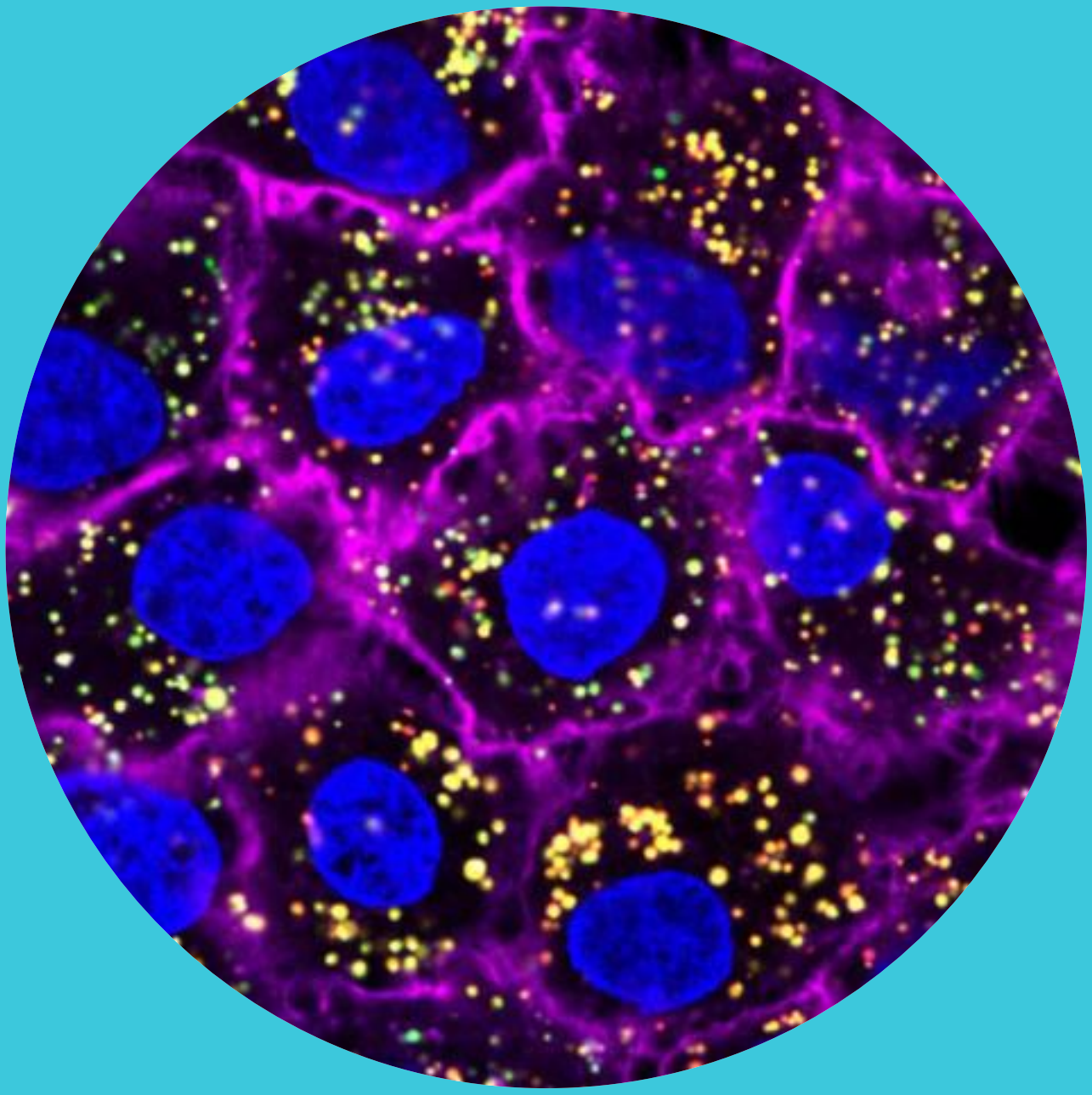
Researchers in Schools



How to prevent nano-detectives from going rogue

Key Stage 4 Programme

Pupil Name

Coursebook Designed by **Dr A. Shukur**

Timetable and Assignment Submission

Timetable – Tutorials

Tutorial	Date	Time	Location
1			Thinktank Birmingham Science Museum
2			Sandwell Academy
3			Sandwell Academy
4			Sandwell Academy
5			Sandwell Academy
6 (Feedback)			Sandwell Academy
7 (Feedback)			Sandwell Academy

Timetable – Homework Assignments

Homework Assignment	Description	Due Date
Tutorial 1	Baseline assignment	
Tutorial 2	Watch a video on the application of nanomaterials in medicine.	
Tutorial 3	A quiz on Nanoparticles and their Applications.	
Tutorial 4	Write a summary	
Tutorial 5	Final assessment	

Assignment Submission – Lateness and Plagiarism

Lateness	
Submission after midnight on 9th August	10 marks deducted
Plagiarism	
Some plagiarism	10 marks deducted
Moderate plagiarism	20 marks deducted
Extreme plagiarism	Automatic fail

Contents

Course Rationale **4**

Mark Scheme **5-6**

Glossary of Keywords **9-10**

Tutorial 1 – What is Biosafety? **11**

Activity 1: 'Working in Groups of 3' **12-13**

Activity 2: 'Working in Pairs' **13**

Activity 3: 'Individual Activity' **13**

Tutorial 2 – The Nanoscale **15**

Activity 1: 'Calculation' **20**

Activity 2: 'Working in Groups of 3' **21**

Activity 3: 'Working in Pairs' **21**

Tutorial 3 – Physicochemical Properties of Nanomaterials **22**

Activity 1: 'Think, Pair and Share' **24**

Activity 2: 'Make Notes' **24**

Activity 3: 'Card Sort' **24**

Tutorial 4 **25**

Activity 1: 'Independent Work' **28**

Activity 2: 'Working in Pairs' **28**

Tutorial 5 – The Advantages versus Disadvantages of Nanotechnology **29**

Activity 1: 'Identify' **31-33**

Activity 2: 'Think, Pair and Share' **34**

Activity 3:'Group Activity' **34**

Tutorial 6 – Feedback tutorial **36**

Reflection on feedback **36-37**

Tutorial 7 – Final tutorial **38**

Reflecting on the course **39**

References **40-41**

Reading List **42**

Appendices **43**

Referencing correctly **43-44**

Course Rationale

The course is entitled ‘How to prevent nano-detectives from going rogue’. The aim of the course is to allow you to understand the biosafety concerns associated with the application of nanomaterials. Nano-scale dye-encapsulated nanomaterials will be the main focus as these are being used in imaging diagnostics and medical therapeutics.

During the initial phase of the course you will learn how tiny materials at the nano-scale were discovered and applied in various scientific disciplines. You will acquire the knowledge required to define 'Nanotechnology' as a scientific discipline involved in manipulating matter at the Nano-scale. In the second part of the course you will learn how nanoparticles are made, their physicochemical properties and their application in various settings.

The final part of the course will be focused on how these nanomaterials interact with our human body through e.g. direct skin contact, inhalation and intravenous injection. You will learn how the understanding of the latter will enable us to safely administer the latter materials to diagnose and treat disease. The biocompatibility of nanomaterials will be assessed based on their advantages (benefits) and disadvantages (negative effects). You will also be able to discuss the impact of nanomaterials on human health and ways to overcome them. Despite the negative impact of nanomaterials, we may be able to suggest alternative ways (strategies) in which this technology can be safely used. You will therefore identify, critique and appraise some of the strategies into the safe application of nanomaterials in medicine. Various materials, activities and assessments will aid the latter understanding and reinforce the concepts discussed throughout the course.

Uni Pathways Mark Scheme 2019 – Essay-based assignments

	Skills	1st (70-100)	2:1 (60-69)	2:2 (50-59)	3rd (40-49)	Mark /100
Subject knowledge	Knowledge and understanding	o All content included and materials used are relevant to the general topic and to the specific question/title o Good understanding of all the relevant topics. o Technical terms are defined and used accurately throughout o Clear justification of how the material and content included is related to the specific issues that are the focus of the assignment	o Most of the materials used and content included are relevant to the general topic and to the specific question/title o Good understanding of most the relevant topics o Technical terms are mostly defined and used accurately o Adequate justification of how the material used and content included are related to the specific issues that are the focus of the essay	o Some of the materials used and content included are relevant to the general topic and to the specific question/title o Good understanding on some of the relevant topics but occasional confusion on others o Technical terms are sometimes used and defined accurately o Some justification of how the material used and content included are related to the specific issues that are the focus of the essay	o The content included and materials used are not applied to the question/title in a relevant manner o There is confusion in how understanding of the topics is expressed	
Critical thinking	Research and evidence	o Includes rich sources of research findings, data, quotations or other sourced material as evidence for the claims/ideas o Uses evidence/calculations to support claims/assertions/ideas, consistently clearly and convincingly o Evidence of further reading beyond materials provided which were used in an appropriate context o Data is effectively analysed and appropriate assumptions/conclusions are reached	o Includes adequate sources of research findings, data, quotations or other sourced material as evidence for the claims/ideas o Uses evidence/calculations to support claims/assertions/ideas, mostly clearly and convincingly o Evidence of further reading beyond materials provided o Data is analysed and the assumptions/conclusions that are reached are mostly appropriate	o Includes some sources of research findings, data, quotations or other sourced material as evidence for the claims/ ideas o Uses evidence/calculations to support claims/assertions/ideas, at times clearly and convincingly o Limited evidence of further reading beyond materials provided o There is an attempt to analyse data and draw assumptions/conclusions	o Inclusion sources and materials is very limited and mostly not attributed o Applicable sources are rarely used to support ideas. o Data is not used or few appropriate conclusions are drawn from it.	
	Developing an argument	o A point of view or position in relation to the title or question is consistently clear. The position is developed effectively and consistently throughout the essay o Argument is exceptionally well-developed and well-justified o Makes links effectively between subjects that have not previously been associated o Uses concepts from the tutorials in an unfamiliar context and does so accurately and confidently. o Content is analysed effectively to support the argument	o A point of view or position in relation to the title or question is adequately clear. The position is well-developed in most of the essay o Argument is clear and well-developed, and position is justified o Some evidence of linking subjects that have not previously been associated o Uses some concepts from the tutorials in an unfamiliar context, but not always accurately o Analyses content to support the argument	o A point of view or position in relation to the title or question is somewhat clear. The position is well-developed in parts of the essay o Argument is clear but not well-developed o Limited evidence of linking subjects that have not previously been associated o Limited use of concepts from the tutorials in other contexts o Uses some analysis of content to support the argument	o There is not a clear point of view or position taken and sometimes the argument is not clearly established	
	Critical	o Moves beyond description to an assessment of the value or	o Mostly description but some assessment of the value or	o Describes with minimal assessment of the value or significance of	o The work is descriptive in nature and there is a	

	evaluation	significance of what is described o Evaluative points are consistently explicit/systematic/reasoned/justified o Effectively critiques the reliability of sources provided	significance of what is described o Evaluative points are mostly explicit/systematic/reasoned/justified o Some evidence of critiques on the reliability of sources provided	what is described o Evaluative points are at times explicit/systematic/reasoned/justified o Limited evidence of critiques on the reliability of sources provided	lack of critical engagement in the value of sources	
Written communication	Structure and presentation	o Ideas are presented in paragraphs and arranged in a logical structure that is appropriate for the assignment o The introduction clearly outlines how the essay/report will deal with the issues o The conclusion summarises all the main points clearly and concisely o Tables and graphs are effectively constructed including appropriate headings, units and scales. o All sources are referenced correctly in an agreed format	o Ideas are presented in paragraphs and arranged in a structure that is mostly appropriate for the assignment o The introduction adequately describes how the essay/report will deal with the issues o The conclusion summarises most of the main points clearly o Most tables and graphs are well constructed o Most sources are referenced correctly in an agreed format	o Ideas are presented in paragraphs and arranged in a structure o The introduction mentions how the essay/report will deal with the issues o The conclusion summarises some of the main points clearly o Some tables and graphs are well constructed but contains some errors o Some sources are referenced correctly in the agreed format with occasional errors	o Ideas are presented in paragraphs but there is a lack of structure in how the work is presented o The work lacks an introduction that establishes the scope of the question o The work lacks a conclusion that summarise the main points raised o Work is not referenced accurately	
	Language and style	o No spelling, grammar or punctuation errors o Writing style consistently clear, tone appropriate and easy to follow o Accurate and consistent use of technical language and vocabulary	o Minimal spelling, grammar or punctuation errors o Writing style mostly clear, tone appropriate and easy to follow o Some attempts of using technical language and vocab alary, but not always accurate	o Some spelling, grammar or punctuation errors o Writing style moderately clear, tone appropriate and easy to follow o Use of simple language and vocabulary effectively but struggles to use technical language	o There are a significant number of spelling, grammar and punctuation errors o Use of simple language and vocabulary effectively but a lack of technical language	
Overall Mark (average of the 6 marks from the criteria above)						

Baseline Assignment (essay based): Pupil Feedback Report

Name of Pupil	
Name of School	
Name of RIS teacher	
Title of Assignment	'How can awareness of biosafety keeps us away from harm?'

