**null hypothesis**' proposes that there will be no statistically significant effect as a result of the experiment treatment ▫and construct a null hypothesis for a given experiment.
	failure to find an effect is a valid finding, as long as an experiment is well designed.
	conflicting data or conclusions can be resolved through careful evaluation or can lead to further experimentation.
	if there is evidence for an effect, unlikely due to chance, then the null hypothesis is rejected.
	scientific ideas are only accepted once they have been checked independently.
	effects must be reproducible; one-off results are treated with caution.
(b) Scientific Literature and Communication	
	importance of **publication** of methods, data, analysis and conclusions in scientific reports so that others are able to repeat an experiment
	that common methods of sharing original scientific findings include seminars, talks and posters at conferences, and publishing in academic journals
	peer review is when specialists with expertise in the relevant field assess the scientific quality of a submitted manuscript and make recommendations regarding its suitability for publication.
	the importance of peer review and critical evaluation by specialists with expertise in the relevant field
	a review article summarises current knowledge and recent findings in a particular field
	critical evaluation of science coverage in the wider media.
	increasing the **public understanding** of science and the issue of misrepresentation of science in the media

(c) Scientific Ethics	
	Importance of **integrity** and **honesty** - unbiased presentation of results, citing and providing references, avoiding plagiarism.
	while judgements and interpretations of scientific evidence may be disputed, integrity and honesty are of key importance in science
	replication of experiments by others reduces the opportunity for dishonesty or the deliberate misuse of science.
	the concepts of **replacement**, **reduction** and **refinement** are used to avoid, reduce or minimise the harm to animals.
	informed consent, the right to withdraw data and confidentiality in human studies
	Justification for scientific research and assessment of any risks
	The value or quality of science investigations must be justifiable in terms of the benefits of its outcome, including the pursuit of scientific knowledge
	As a result of the **risks** involved, many areas of scientific research are highly regulated and licensed by governments
	the risk to and safety of subject species, individuals, investigators and the environment must be taken into account□.
	Legislation, regulation, policy and funding can all influence scientific research
	Legislation limits the potential for the misuse of studies and data.

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3.2 Experimentation

	I can state or explain the following
Validity, reliability, accuracy and precision	
	validity: variables are controlled so that any measured effect is likely to be due to the independent variable
	reliability: consistent values in repeats and independent replicates.
	accuracy: when data, or means of data sets, are close to the true value.
	precision: measured values are close to each other
(a) Pilot Study	
	a pilot study is integral to the development of an investigation; it is used to help plan procedures, assess validity and check techniques.
	a pilot study allows **evaluation** and **modification** of experimental design
	The use of a pilot study can ensure an **appropriate range of values** for the independent variable
	a pilot study also allows the investigator to establish the **number of repeat measurements** required to give a representative value for each independent datum point
(b) Experimental Design (i) Independent and Dependent variables	
	independent variable is the variable that is changed in a scientific experiment.
	dependent variable is the variable being measured in a scientific experiment.
	independent and dependent variables can be **continuous** or **discrete**.
	experiments involve the manipulation of the independent variable by the investigator.
	The experimental treatment group is compared to a **control group**
	The use and limitations of simple (one independent variable) and multifactorial (more than one independent variable) experimental designs
	The control of laboratory conditions allows simple experiments to be conducted more easily than in the field. However, a drawback of a simple experiment is that its findings may not be applicable to a wider setting.
	A multifactorial experiment involves a combination of more than one independent variable or combination of treatments.
	Investigators may use groups that already exist, so there is no truly independent variable
	Observational studies are good at detecting correlation, but since they do not directly test a hypothesis, they are less useful for determining causation
	In observational studies the independent variable is not directly controlled by the investigator, for ethical or logistical reasons.
(b) Experimental Design (ii) Confounding Variables	
	Due to the complexities of biological systems, other variables besides the independent variable may affect the dependent variable
	These **confounding variables** must be held constant if possible, or at least monitored so that their effect on the results can be accounted for in the analysis

	In cases where confounding variables cannot easily be controlled, a randomised block design could be used
	Randomised blocks of treatment and control groups can be distributed in such a way that the influence of any confounding variable is likely to be the same across the treatment and control groups.
(b) Experimental Design (iii) Controls	
	Control results are used for comparison with the results of treatment groups
	Negative and positive controls may be used
	The **negative control** provides results in the absence of a treatment.
	A **positive control** is a treatment that is included to check that the system can detect a positive result when it occurs.
	Use of **placebos** and the placebo effect
	Placebos can be included as a treatment without the presence of the independent variable being investigated.
	Placebo effect is a measurable change in the dependent variable as a result of a patient's expectations, rather than changes in the independent variable.
(b) Experimental Design (iv) *In vitro* and *In vivo* studies	
	In vitro refers to the technique of performing a given procedure in a controlled environment outside of a living organism
	Examples of in vitro experiments: cells growing in culture medium, proteins in solution, purified organelles.
	In vivo refers to experimentation using a whole, living organism
	Advantages and disadvantages of in vivo and in vitro studies
(c) Sampling	
	Where it is impractical to measure every individual, a representative sample of the population is selected
	The extent of the natural variation within a population determines the appropriate sample size
	More variable populations require a larger sample size
	A **representative sample** should share the same mean and the same degree of variation about the mean as the population as a whole
	In **random sampling**, members of the population have an equal chance of being selected.
	In **systematic sampling**, members of a population are selected at regular intervals.
	In **stratified sampling,** the population is divided into categories that are then sampled proportionally.
(d) Reliability	
	Variation in experimental results may be due to the reliability of measurement methods and/or inherent variation in the specimens
	The precision and accuracy of repeated measurements
	The reliability of measuring instruments or procedures can be determined by repeated measurements or readings of an individual datum point. The variation observed indicates the precision of the measurement instrument or procedure but not necessarily its accuracy.

