**Areas of study: 1.1 Classification of drugs, 1.2 Properties of drugs, 1.3 Actions of drugs and 1.4 Drug delivery**

**Lessons**

| **Lesson number** | **Specification coverage** | **GLH** | **Lesson aims and outcomes** | **Lesson ideas, key words and activities** | **Useful resources** | **Student independent learning – ideas and useful resources** |
| --- | --- | --- | --- | --- | --- | --- |
| **1** | **1.1 Classification of drugs:*** **stimulants**
* **depressants**
 | **1** | By the end of the lesson students should:* know the purpose of each type of pharmaceutical drug
* understand the structure, mechanism of action and therapeutic use of each category of drug.
 | **Example 1 ideas/activities**Assess students' prior understanding of drugs. Using mini whiteboards, ask students to define a ‘**drug**’ and describe the **physiological** effects they think a **stimulant** and a **depressant** would have.Discuss the descriptions given by students to arrive at a definition of each category in terms of broad physiological effect, e.g. stimulants increase heart and respiration rates and blood pressure.Discussion/teacher led section describing the general purpose, broad mechanism of action (not a detailed chemical mechanism) and overall **therapeutic** uses of each category of drug. Suggested examples that could be used for each category are:Stimulants: amphetamines, methylphenidate Depressants: benzodiazepines, alcohol(It should be noted that **opioids** and **cannabinoids** would also fall into this category but they will be focused on in the next lesson).Students summarise the information for each drug category in a table or mind map.Flipped learning task: research the potential for abuse of stimulants and depressants. For each category find out the drugs which are most commonly abused and the physiological (and pathological) effects of abuse. | [Pharmacology Education Project:](https://pharmacologyeducation.org/pharmacology) The educational website of the International Union of Basic and Clinical Pharmacology. It provides a comprehensive overview of the fundamental aspects of pharmacology. This is a useful resource to inform the teacher led section.[Basic Pharmacology](https://open.lib.umn.edu/pharmacology/chapter/introduction-to-pharmacology/)A free online textbook covering the basic principles of pharmacology including mechanisms of actions and pharmacodynamics. Useful for clarification of key terms throughout the topic area. | [Alcohol and Drug Foundation](https://adf.org.au/drug-facts/#list)The ‘Drug Wheel’ from the Alcohol and Drug Foundation provides information on abuse and addiction, organised into each of the main categories of drugs. This resource is a good starting point for students to use for the flipped learning task. |
| **2** | **1.1 Classification of drugs:*** **cannabinoids**
* **opioids**
* **hallucinogens**
 | **1.5** | By the end of the lesson students should:* know the purpose of each type of pharmaceutical drug
* understand the structure, mechanism of action and therapeutic use of each category of drug
 | **Example 1 ideas/activities**Flipped learning: students present their findings from the flipped learning task in previous lesson focusing on abuse of stimulants and depressants.Discussion/teacher led section introducing **cannabinoids** and **opioids** as drugs which could also be categorised as depressants. Describe the general purpose, broad mechanism of action (not a detailed chemical mechanism) and overall therapeutic uses of each category of drug (emphasising that therapeutic use of cannabis is experimental).Suggested examples that could be used for each category are:Cannabinoids: tetrahydrocannabinol (THC), cannabidiol (CBD) Opioids: codeine, diamorphine/heroin, methadone (as an example of an opioid whose function is treatment of addiction rather than pain relief)Students summarise the information for each drug category in a table or mind map.**Example 2 ideas/activities**Students carry out research to identify the major **hallucinogens** (LSD, psilocybin, MDMA) and describe:physiological effectsrisk/effects of abusebroad mechanism of actionDiscuss the potential therapeutic uses of hallucinogens (focusing on the use of psilocybin in the treatment of PTSD, anxiety and end-of-life care).Give students a short quiz to assess their understanding of each of the categories of drugs.**Example 3 ideas/activities**Divide students into groups and provide groups with a set of drug name cards with a brief description of the action of the drug on each cardAsk them to sort the drugs into the appropriate categories (simulants, depressants, hallucinogens, cannabinoids, opioids) based on their descriptions.Reconvene as a class and review each group’s classification. For each drug, discuss why it fits into a specific category and address any disputes or uncertainties.Highlight any drugs that could belong to multiple categories e.g. marijuana has properties of cannabinoids and depressants | [Pharmacology Quizzes](https://pharmafactz.com/pharmacology-quizzes/)The Pharmafactz website has a number of multiple choice quizzes which can be used as a resource bank to construct a short quiz to assess students’ understanding. | [Drug Wheel - Psychadelics](https://adf.org.au/drug-facts/psychedelics/#list)The resource can be used by students for the independent research into hallucinogens/psychedelic drugs. |
| **3** | **1.2 Properties of drugs:** **General properties of drugs*** **pharmacodynamics**
* **pharmacokinetics**
 | **1** | By the end of the lesson students should:* understand how pharmacodynamic and pharmacokinetic parameters influence the development of a new drug
 | **Example 1 ideas/activities**Using mini whiteboards ask students what factors they think are important when developing a new drug. Students could be prompted to consider effect, side effects, how long the drug is in the bodyCollate student responses to create a list of properties which need to be considered in drug developmentDiscussion/teacher led section defining the ‘journey’ of a drug through the stages of **pharmacokinetics** * **absorption**
* **distribution**
* **metabolism**
* **excretion**