How your assignment is graded:

Grade	Marks	What this means
1st	70+	Performing to an excellent standard at A-level
2:1	60-69	Performing to a good standard at A-level
2:2	50-59	Performing to an excellent standard at GCSE
3rd	40-49	Performing to a good standard at GCSE
Working towards a pass	0-39	Performing below a good standard at GCSE
Did not submit	DNS	No assignment received by The Brilliant Club

Lateness	
Any lateness	10 marks deducted
Plagiarism	
Some plagiarism	10 marks deducted
Moderate plagiarism	20 marks deducted
Extreme plagiarism	Automatic fail

Marks

OVERALL MARK / 100		FINAL MARK / 100(including any deductions)	
DEDUCTED MARKS		FINAL GRADE	

If marks have been deducted (e.g. late submission, plagiarism) the teacher should give an explanation in this section:

Mark Breakdown and Feedback

Knowledge and Understanding		Research and Evidence	
	mark		*mark*
Developing an Argument		**Critical Evaluation**	
	mark		*mark*
Structure and Presentation		**Language and Style**	
	mark		*mark*

Final Assignment (essay based): Pupil Feedback Report

Name of Pupil	
Name of School	
Name of RIS teacher	
Title of Assignment	Should nanotechnology be utilised to revolutionise the way we detect and treat disease?

How your assignment is graded:

Grade	Marks	What this means
1st	70+	Performing to an excellent standard at A-level
2:1	60-69	Performing to a good standard at A-level
2:2	50-59	Performing to an excellent standard at GCSE
3rd	40-49	Performing to a good standard at GCSE
Working towards a pass	0-39	Performing below a good standard at GCSE
Did not submit	DNS	No assignment received by The Brilliant Club

Lateness	
Any lateness	10 marks deducted
Plagiarism	
Some plagiarism	10 marks deducted
Moderate plagiarism	20 marks deducted
Extreme plagiarism	Automatic fail

Marks

OVERALL MARK / 100		FINAL MARK / 100(including any deductions)	
DEDUCTED MARKS		FINAL GRADE	

If marks have been deducted (e.g. late submission, plagiarism) the teacher should give an explanation in this section:

Mark Breakdown and Feedback

Knowledge and Understanding		Research and Evidence	
	mark		*mark*
Developing an Argument		**Critical Evaluation**	
	mark		*mark*
Structure and Presentation		**Language and Style**	
	mark		*mark*

Subject Vocabulary

Word	Definition	In a sentence
Biosafety	Biosafety is the prevention of large-scale loss of biological integrity, focusing both on ecology and human health. These prevention mechanisms include conduction of regular reviews of the biosafety in laboratory settings, as well as strict guidelines to follow. Biosafety is used to protect from harmful incidents.	
Encapsulation	Encapsulation refers to any technological process that allows one or more active compounds to be enclosed within an inert material. Encapsulated substances are therefore protected against harsh environments, such as hydrochloric acid within the stomach, and can also offer a controlled release of drugs.	
Fluorescence	Fluorescence is the emission of light by a substance that has absorbed light or other electromagnetic radiation. It is a form of luminescence. In most cases, the emitted light has a longer wavelength, and therefore lower energy, than the absorbed radiation.	
Luminescence	Is spontaneous emission of light by a substance not resulting from heat; or "cold light". it is thus a form of cold-body radiation. It can be caused by chemical reactions, electrical energy, subatomic motions or stress on a crystal.	
Nanoparticles	Nanoparticles are 1 nm to 100 nm in size. They have very large surface area to volume ratios. The properties of nanoparticulate substances are different from those of the same substance in bulk.	
Nanomaterial	Nanomaterials describe, in principle, materials of which a single unit is sized (in at least one dimension) between 1 to 1000 nanometres (10−9 meter) but usually is 1 to 100 nm (the usual definition of nanoscale).	

Nanomedicine	Nanomedicine is a branch of medicine that applies the knowledge and tools of nanotechnology to the prevention and treatment of disease. Nanomedicine involves the use of nanoscale materials, such as biocompatible nanoparticles and nanorobots, for diagnosis, delivery, sensing or actuation purposes in a living organism.	
Nanotechnology	Nanotechnology is defined as the study and use of structures between 1 nanometre and 100 nanometres in size. To give you an idea of how small that is, it would take eight hundred 100 nanometre particles side by side to match the width of a human hair.	
Risk	Risk is the possibility of losing something of value. Values (such as physical health, social status, emotional well-being, or financial wealth) can be gained or lost when taking risk resulting from a given action or inaction, foreseen or unforeseen (planned or not planned).	

Tutorial 1 – What is Biosafety?

What is the Purpose of Tutorial 1?

By the end of this tutorial I will be able to…

- Objective 1: Define the concept of biosafety and increase awareness in this area of research.
- Objective 2: Explain the pros and cons of life-style choices, science and technology.

Starter:

Think about the dangers that you are exposed to in everyday life? Can you describe some of these risks (dangers and hazards) and what precautions would you take to tackle them?

Biosafety is the prevention of large-scale loss of biological integrity, focusing on both ecology and human health. These prevention mechanisms include conduction of regular reviews of the biosafety in laboratory settings, persons outside of the laboratory, and the environment to potentially infectious agents (Shield, 2019). Biosafety is used to protect from harmful incidents using knowledge, techniques and equipment to prevent personal, laboratory and environmental exposure to potential harmful agents.

Albert Einstein created a formula in 1905 which turned disastrous (**Figure 1**)...
Einstein taught us a lesson, that is to question, check and critique the biocompatibility or biosafety of things we create, implement or use as a technology, medication, new intervention or discovery related to any aspect of life.

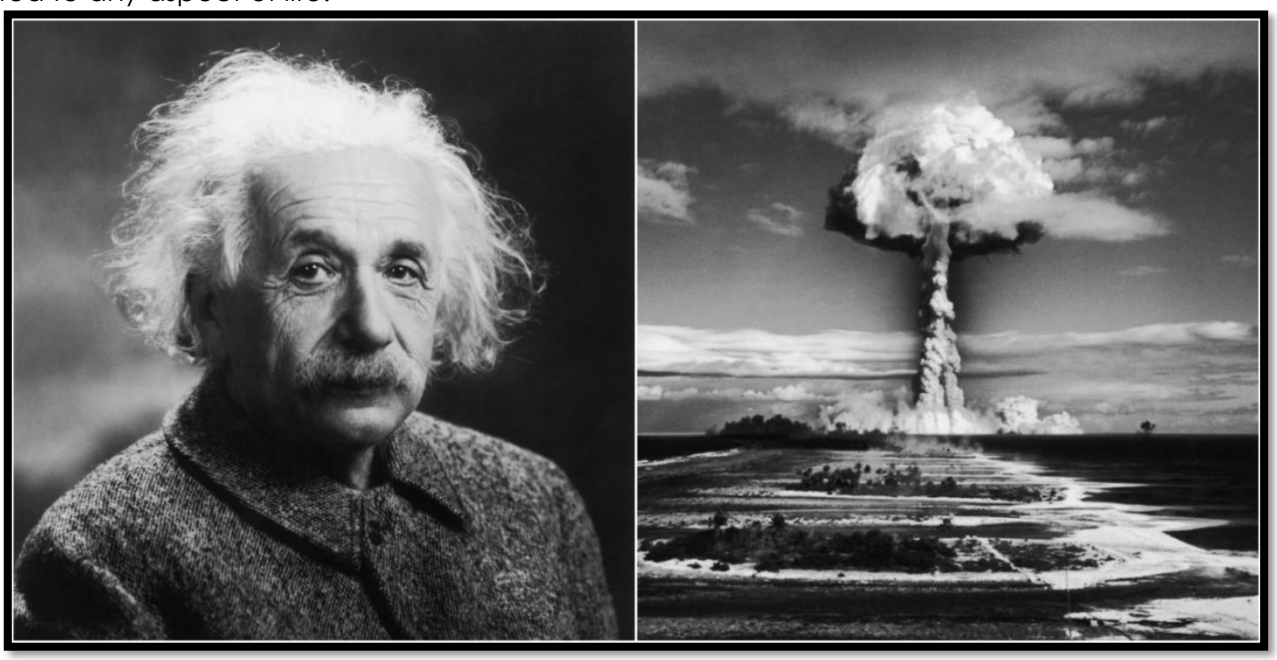


Figure 1. Despite advancements in nuclear medicine, the creation of nuclear bombs left Einstein in deep regret. Albert Einstein around 1939 and nuclear explosion in French Polynesia in October 1971. MPI/Getty Images/Michel BARET/Gamma-Rapho via Getty Images.

Activity 1: 'Working in Groups of 3'

Using **Table 1** As an example; complete the table of hazards and risks that may be implicated in illness, disease and/or environmental pollution.
Hint: Use the list of key words, images and hazard symbol notations as prompts.

Table 1. Common hazards.

Hazard	Classification	Mode of Exposure/Uptake	Effects	Preventative Measures (precautions)	Reference
Influenza Virus	Biological	Respiratory (Inhalation)	Sore throat, headache and fatigue	Vaccination	Blut, 2009
Mobile Phones	Smart Phone Technology	Dermal (Skin absorption)	Radiowaves may cause brain tumours and infertility.	Reduce usage and turn off during sleep.	Cardis et al., 2011
Lactose Intolerance	Biological (Nutrition)	Oral	decreased ability to digest lactose	Avoid dairy products	NHS, 2019
Caffeine	Chemical	Oral	Stimulant and depletes bone from calcium, leading to osteoporosis.	Moderate drinking of coffee, tea, colas and energy drinks.	Dixit et al., 2006; Fisone et al., 2004; Fredholm et al., 1999; Westerterp-Plantenga et al., 2006; Zou and Li, 2006
Quantum Dots nanomaterial	Nanotechnol-ogy	Intravenous injection	Compromise in arterial function and drug interference.	Enhance their biocompatibility with antibody coatings for specific targetting *in vivo*.	Shukur et al., 2013
Salmonella	Biological	Gastrointestinal tract ingestion	Food poisoning	Diarrhoea and loss of appetite	Hohmann, 2016

Activity 2: 'Working in Pairs'

In groups, think about the ways (measure) in which you can minimise, reduce and/or prevent the harmful effects of materials and technologies, and keeping away from dangers and risks.

Activity 3: 'Individual Activity'

Try to provide a sentence to describe the terms mentioned in the vocabulary list.

Baseline Essay

Baseline assignment title:
'How can awareness of biosafety keeps us away from harm?'

Baseline assignment instructions:
Define what is meant by the term 'Biosafety' and explain why it is important.
Give at least three examples of materials and/or technologies that we use and evaluate whether they are biosafe. Give evidence to back up your points.

Baseline assignment success criteria:

The Brilliant Club Mark Scheme Skills	Success Criteria
Knowledge and understanding	Include content that is relevant to the topic and the specific assignment title or question. Include key words from the glossary and demonstrate that you understand them by explaining what they mean and how they relate to the topic.
Research and evidence	Include research findings from a wide range of sources. As well as using the sources provided, you should be discovering some sources yourself from the independent work that you do outside tutorials.
Developing an argument	Give reasons and evidence to back up the points that you make. You might find the PEE structure helpful: • Point – make the key point clear • Evidence – explain the evidence for the point • Explanation – explain why your point is relevant and important Make links to topics you have covered during tutorials as well as some topics that you have not discussed during tutorials.
Critical evaluation	Include evaluation of what is being described and provide clear justification and reasoning. Select relevant research evidence to back up your thinking.Think about the how harmful things around us may compromise our health and impact our wellbeing.
Structure and presentation	Organise your ideas in paragraphs with a logical structure Include an introduction that clearly outlines what the assignment will contain. Include a conclusion that summarises all the key points clearly. Make sure that you have referenced everything correctly
Language and style	Make sure your spelling, grammar and punctuation are accurate. Use a formal style of writing that is appropriate for an academic essay.

Tutorial 2 – The Nanoscale – 'Our Tiny World!'