	The natural variation in the biological material being used can be determined by measuring a sample of individuals from the population
	The mean of these repeated measurements will give an indication of the true value being measured
	The range of values is a measure of the extent of variation in the results
	If there is a narrow range then the variation is low
	Independent replication should be carried out to produce independent data sets
	Overall results can only be considered reliable if they can be achieved consistently.
	These independent data sets should be compared to determine the reliability of the results
(e) Presentation of data	
	Discrete and continuous variables give rise to qualitative, quantitative, or ranked data
	Qualitative data is subjective and descriptive.
	Quantitative data can be measured objectively, usually with a numerical value
	Ranked data refers to the data transformation in which numerical values are replaced by their rank when the data are sorted from lowest to highest.
	The type of variable being investigated has consequences for any graphical display or statistical tests that may be used
	Identification and calculation of **mean, median** and **mode**
	Use of **box plots** to show variation within and between data sets
	Median, lower quartile, upper quartile and inter-quartile range.
	Interpret **error bars** on graphical data
	Correlation exists if there is a relationship between two variables
	Correlation is an association and **does not imply causation**.
	Causation exists if the changes in the values of the independent variable are known to cause changes to the value of the dependent variable
	Positive and negative correlations
	A **positive correlation** exists when an increase in one variable is accompanied by an increase in the other variable.
	A **negative correlation** exists when an increase in one variable is accompanied by a decrease in the other variable.
	Strong and weak correlations
	Strength of correlation is proportional to spread of values from line of best fit.
	Correlation values are not required.

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3.3 Reporting and Critical Evaluation of Biological Research

	I can state or explain the following
(a) Background information	
	scientific reports should contain an explanatory **title**, an **abstract** including **aims** and **findings**, an **introduction** explaining the purpose and context of the study including the use of several **sources**, **supporting statements**, **citations**, and **references**.
	background information should be **clear**, **relevant** and **unambiguous**.
	A **title** should provide a succinct explanation of the study.
	An **abstract** should outline the aims and findings of the study.
	an **aim** must link the independent and dependent variables
	introduction should provide any information required to support: choices of method, results, and discussion.
	An introduction should explain why the study has been carried out and place the study in the context of existing understanding.
	Key points should be summarised and supporting and contradictory information identified.
	Several **sources** should be selected to support statements, and citations and references should be in a standard form..
	Decisions regarding basic selection of study methods and organisms should be covered, as should the aims and hypotheses
(b) Reporting and evaluating experimental design	
	a **method** section should contain sufficient information to allow another investigator to repeat the work.
	the experimental design should address the intended aim and test the hypothesis
	The **validity** and reliability of the experimental design should be evaluated.
	An experimental design that does not address the intended aim or test the hypothesis is invalid.
	treatment effects should be compared to **controls**
	any **confounding variables** should be taken into account or standardised across treatments.
	the **validity** of an experiment may be compromised when factors other than the independent variable influence the value of the dependent variable
	explain the effect of **selection bias** and **sample size** on representative sampling
	Selection bias is the selection of a sample in a non-random way, so that the sample is not representative of the whole population.
	Selection bias may have prevented a representative sample being selected.

	Sample size may not be sufficient to decide without bias whether the change to the independent variable has caused an effect in the dependent variable.
(c) Data analysis	
	make appropriate use of graphs, mean, median, mode, standard deviation and range in interpreting data
	that in results, data should be presented in a clear, logical manner suitable for analysis.
	Consideration should be given to the validity of **outliers and anomalous results**.
	Statistical tests are used to determine whether the differences between the means are likely or unlikely to have occurred by chance.
	a **statistically significant result** is one that is unlikely to be due to chance alone.
	error bars indicate the variability of data around a mean
	if the treatment mean differs from the control mean sufficiently for their error bars not to overlap, this indicates that the difference may be significant.
(d) Evaluating Results and Conclusions	
	conclusions should refer to the aim, the results and the hypothesis
	that the validity and reliability of the experimental design should be taken into account.
	consideration should be given as to whether the results can be attributed to **correlation or causation.**
	evaluation of conclusions should also refer to existing knowledge and the results of other investigations..
	Meaningful scientific discussion would include consideration of findings in the context of existing knowledge and the results of other investigations.
	Scientific writing should reveal an awareness of the contribution of scientific research to increasing scientific knowledge, and to the social, economic and industrial life of the community