What is the Purpose of Tutorial 2?

By the end of this tutorial I will be able to…

- Objective 1: Understand the Nanoscale, define nanoparticles and describe their sources, corresponding shapes, and applications.
- Objective 2: Explain why nanoparticles have a high surface area:volume ratio.

Starter:

Investigate size and scale using the metric system (try this!):

1. Arrange the scale cards in a line across the top of your table, from smallest to biggest.
2. Make additional rows of object cards, placing them under the scale card that best fits the measurement of each object.

Materials

- Set of scale cards
- Set of object cards

Nanoparticle definition, sources and applications

The Nanoscale--How Big Is It?

A nanometre (nm) is a billionth (one thousand millionth) of a metre (3i, 2002). For comparison, a single human hair is about 80,000 nm wide, a red blood cell is approximately 7,000 nm wide and a water molecule is almost 0.3 nm across (**Figure 2**). Thus the size of a typical nanomolecule is a hundred-thousandth the width of a human hair. Scientists are interested in the nanoscale (which we define to be from 100 nm down to the size of atoms (approximately 0.2 nm)) because it is at this scale that the properties of materials can be very different from those at a larger scale. Nanoscience is defined as the study of phenomena and manipulation of materials at atomic, molecular and macromolecular scales, where properties differ significantly from those at a larger scale; and nanotechnologies as the design, characterisation, production and application of structures, devices and systems by controlling shape and size at the nanometre scale.

Researchers are building incredibly small, nanoscale devices with vast potential: imagine transistors a thousandth their present size, or nanoprobes inside living cells traveling on truly fantastic voyages. One nanometre (nm) is 10−9 or 0.000,000,001 meter. When two carbon atoms join together to make a molecule the distance between them is in the range of 0.12-0.15 nm.

DNA double helix is about 2 nm from one side to the other. It develops into a new field of DNA nanotechnology. In future DNA can be manipulated that can lead to new revolution. Human genome can be manipulated according to requirements. A nanometre and a meter can be understood as the same size-difference as between golf ball and the Earth.

One nanometre is about one twenty-five-thousandth the diameter of a human hair.
Fingernails grow one nanometre per second.

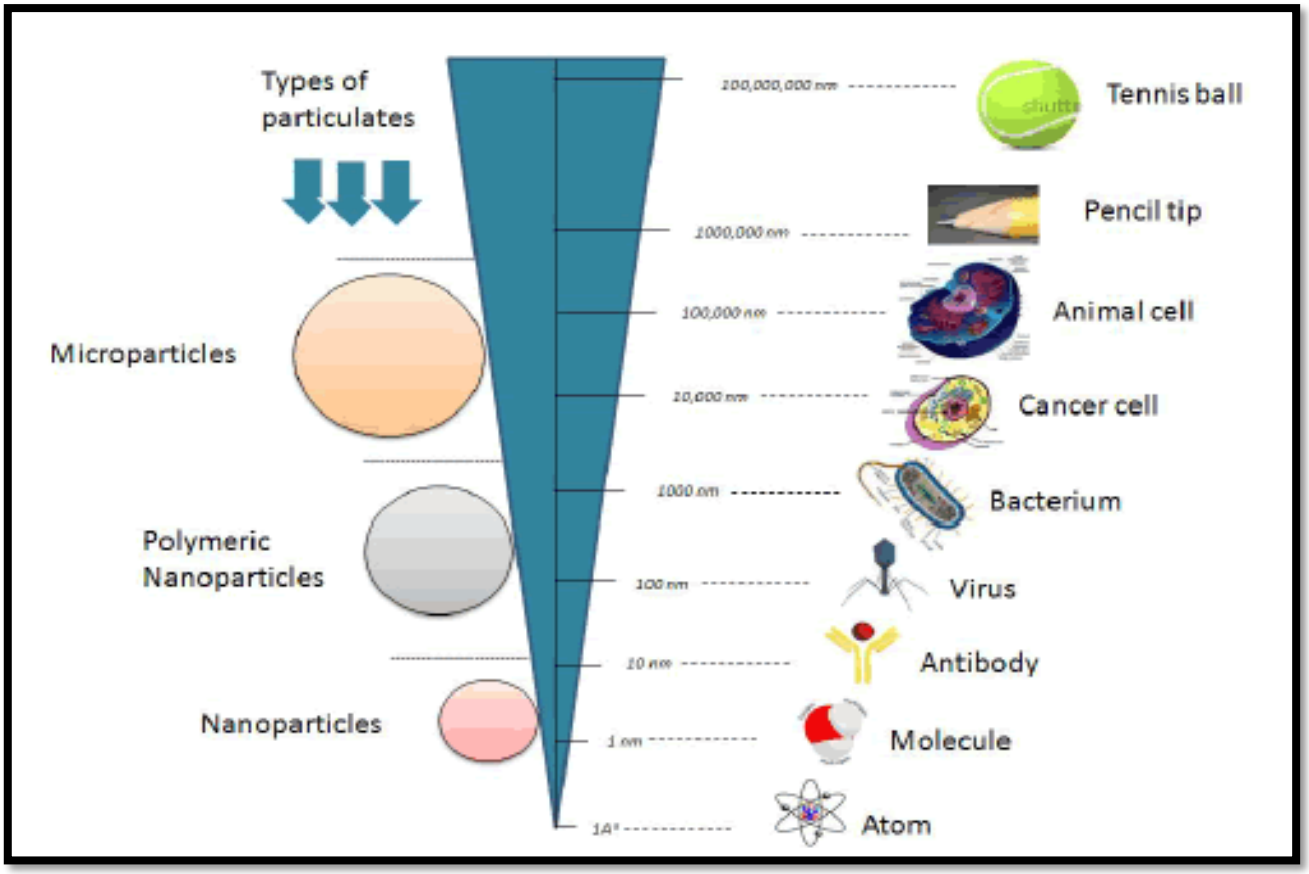


Figure 2: Scale representing the size between particles and main living units. Adapted from: Riasat, G.N., Riasat, Z., Aslam, I., 'Effects of nanoparticles on gastrointestinal disorders and therapy', *J. Clin. Toxicol*. 26 July 2016.

The Nanoscopic Scale

A nanometre is **one millionth** of a millimetre and **one billionth** of a metre.

Unit	Decimal	Standard form
1 cm	0.01 m	1×10^{-2} m
1 mm	0.001 m	1×10^{-3} m
1 µm	0.000,001 m	1×10^{-6} m
1 nm	0.000,000,001 m	1×10^{-9} m

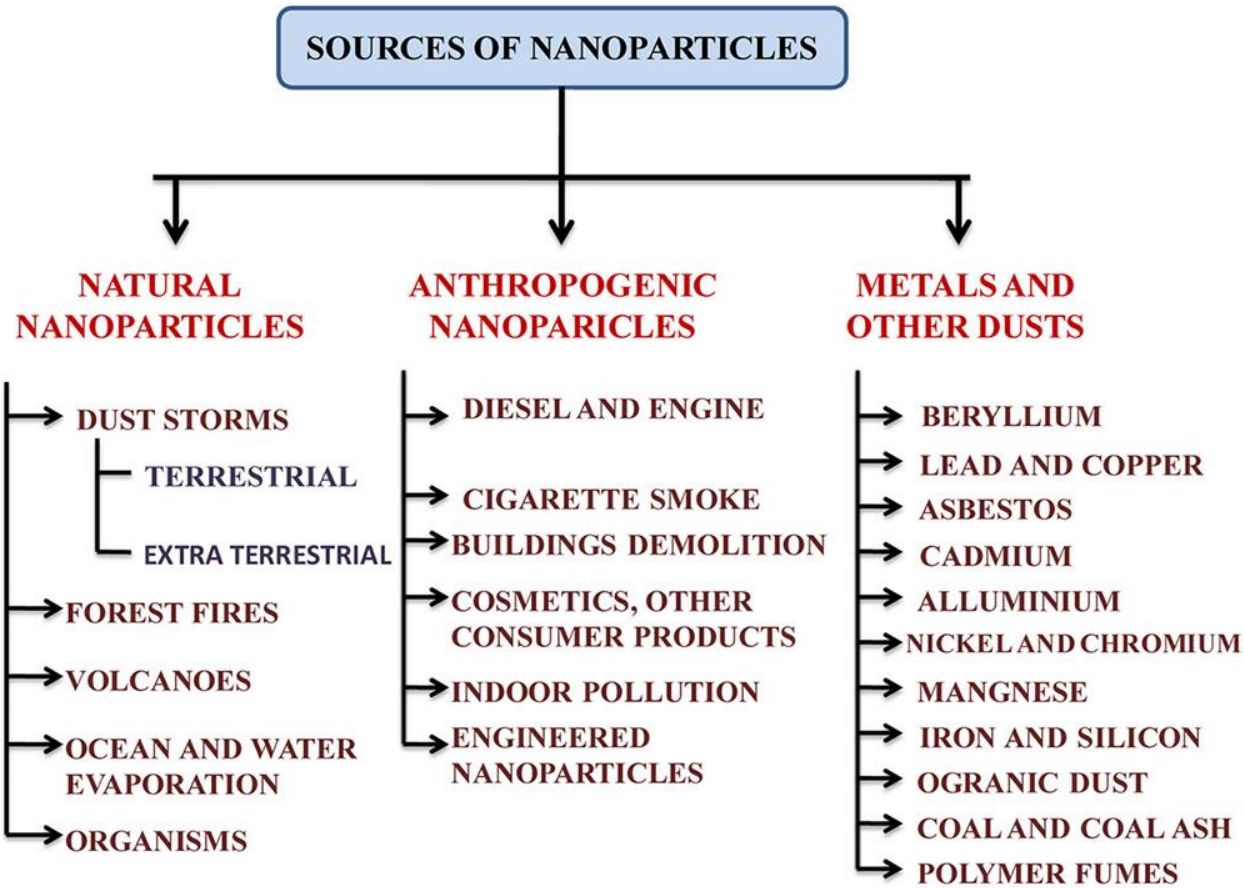


Figure 3A. An outline of the various sources of nanoparticles in the environment. Adapted from: Tripathi, D. K., Tripathi, A., Shweta, Singh, S., Singh, Y., Vishwakarma, K., Yadav G., Sharma S., Singh V. K., Mishra R. K., Upadhyay R. G., Dubey N. K., Lee Y., Chauhan, D. K., 'Uptake, Accumulation and Toxicity of Silver Nanoparticle in Autotrophic Plants, and Heterotrophic Microbes: A Concentric Review', *Frontiers in Microbiology*, 26 January 2017.

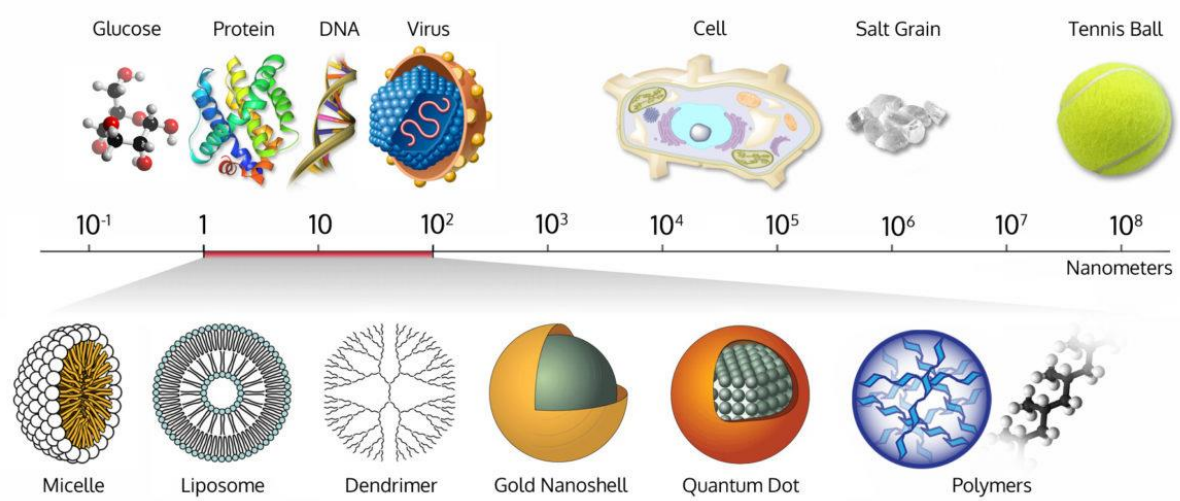


Figure 3B. Size-comparison of nanoparticles to other biomaterials on a nanochart ruler. Adapted from: WichLab. 'Size-comparison of nanoparticles', *https://www.wichlab.com/nanometer-scale-comparison-nanoparticle-size-comparison-nanotechnology-chart-ruler-2/*, 09 September 2019.

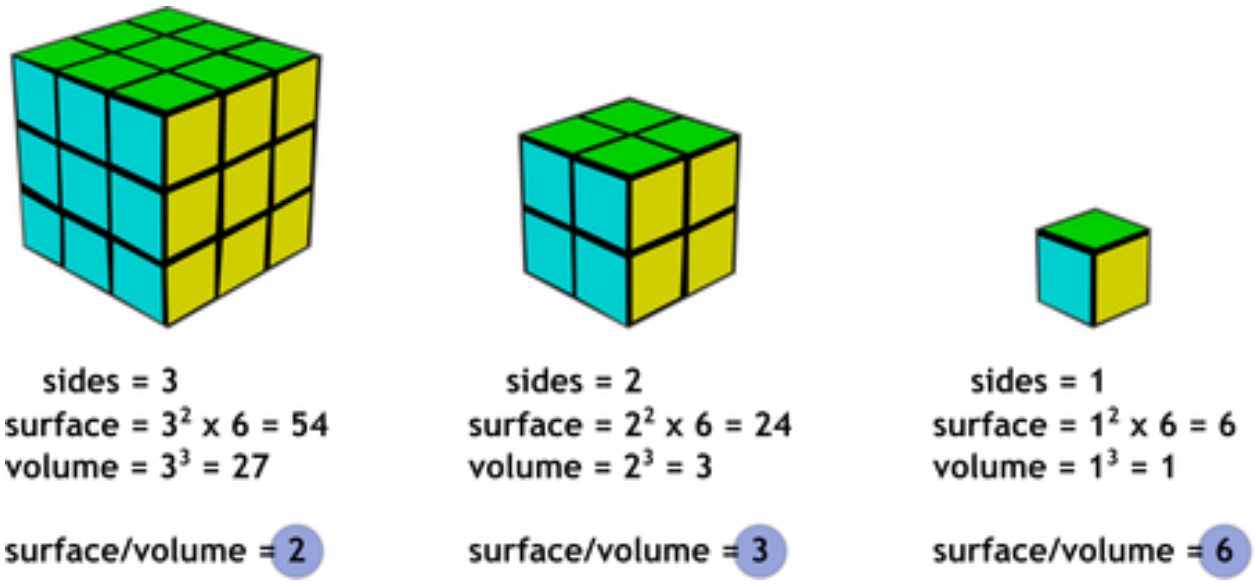
Nanoparticles Surface Area

Nanoparticles have a very large surface area compared with their volume. So they are often able to react very quickly. This makes them useful as catalysts to speed up reactions. For example, they can be used in self-cleaning ovens and windows.

Nanoparticles also have different properties to the same substance in normal-sized pieces. For example, titanium dioxide is a white solid used in house paint and certain sweet-coated chocolates. Titanium dioxide nanoparticles are so small they do not reflect visible light, so cannot be seen. They are used in sunblock creams to block harmful ultraviolet light without appearing white on the skin.

Nanoparticles of a material show different properties compared to larger particles of the same material. Forces of attraction between surfaces can appear to be weak on a larger scale, but on a nanoscale they are strong.

One reason for this is the **surface area to volume ratio**. In nanoparticles this is very large. Atoms on the surface of a material are often more reactive than those in the centre, so a larger surface area means the material is more reactive.



Shape Geometries of Nanoparticles

Consider the different shapes provided to predict the properties of nanomaterials (**Figures 4A and B**). Try to link these shapes to their potential application in e.g. Nanomedicine?
Hint: Imagine the cylindrical shape as being hollow, and the spherical shape being porous! Think about how their shape can fit their purpose in e.g. Being a drug carrier, drug loading and imaging and/or labelling.

As particle size gets smaller, the surface area to volume ratio gets larger. Nanoparticles are almost all surface!

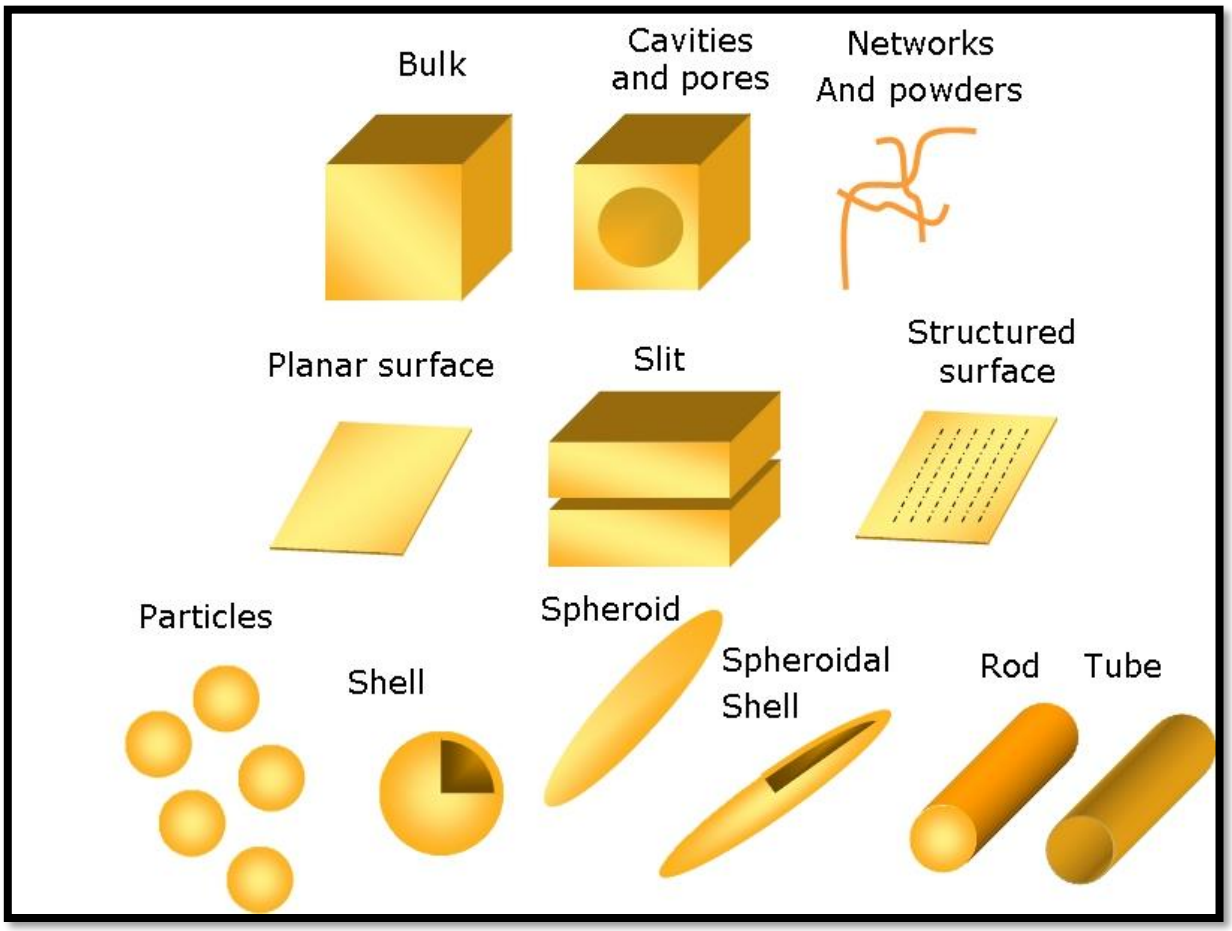


Figure 4A. Nanostructure geometries. Adapted from: Kiddle.co, 'Nanostructure Geometries'. https://kids.kiddle.co/Image:Nanostructure_geometries.jpg. [09 September 2019].

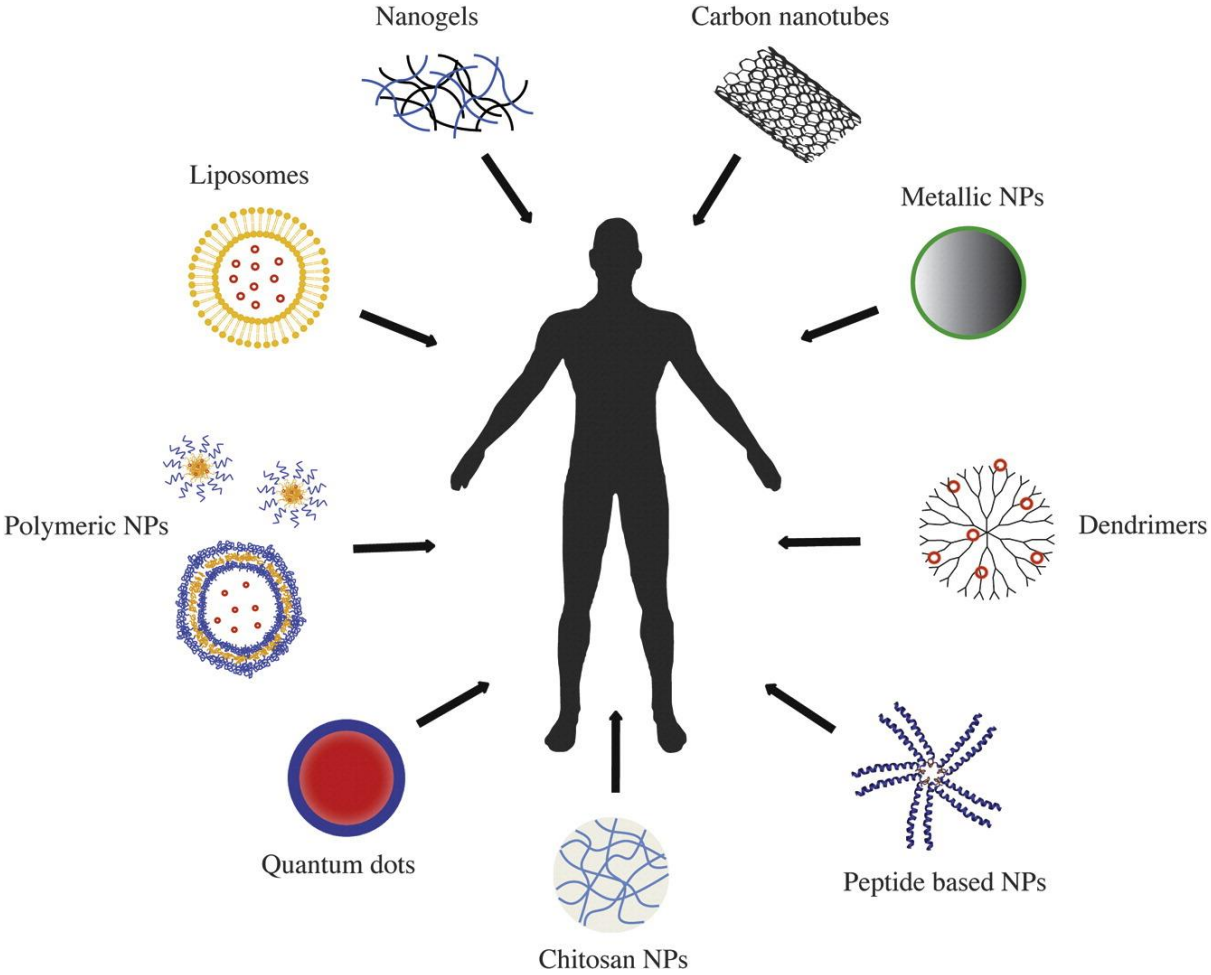
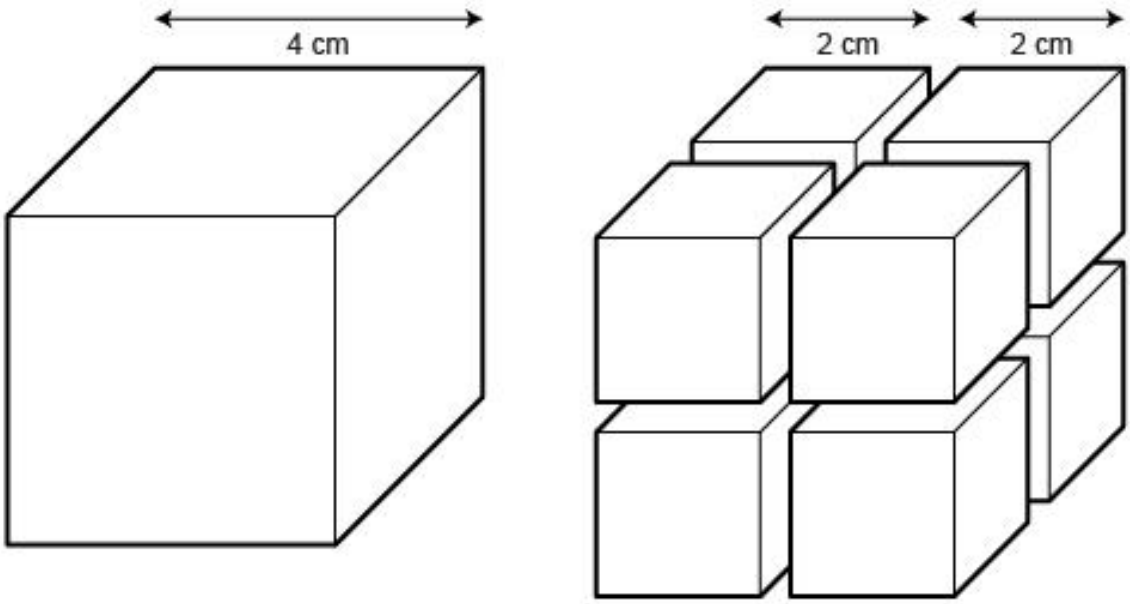


Figure 4B. Schematic picture, presentation nanocarrier platforms (NPs) of various shapes and applications. Adapted from: Lehner, R., Wang, X., Marsch, S., Hunziker, P., 'Intelligent nanomaterials for medicine: carrier platforms and targeting strategies in the context of clinical application', *Nanomedicine: Nanotechnology, Biology and Medicine*, 19 February 2013.

Activity 1: 'Calculation of Surface Area'

Workout the surface area of the objects provided below?

Hint: The cube on the left has the same volume as the smaller cubes added together on the right. However, the total surface area is much larger for the smaller cubes.



Activity 2: 'Working in Groups of 3'

Examine the various shape geometries provided: Think about the properties of each shape and how its geometry allows it to carry out its purpose. Discuss with your fellows and generate a list of possibilities (shape vs. potential application).

Activity 3: 'Working in Pairs'

Relate common NP shapes to their future roles using the sheets provided.

Homework

Homework title:
The Medical Applications of various Nanomaterials

Homework instructions:
Watch a short video on the application of nanomaterials in medicine and write a short reflection (150 words).

Homework success criteria:
The reflection should include the nanoparticle type, its properties and the capacity in which it is applied and/or the potential clinical setting in which it is used.

Tutorial 3 – Physicochemical Properties of Nanomaterials

What is the Purpose of Tutorial 3?

By the end of this tutorial I will be able to…

- Objective 1: Distinguish between the various physical, chemical and biological properties of nanoparticles.
- Objective 2: Learn the types and Applications of Nanomaterials as well as the models which have been used to study the effects of these nanomaterials *ex vivo* and *in vivo*. You will also understand the mode of entry of nanomaterials into living organisms.

Starter:

What have I learned? Reflecting back on Tutorial 2; answer the following questions:

1. What are nanoparticles?

2. Describe some of the uses of nanoparticles?

3. Explain how the properties of nanoparticles are linked to their use?

4. What are the possible problems of nanoparticles?

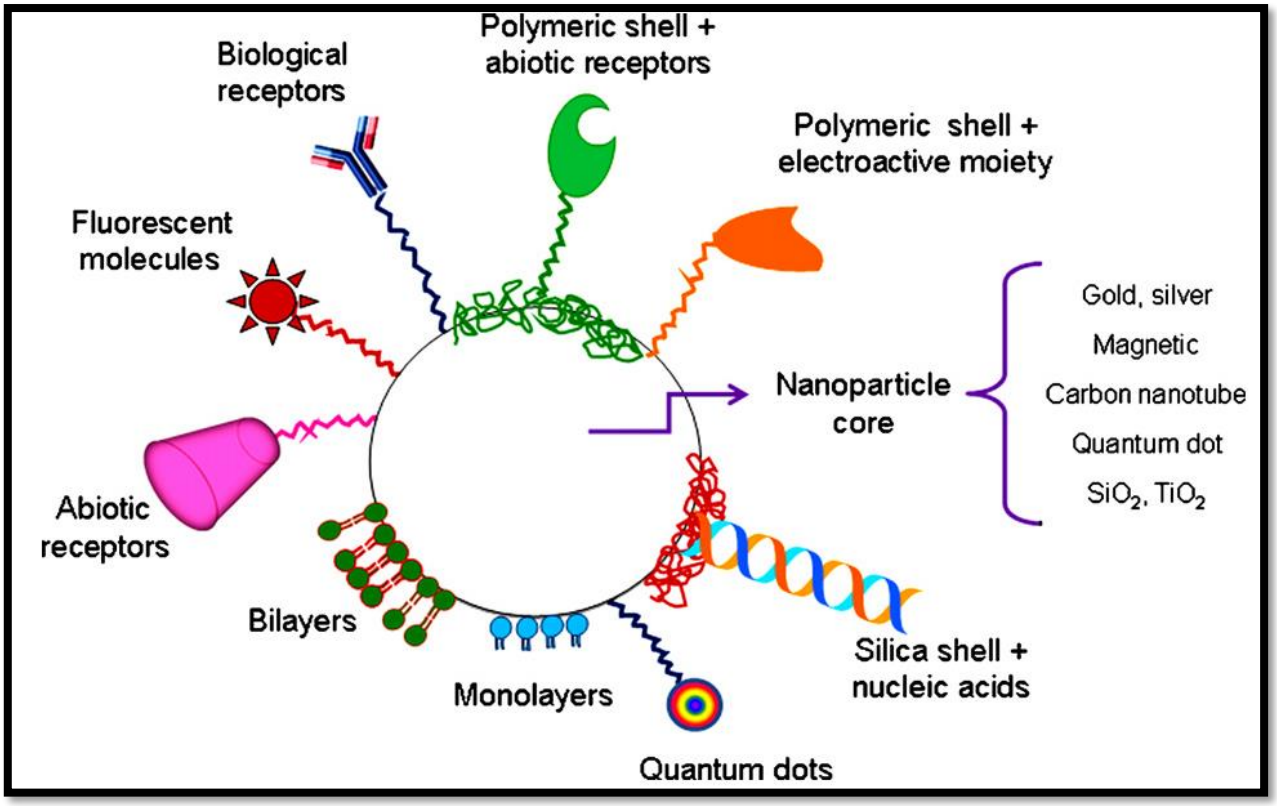


Figure 5. The utility of nanoparticle properties in various applications. Adapted from: Dios, A.S., and Díaz-García, M.E., 'Multifunctional nanoparticles: analytical prospects'. *Analytica chimica acta*, 25 March 2010.

Modes of Nanomaterial Uptake

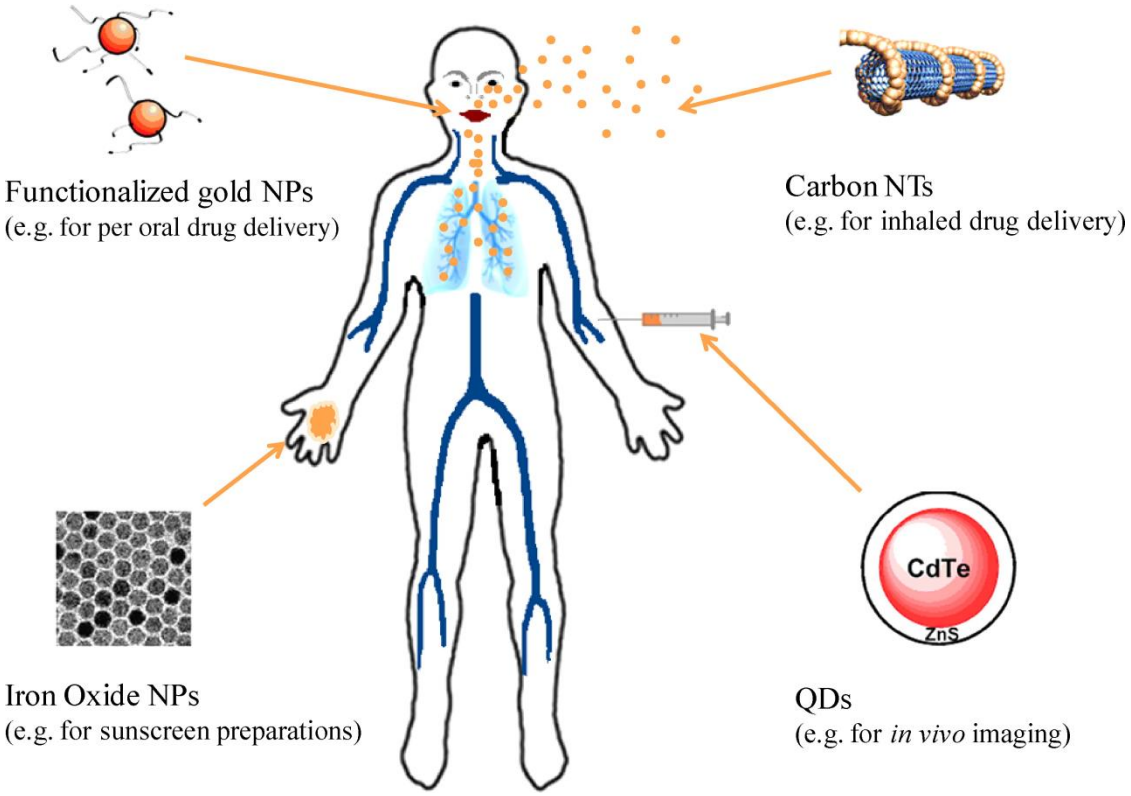


Figure 6. Modes of Nanomaterial entry in the human body. Adapted from: Yildirimer, L., Thanh, N. T., Loizidou, M., Seifalian, A. M., 'Toxicology and clinical potential of nanoparticles', *Nano today*, 30 November 2011.

Activity 1: 'Think, Pair and Share'

Think about the different properties of matter, categorise them and give examples, pair with another individual and share your thoughts.

Activity 2: 'Make Notes'

Make notes as the tutor discusses the various properties of nanoparticles and their relevance to their roles (e.g. imaging and drug loading).

Activity 3: 'Card Sort'

Use a card sort method to distinguish between the physical, chemical and biological properties of nanoparticles using various examples and study models. Also match the properties to the purposes nanoparticles can serve.

Homework

Homework title:
Nanoparticles and their Applications

Homework instructions:
Answer a short quiz about Nanoparticles and their Applications.

Homework success criteria:
Reflect on what you have learned so far, your notes, further reading and tutorial contents to answer the provided quiz.

Tutorial 4 – Synthesis and Applications of Nanomaterials

What is the Purpose of Tutorial 4?

By the end of this tutorial I will be able to…

- Objective 1: Describe the various chemical methods, procedures and techniques used to make (design, fabricate and synthesise) and characterise (analyse their featured shape, topology and 3D morphology) nanoparticles. You we will account for most common ways to make nanomaterials in the laboratory and commercially.
- Objective 2: Identify a list of most commonly employed techniques in nanoparticle fabrication and surface elemental analysis including their corresponding applications.

Starter:

Using your knowledge about the sources of Nanomaterials: How do think nanopartciles are made (discuss in pairs)?

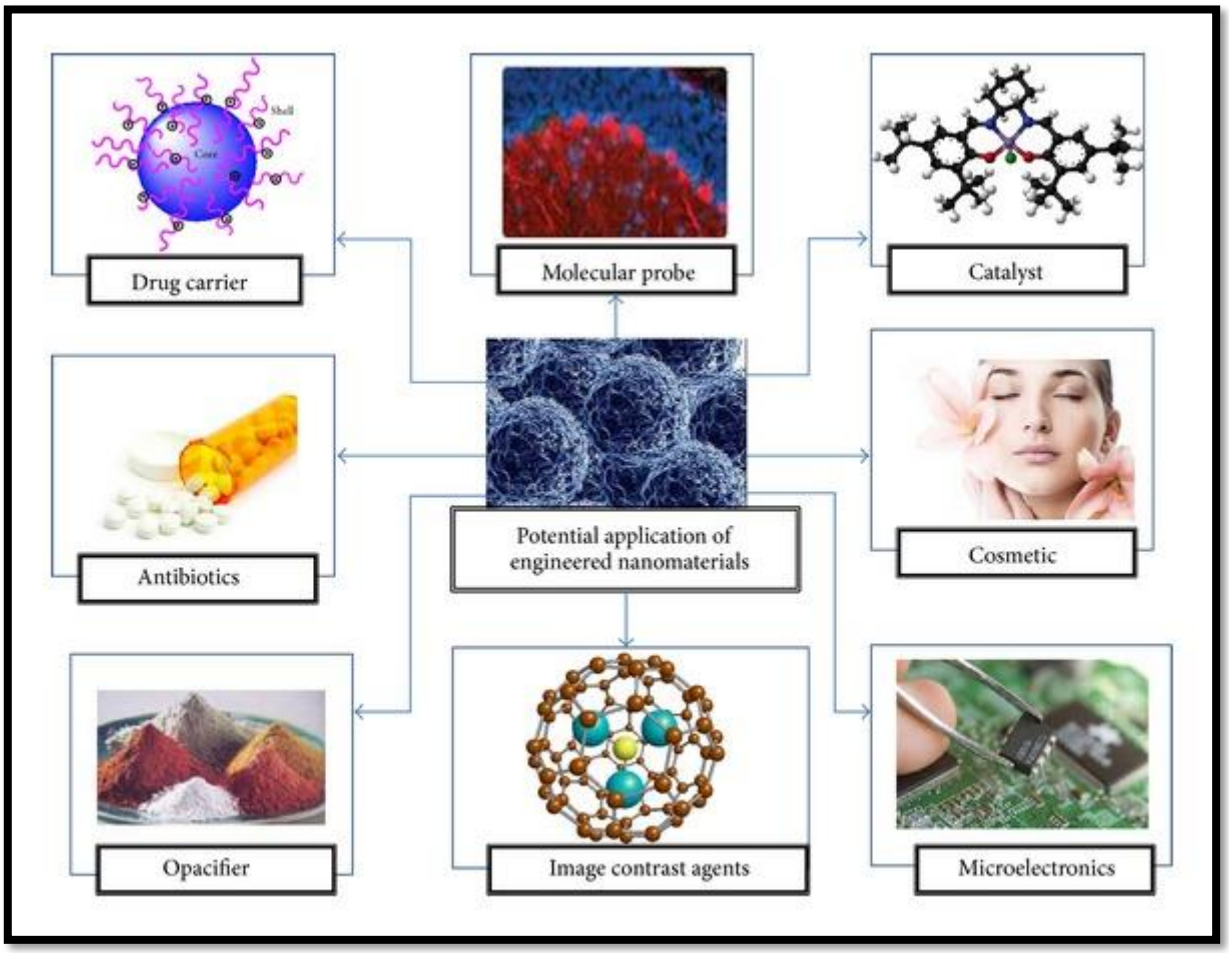


Figure 7. List of Nanomaterials' potential applications. Adapted from: Aslani, F., Bagheri, S., Muhd Julkapli, N., Juraimi, A.S., Hashemi, F.S., Baghdadi, A., 'Effects of engineered nanomaterials on plants growth: an overview'. *The Scientific World Journal*, 14 August 2014.

NPs in Cancer Treatment

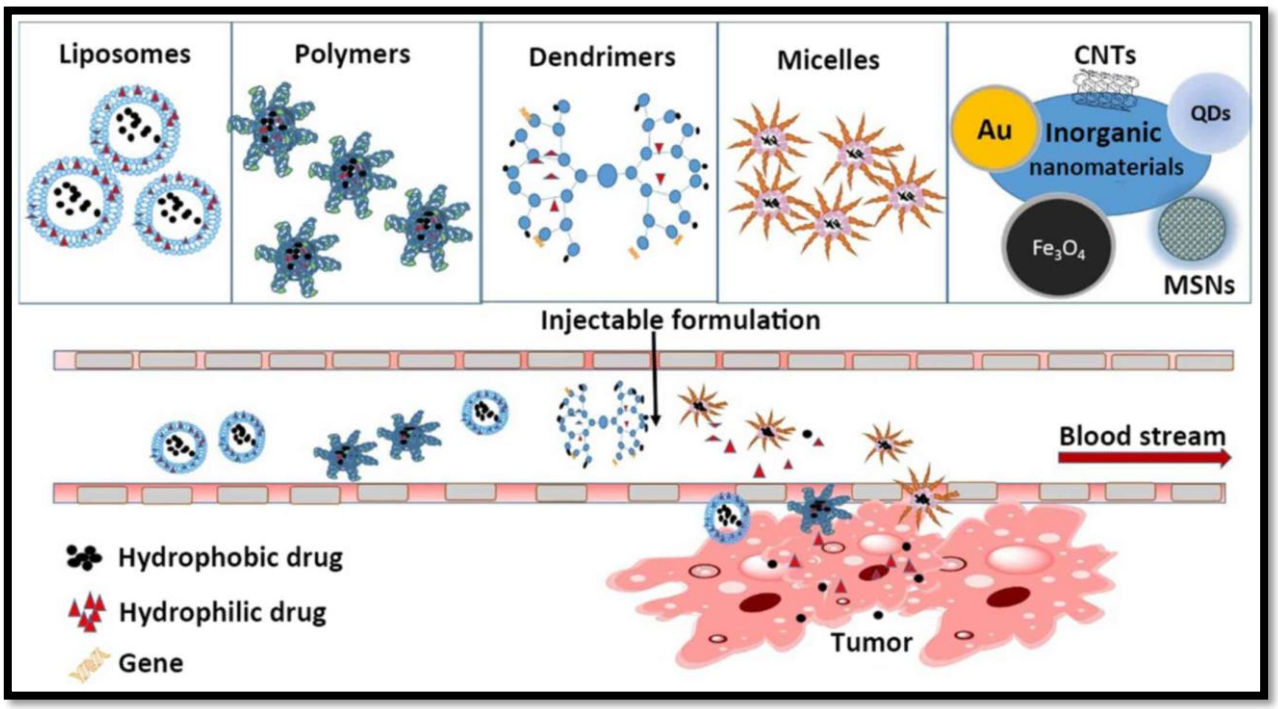


Figure 8. Nanomaterials used as drug carriers for cancer therapy. With their distinct biological characteristics, nanomaterials can improve the enhanced permeability and retention effect, increase bioavailability, reduce the toxicity of chemotherapy drugs, release hydrophobic or hydrophilic chemotherapy drugs into the bloodstream, and achieve cytotoxic effects against cancer cells. CNTs, carbon nanotubes; QDs, quantum dots; MSNs, metal nanoparticles. Adapted from: Li, Z., Tan, S., Li, S., Shen, Q., Wang, K, 'Cancer drug delivery in the nano era: An overview and perspectives (Review)', *Oncology Reports*, 14 June 2017.

Smart NPs for combination therapy of antiangiogenesis and apoptosis

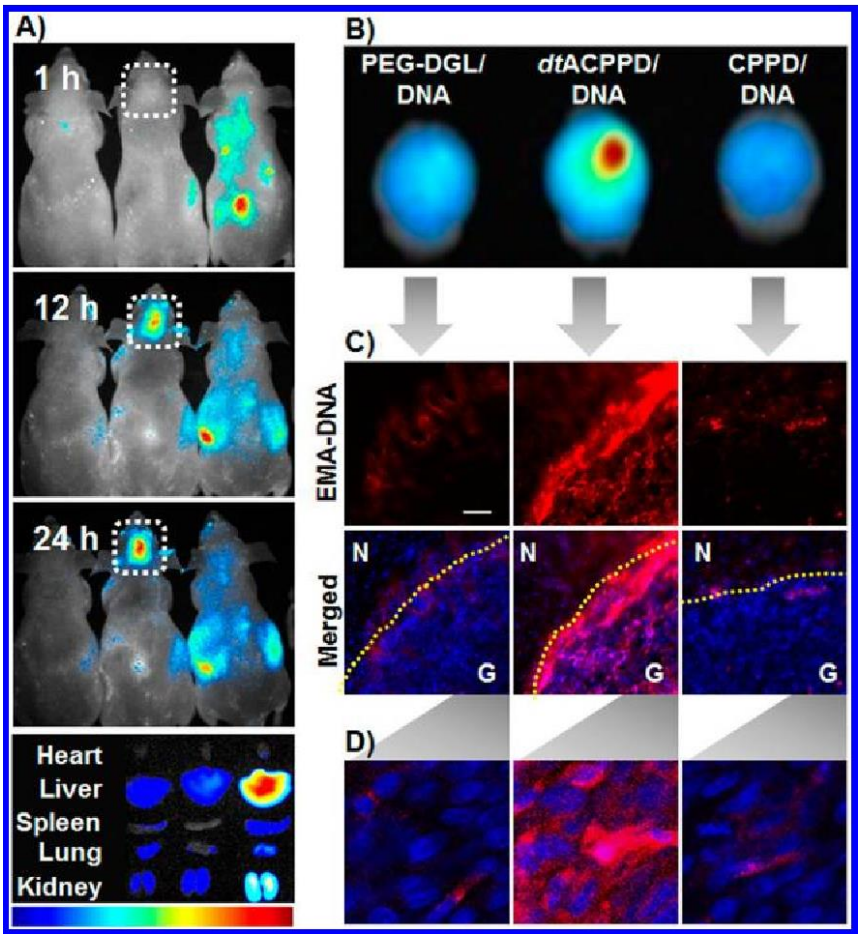


Figure 9. *In vivo* fluorescence imaging showed the distribution and subcellular location of nanoparticles (nonviral vector, dendrigraft poly-L-lysine nanocarrier coupled with RNA and cell-penetrating peptides) in the gliomabearing mice. N = normal brain; G = glioma; yellow dashed line = boundary of the glioma. Adapted from: Huang, S., Shao, K., Liu, Y., Kuang, Y., Li, J., An, S., Guo, Y., Ma, H., Jiang, C., 'Tumor-targeting and microenvironment-responsive smart nanoparticles for combination therapy of antiangiogenesis and apoptosis', *ACS nano*, 01 March 2013.

NPs as Anti-inflammatory Treatment in Vascular Disease

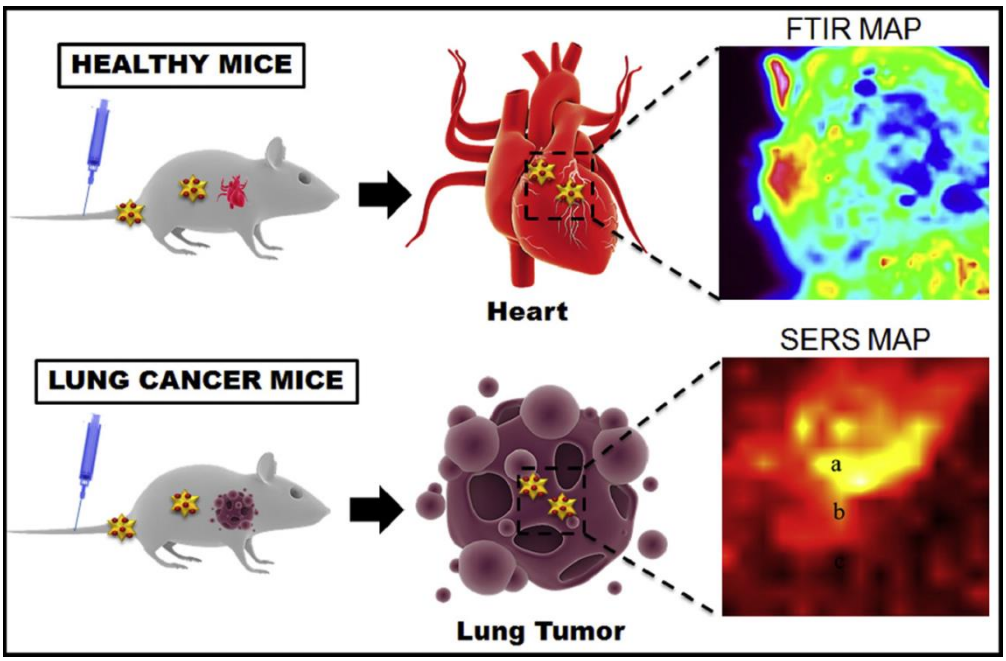


Figure 10. *In vivo* images of mitoxantrone-loaded gold nanostars in a mouse model after intravenous injection. Adapted from: Tian, F., Conde, J., Bao, C., Chen, Y., Curtin, J., Cui, D., 'Gold nanostars for efficient in vitro and in vivo real-time SERS detection and drug delivery via plasmonic-tunable Raman/FTIR imaging', *Biomaterials*, 12 August 2016.

Activity 1: '**Independent Work**'

Watch a series of videos displaying the materials, methods, techniques and instruments (apparatus and equipment) used to observe how NPs are made (reagents. reaction setup, steps and conditions) and characterised. Make notes on sticky notes of the key procedures and materials used. Then share your answers to come up with the most relevant answers.

Activity 2: '**Working in Pairs**'

Work in pairs to match a random list of key techniques, apparatus and equipment to their corresponding uses and applications in nanoparticle synthesis and characterisation (using common examples).

Homework

Homework title:
Write a Summary on Nanobiosafety

Homework instructions:
Summarise (100 words) an article regarding the direct and/or indirect implications of Nanoparticles on our health (Nanobiosafety). Read an article and make notes describing the pros and cons of nanotechnology.

Homework success criteria:
Give examples of the different nanoparticles used, their application, mode of entry into the animal or human body models, and the subsequent effects at the organ, tissue, cellular and molecular levels.

Tutorial 5 – The Advantages versus Disadvantages of Nanotechnology

What is the Purpose of Tutorial 5?

By the end of this tutorial I will be able to…

- Objective 1: Understand the pros and cons to nanotechnology and its applications.
- Objective 2: To have more detailed knowledge regarding the strategies to the safe application and/or administration of nanoparticles.
- Objective 3: To prepare for the essay question by carefully reading and understanding the success criteria.

Starter:

Questioning and reflection: What do you think the significance of each article you have read?

Nanoparticle Distribution into animal tissues:

A) Nanoparticle Distribution into the lung tissues

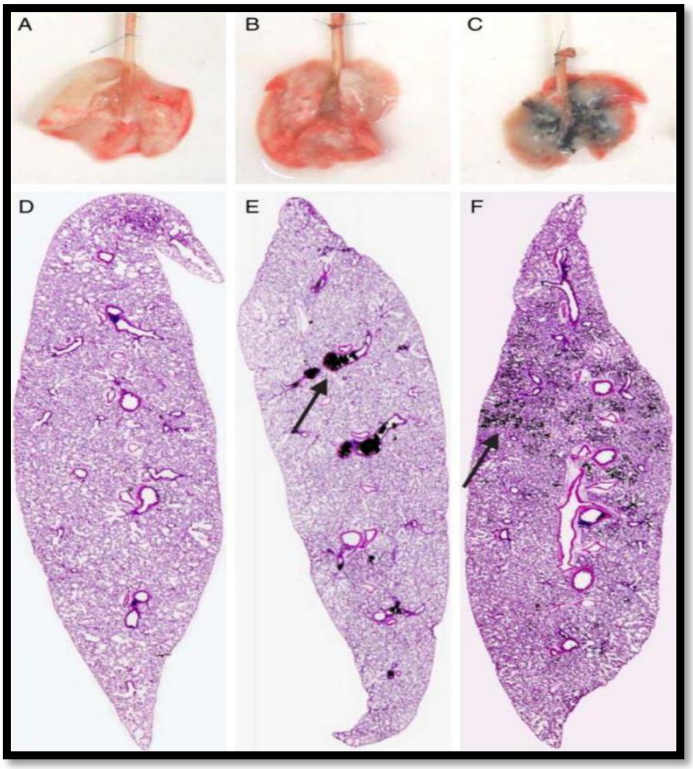


Figure 11. Distribution of carbon nanotubes (CNT) in the lung of rat following the intratrachial administration (A, D are without CNT and B-F are with CNT). Adapted from: Muller, J., Huauxa, F., Moreaub, N., Missona, P., Heiliera, J.F., Delosc M,Arras, M., Fonseca, A., Nagy J. B., Lison, D., 'Respiratory toxicity of multi-wall carbon nanotubes', *Toxicol Appl Pharmacol*, 05 March 2005.

B) Nanoparticle Distribution into the heart tissues

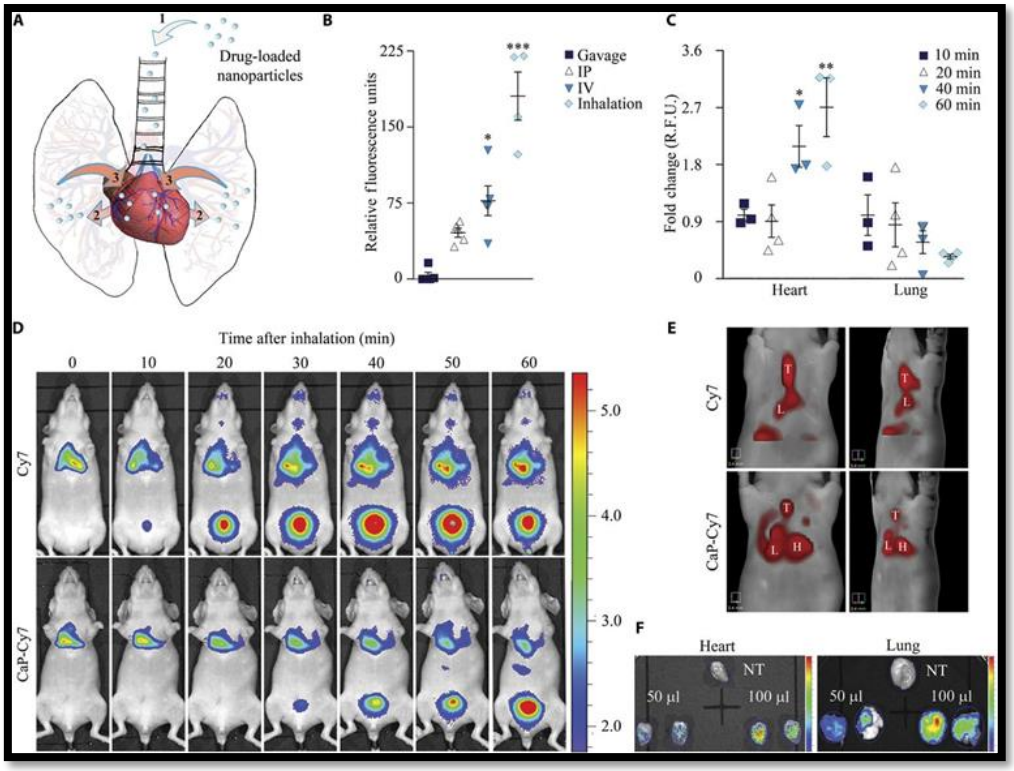


Figure 12. Calcium phosphate nanoparticles (CaPs) targeting of the heart and lungs via the inhalation route into the mouse. Adapted from: Miragoli, M., Ceriotti, P., Iafisco, M., Vacchiano, M., Salvarani, N., Alogna, A., Carullo, P., Ramirez-Rodríguez, G. B, Patrício, T., Esposti, L. D., Rossi, F., Ravanetti, F., Pinelli, S., Alinovi, R., Erreni, M., Rossi, S., Condorelli, G., Post, H., Tampieri, A., Catalucci, D., 'Inhalation of peptide-loaded nanoparticles improves heart failure', *Sci Transl Med*, 17 January 2018.

Assessment of nanoparticle toxicity

Types	Experimental models	Toxic effects
Carbon nanoparticles Gold nanoparticles Silver nanoparticles	• Bacteria, microalgae, crustacean, zebrafish, *Drosophila melanogaster, Caenorhabditis elegans* • Fish, oysters, Pigs, guinea pig, mouse, rat,	• Metabolic activity, membrane activity • Cell viability • Mitochondrial damage • Mitochondrial integrity • Reactive oxygen species production
Quantum dots Fullerenes Aluminum nanoparticles Zinc nanoparticles Iron nanoparticles	• Astrocyte • Breast cancer cells • Human epidermal keratinocyte cells • Hippocampal neuronal cells • Human hepatoma cells • Human hepatocytes • Human lymphocytes • Carcinoma cells • Human bronchial epithelial cells • Messenchymal stem cells • Mouse lung epithelial cells	• Oxidative stress • DNA damage • Apoptosis • Actin filament integrity • Blood brain barrier destruction • Alteration of gene expression
Titanium nanoparticles Silicon nanoparticles	• Liver, spleen, colon mucosa, kidney • Sperms, lung, gill, pulmonary organs • Human skin	

Figure 13. Nanoparticles types, experimental models used for the studies and toxic effects of nanoparticles. Adapted from: Kumar, V., Sharma, N., Maitra, S. S., 'In vitro and in vivo toxicity assessment of nanoparticles', *International Nano Letters*,25 November 2017.

Activity 1: 'Identify'

A) In pairs; analyse **Table 2** and discuss the way in which it is organised?

B) In pairs; describe the pros and/or cons of each nanomaterial used?

Table 2. Effects of some Nanomaterials on different body organs, tissues and/or cells.

Nanomater-ial	Shape	Diameter (size)	Model	Application	Effects (positive and/or negative)	Reference
Carbon Nanotubes	Tubes	20 nm; length of 200 nm	Human cervical cancer cells	Gene Therapy	Nanotube-based gene delivery vector system.	Pantarotto et al., 2004
Silver (AgNPs)	Spherical	10-15 nm	*Chara vulgaris* Algae	Safety on aquatic environment	Green coloured thalli turned yellow due to progressive loss of chlorophyll. Bioengineering strategy to control growth of noxious algal weeds that clog the municipal water supply and water channels and produce fouling of water bodies.	Dash et al., 2012
Silica (Si) NPs	Spherical	98 nm	Rat mesenteric arteries	Imaging diagnostics	Dose-dependent influence of SiNPs on arterial function.	Shukur et al., 2016
Gold (Au) NPs	Spherical	12 nm	Bovine aortic endothelial cells and Rat aortic vessels	Medical therapeutics (drug delivery platforms)	Surface modification-dependent effects on vessel function.	Mohamed et al., 2017
Zinc Oxide (ZnO) NPs	Crystalline	25 nm	Peanut (Arachis hypogaea)	Agriculture	1000 parts/million (ppm) suppress plant disease (promoted seed germination, seedling vigour and early establishment in soil manifested by early flowering and higher leaf chlorophyll content) and enhance crop yield (increased stem and root growth). The inhibitory effect with higher concentration (2000 ppm) reveals the need for judicious usage of these particles in such applications	Prasad et al., 2012
Calcined SnO_2-graphene nanocomposite	Crystalline Layers interspaced by graphene stacks	4-5 mn	Lithium-ion Battery anode insertions	Energy	Increases battery capacity (battery life).	Wand et al., 2010
Ultrafine titanium dioxide	Crystalline	10 and 20 nm	Human bronchial	Intratracheal Administration	Induced oxidative DNA damage, lipid peroxidation, and	Gurr et al. 2005

(TiO_2) particles			epithelial cell line		micronuclei formation, and increased hydrogen peroxide and nitric oxide production in cells, a in a size-dependent manner (≥200 nm did not).	
Crocetin nanocarrier based on poly(lactic-co-glycolic acid) (PLGA) polymer	Spherical	288 nm	Carcinoma cell line	Medical (anti-cancer agents)	Promising applications in breast cancer chemotherapy. Non-PLGA NPs are toxic.	Langroodi et al., 2016

Activity 2: 'Think, Pair and Share'

In groups of two:

A) Identify (what?) the key **application** of the nanoparticles by putting a circle around the word(s) from the articles provided.

B) Highlight and colour-code (which/how?) the advantages (positive effects; the **pros**) versus the disadvantages (concerns, negative implications and log-term effects; the **cons**)

C) Underline a justification (why?) for your highlighted sections in B and give an account to the ways in which the authors have tackled the problems (e.g. through varying dosage, using of different coating materials or/and adapting **biocompatible strategies**).

Activity 3:'Group Activity'

In two groups; Debate in an open-discussion, the protective measures that authors have adopted to minimise the toxicity of nanoparticles, if any and **critically appraise**(think and critique) whether they are sufficient to rectify the biosafety concerns. Include the effects of nanoparticles in each scenario.Present your findings as two groups of 3 each. Each group's member should participate in doing either the identification process in A, the selection process in B and the justification in C. Tabulate and/or sketch your findings as appropriate in an A3 poster sheet provided.
NB: Think about the variation in size, dosage and surface coatings.

Final Essay

Final assignment title:
'Should nanotechnology be utilised to revolutionise the way we detect and treat disease?'

Final assignment instructions:
Write an essay Explaining your views on whether nanotechnology should be banned or used in medical applications and biomedical research? Support with evidence from the literature and available research (evidence-based).

Final assignment success criteria:

The Brilliant Club Mark Scheme Skills	Success Criteria
Knowledge and understanding	Include content that is relevant to the topic and the specific assignment title or question. Include key words from the glossary and demonstrate that you understand them by explaining what they mean and how they relate to the topic. • Discuss the various benefits of NPs in food, clothing, medicine and computing. • Discuss the other side of the coin or cones: e.g. despite their utility, there are biosafery concerns that are associated with the use of NPs.
Research and evidence	Include research findings from a wide range of sources. As well as using the sources provided, you should be discovering some sources yourself from the independent work that you do outside tutorials.
Developing an argument	• Give examples of the negative effects, disadvantages and health concerns related to NPs, analyse and explain why (e.g. due to their ability to internalise and interact with cells and the human body, ultimate fate and long term effects if not proceeded (i.e. ability to bypass body's defence mechanisms) by referring to the lecture martial and the reading list. • What protective measures do you suggest from the current research or your own thoughts could be implemented to minimise their detrimental effects on our health. Give reasons and evidence to back up the points that you make. You might find the PEE structure helpful: • Point – make the key point clear • Evidence – explain the evidence for the point • Explanation – explain why your point is relevant and important Make links to topics you have covered during tutorials as well as some topics that you have not discussed during tutorials.
Critical evaluation	Include evaluation of what is described and provide clear justification, construct detailed arguments and reasoning. In light of advantages vs. disadvantages of NPs, would you use them and why? Select relevant research evidence to back up your thinking.
Structure and presentation	Organise your ideas in paragraphs with a logical structure Include an introduction that clearly outlines what the assignment will contain. Include a conclusion that summarises all the key points clearly. Make sure that you have referenced everything correctly
Language and style	Make sure your spelling, grammar and punctuation are accurate. Use a formal style of writing that is appropriate for an academic essay.

Tutorial 6 – Feedback tutorial

What is the Purpose of Tutorial 6?

- To receive feedback on your final assignment
- To respond to the feedback from your Uni Pathways teacher
- To write targets for improvement on your final assignment

Final assignment feedback from your Uni Pathways Teacher

(Remember to look at the mark scheme to help you understand what you have done well so far, and how you can do even better in your final assignment)

Here are three things that my Uni Pathways Teacher thought I did well in my draft assignment
•   •   •

Here are three things that my Uni Pathways Teacher thinks that I could do to get a higher mark in my final assignment
•   •   •

Tasks from my Uni Pathways Teacher to do during the feedback tutorial to help me improve
•   •   •
My response:

Actions I will take to improve my final assignment after this tutorial…
•   •   •

Hand in date for my final assignment:	

Tutorial 7 – Final tutorial

What is the Purpose of Tutorial 7?

- To receive feedback and a grade on your final assignment.
- To reflect on the programme including what you enjoyed and what was challenging.
- To ask any questions you may have about university.

Final assignment feedback from my Uni Pathways Teacher

Final mark:	University style grade:
Feedback: Here are three things that my Uni Pathways teacher thought I did well in my final assignment • • •	

Here are three things that my Uni Pathways teacher thinks I should remember for when I am doing this kind of study in the future
• • •

University

What questions do you still have about University after taking part in Uni Pathways?
•   •   •

Reflecting on Uni Pathways

What did you most enjoy about Uni Pathways?
•   •   •

What did you find challenging about the programme?	How did you overcome these challenges?
• • •	• • •

References

Blut, A., Untergruppe «Bewertung Blutassoziierter Krankheitserreger», 'Influenza Virus', *Transfus Med Hemother*, offizielles Organ der Deutschen Gesellschaft fur Transfusionsmedizin und Immunhamatologie, February 2009.

Cardis E., Armstrong, B.K., Bowman, J.D., Giles, G.G., Hours M., Krewski D., McBride, M., Parent, M.E., Sadetzki, S., Woodward, A., Brown, J., Chetrit, A., Figuerola, J., Hoffmann, C., Jarus-Hakak, A., Montestruq, L., Nadon, L., Richardson, L., Villegas, R., Vrijheid, M., 'Risk of brain tumours in relation to estimated RF dose from mobile phones: results from five Interphone countries', *Occup Environ Med*. 09 June 2011.

Dash, A., Singh, A.P., Chaudhary, B.R., Singh, S.K., Dash, D., 'Effect of silver nanoparticles on growth of eukaryotic green algae', *Nano Micro Lett*, 25 September 2012.

Dixit, A., Vaney, N., Tandon, O.P., 'Effect of caffeine on central auditory pathways: An evoked potential study', *Hearing Research*, 17 August 2006.

Langroodi, F.A., Hafezi Ghahestani, Z., Alibolandi, M., Ebrahimian, M., Hashemi, M., 'Evaluation of the effect of crocetin on antitumor activity of doxorubicin encapsulated in PLGA nanoparticles', *Nanomedicine Journal*, 21 June 2016.

Fisone, G., Borgkvist, A., Usiello, A., 'Caffeine as a psychomotor stimulant: mechanism of action', *Cell Mol. Life Sci.*, April 2004.

Fredholm, B.B., Battig, K., Holmen, J., Nehlig, A., Zvartau, E., 'Actions of caffeine in the brain with special reference to factors that contribute to its widespread use', *Pharmacol. Rev.*, 01 March 1999.

Gurr, J.-R., Wang, A. S. S., Chen, C.-H. and Jan, K.-Y, 'Ultrafine titanium dioxide particles in the absence of photoactivation can induce oxidative damage to human bronchial epithelial cells', *Toxicology*, 15 September 2005.

Hohmann, E.L., 'Nontyphoidal salmonella: Gastrointestinal infection and carriage', http://www.uptodate.com/home [21 November 2016].

Mohamed, T., Matou-Nasri, S., Farooq, A., Whitehead, D., Azzawi, M., 'Polyvinylpyrrolidone-coated gold nanoparticles inhibit endothelial cell viability, proliferation, and ERK1/2 phosphorylation and reduce the magnitude of endothelial-independent dilator responses in isolated aortic vessels', *Int J Nanomedicine*, 13 December 2017.

National Health Service (NHS), 'Lactose intolerance', https://www.nhs.uk/conditions/lactose-intolerance/ [25 February 2019].

Pantarotto, D., Singh, R., McCarthy, D., Erhardt, M., Briand, J. P., Prato, M., Kostarelos, K., Bianco, A., 'Functionalized carbon nanotubes for plasmid DNA gene delivery', *Angew. Chem. Int. Ed.*, 29 September 2004.

Prasad, T. N. V. K. V., Sudhakar, P., Sreenivasulu, Y., Latha, P., Munaswamy, V. , Reddy, K. Raja, Sreeprasad, T. S., Sajanlal, P. R., Pradeep, T., 'Effect of nanoscale zinc oxide particles on the germination, growth and yield of peanut', *J Plant Nutr*, 03 April 2012.

Shukur, A., Rizvi, S. B., Whitehead, D., Seifalian, A., Azzawi, M., 'Altered sensitivity to nitric oxide donors, induced by intravascular infusion of quantum dots, in murine mesenteric arteries', *Nanomedicine*, May 2013.

Shukur, A., Whitehead, D., Seifalian, A., Azzawi, M., 'The influence of silica nanoparticles on small mesenteric arterial function', *Nanomedicine (Lond)*, 02 August 2016.

Wang, D., Kou, R., Choi, D., Yang, Z., Nie, Z., Li, J., Saraf, L. V., Hu, D., Zhang, J., Graff, G. L., Liu, J., Pope, M. A., Aksay, I. A., 'Ternary Self-Assembly of Ordered Metal Oxide−Graphene Nanocomposites for Electrochemical Energy Storage', *ACS Nano*, 25 February 2010.

Westerterp-Plantenga, M., Diepvens, K., Joosen, A. M.C.P., Bérubé-Parent, S., Tremblay, A, 'Metabolic effects of spices, teas, and caffeine', *Physiol Behav.*, 30 August 2006.

Zou, J. and Li, N., 'Simple and environmental friendly procedure for the gas chromatographic-mass spectrometric determination of caffeine in beverages', *J Chromatogr A*, 08 December 2006.

Reading List

Ali, A., Zafar, H., Zia, M., Ul Haq, I., Phull, A. R., Ali, J. S., Hussain, A., 'Synthesis, characterization, applications, and challenges of iron oxide nanoparticles', *Nanotechnology, science and applications*, 19 August 2016.

Auffan, M., Rose, J., Bottero, J.-Y., Lowry, G.V., Jolivet, J.-P., Wiesner, M.R., 'Towards a definition of inorganic nanoparticles from an environmental, health and safety perspective', *Nature Nanotechnology*, 13 September 2009.

Bejarano, J., Navarro-Marquez, M., Morales-Zavala, F., Morales, J.O., Garcia-Carvajal, I., Araya-Fuentes, E., Flores, Y., Verdejo, H.E., Castro, P.F., Lavandero, S., Kogan, M.J., 'Nanoparticles for diagnosis and therapy of atherosclerosis and myocardial infarction: evolution toward prospective theranostic approaches', *Theranostics*, 09 September 2018.

Handy, R. D. and Shaw, B. J., 'Toxic effects of nanoparticles and nanomaterials: Implications for public health, risk assessment and the public perception of nanotechnology', *Health, Risk & Society*, 20 June 2007.

Li, Z., Tan, S., Li, S., Shen, Q., Wang, K, 'Cancer drug delivery in the nano era: An overview and perspectives (Review)', *Oncology Reports*, 14 June 2017.

Madani, Seyed Y., Mandel, A., Seifalian, A. M., 'A concise review of carbon nanotube's toxicology', *Nano Reviews*, 03 December 2013.

Miragoli, M., Ceriotti, P., Iafisco, M., Vacchiano, M., Salvarani, N., Alogna, A., Carullo, P., Ramirez-Rodríguez, G. B, Patrício, T., Esposti, L. D., Rossi, F., Ravanetti, F., Pinelli, S., Alinovi, R., Erreni, M., Rossi, S., Condorelli, G., Post, H., Tampieri, A., Catalucci, D., 'Inhalation of peptide-loaded nanoparticles improves heart failure', *Sci Transl Med*, 17 January 2018.

Servin, A., Elmer W., Mukherjee, A., De la Torre-Roche, R., Hamdi, H., White, J. C., Bindraban, P., Dimkpa, C., 'A review of the use of engineered nanomaterials to suppress plant disease and enhance crop yield', *J Nanopart Res*, 13 February 2015.

Appendix 1 – Referencing correctly

When you get to university, you will need to include references in the assignments that you write, so we would like you to start getting into the habit of referencing in your Brilliant Club assignment. This is really important, because it will help you to avoid plagiarism. Plagiarism is when you take someone else's work or ideas and pass them off as your own. Whether plagiarism is deliberate or accidental, the consequences can be severe. In order to avoid losing marks in your final assignment, or even failing, you must be careful to reference your sources correctly.

What is a reference?

A reference is just a note in your assignment which says if you have referred to or been influenced by another source such as book, website or article. For example, if you use the internet to research a particular subject, and you want to include a specific piece of information from this website, you will need to reference it.

Why should I reference?

Referencing is important in your work for the following reasons:

- It gives credit to the authors of any sources you have referred to or been influenced by.
- It supports the arguments you make in your assignments.
- It demonstrates the variety of sources you have used.
- It helps to prevent you losing marks, or failing, due to plagiarism.

When should I use a reference?

You should use a reference when you:

- Quote directly from another source.
- Summarise or rephrase another piece of work.
- Include a specific statistic or fact from a source.

How do I reference?

There are a number of different ways of referencing, and these often vary depending on what subject you are studying. The most important to thing is to be consistent. This means that you need to stick to the same system throughout your whole assignment. Here is a basic system of referencing that you can use, which consists of the following two parts:

1. **A marker in your assignment**: After you have used a reference in your assignment (you have read something and included it in your work as a quote, or re-written it your own words) you should mark this is in your text with a number, e.g. [1]. The next time you use a reference you should use the next number, e.g. [2].
2. **Bibliography**: This is just a list of the references you have used in your assignment. In the bibliography, you list your references by the numbers you have used, and include as much information as you have about the reference. The list below gives what should be included for different sources.

    a. **Websites** – Author (if possible), title of the web page, website address, [date you accessed it, in square brackets].

    E.g. Dan Snow, 'How did so many soldiers survive the trenches?', http://www.bbc.co.uk/guides/z3kgjxs#zg2dtfr [11 July 2014].

    b. **Books** – Author, date published, title of book (in italics), pages where the information came from.

    E.g. S. Dubner and S. Levitt, (2006) *Freakonomics*, 7-9.

    c. **Articles** – Author, 'title of the article' (with quotation marks), *where the article comes from* (newspaper, journal etc.), date of the article.

    E.g. Maev Kennedy, 'The lights to go out across the UK to mark First World War's centenary', Guardian, 10 July 2014.

Notes

Notes

Notes

UNI PATHWAYS

UNI PATHWAYS

researchersinschools.org