This may be best explained using a specific, familiar drug, for example ibuprofen, and describing the absorption from the GI tract, distribution to tissues, metabolism by the liver and excretion by the kidneys. The factors that affect each stage should be listed.Students construct a flow chart illustrating the path of a drug through each of the four pharmacokinetic stages.**Example 2 ideas/activities**Show video to recap the pharmacokinetic parameters and introduce **pharmacodynamics**[Pharmacokinetics versus Pharmacodynamics Explained](https://www.youtube.com/watch?v=XlEGpphUtZk)Discuss the difference between pharmacokinetics and pharmacodynamics. Steer students towards the understanding the pharmacokinetics is how the body affects the drug and pharmacodynamics is how the drug affects the body.Students to independently research explanations for the following terms:* **dose-response curve**
* **efficacy**
* **site of action.**

Give students a short quiz to assess their understanding of the key terms in pharmacokinetics and pharmacodynamics. | [Teach Chemistry](https://edu.rsc.org/resources/challenging-medicines-physiochemical-properties/926.article)The Teach Chemistry website from the Royal Society of Chemistry has extensive resources covering pharmacokinetic and pharmacodynamic principles which can be used to inform the teacher led section (note a free Teach Chemistry account is needed for access) | [Pharmacodynamics Basics](https://denalirx.com/pharmacodynamics/)This resource can be used by the students for independent research into pharmacodynamic parameters.This website also has quizzes which can be used to construct a short quiz to assess students’ understanding of pharmacokinetic and pharmacodynamic parameters |
| **4** | **1.2 Properties of drugs:****General properties of drugs*** **toxicity and adverse reactions**
* **drug-drug interactions**
 | **1** | By the end of the lesson students should:* understand how toxic and adverse events and drug-drug interactions influence the development of a new drug
 | **Example 1 ideas/activities**Ask students what they understand by the term ‘**toxicity**’ and what they would expect this to look like as a physiological response to a drug. Collate student responses and discuss the differences between toxicity and an **adverse reaction,** for example an adverse reaction may be a rash whereas toxicity may cause permanent organ damage. Students should understand that although they are both pathological responses, adverse reactions can be mild.Use examples to demonstrate the different ways that patients can be harmed through drug action:* **toxic dose** (include an explanation of therapeutic window), a suggested example of a drug with a narrow therapeutic window is warfarin
* adverse reactions, for example gastro-intestinal irritation and bleeding with regular aspirin use
* **drug-drug interactions** (define this as the action of one drug being affected by the presence of another drug), for example some antibiotics (bactrim) and warfarin causing significant bleeding.

**Example 2 ideas/activities**Independent task: Students can use the Pharmacology Education Project website to write notes on:* categories of types of adverse reaction
* diagnosis and management of adverse reactions
* how to avoid adverse reactions
* drug allergy
 | [Adverse drug reactions](https://www.msdmanuals.com/home/drugs/adverse-drug-reactions/types-of-adverse-drug-reactions)[Drug Interactions](https://www.goodrx.com/drugs/safety/drug-interactions)The resources both provide information on types of toxic and adverse reactions and also drug-drug interactions. They can be used to inform the discussion or to use alternative examples for the ways that the patient may be harmed through drug action. | [Types of adverse reactions](https://www.pharmacologyeducation.org/clinical-pharmacology/adverse-drug-reactions)The Pharmacology Education Project website can be used by students for the independent research task. |
| **5** | **1.3 Actions of drugs:** **Mechanism of action of drugs*** **receptor activation**
* **agonists and antagonists**
* **enzyme inhibition**
 | **1.5** | By the end of the lesson students should:* understand the general steps in the mechanism of action of drugs
* know examples of drugs from each category of mechanism of action
* understand the advantages and disadvantages of each drug action
 | **Example 1 ideas/activities**Using mini whiteboards check the students’ prior knowledge of **enzyme** action (the ‘lock and key hypothesis’ and ‘induced fit’ model) and their understanding of the term ‘**receptor**’. This is an opportunity to make sure the students have this prerequisite knowledge.Discussion/teacher led section explaining how drugs work through receptor activation by **agonists** and blocking by **antagonists**. Use the cascade of **binding, activation, signal transduction** and **effect** as a scaffold. Suggested examples to use are:Receptor agonist: Salbutamol* **binding** to the ꞵ2 adrenergic receptor
* **activation** of adenylyl cyclase enzyme
* **signal transduction** via an increase in cyclic AMP
* **effect** is relaxation of bronchial smooth muscle

Receptor antagonist: Propranolol ( ꞵ blockers)* **binding** to the ꞵ adrenergic receptors (blocking the effect of adrenaline)
* **decreases activation** of adenylyl cyclase enzyme
* **decreased signal transduction** via an increase in cyclic AMP
* **effect** is decreased heart rate

The students can either draw diagrams to explain each mechanism of action or provide a diagram which they can annotate.**Example 2 ideas/activities**Describe, using an example, how drugs work through **enzyme inhibition**. A suggested example is Aspirin:* **binding** to the active site of COX enzymes preventing the natural substrate (arachidonic acid) from binding
* **decreased activity** of the COX enzymes
* **decreased** production of prostaglandins
* reduced **inflammatory effect**

Students construct a table evaluating the advantages and disadvantages of each mechanism of action.Flipped learning task - use the Teaching Resource Centre resource to research an example of a drug which works via either transporter inhibition or gene expression modulation. | [Home | IUPHAR/BPS Guide to PHARMACOLOGY](https://www.guidetopharmacology.org/)A searchable database from the International Union of Pharmacology with information on drug targets and the prescription drugs which act on them. This is a useful resource for identifying alternative examples to use for the teacher led section. | [Teaching Resource Centre](https://trc-p.nl/)A self teaching website for understanding of mechanisms of actions of drugs, along with pharmacokinetics and pharmacodynamics. This can be used for the flipped learning task researching one of the mechanisms of action.  |
| **6** | **1.3 Actions of drugs:** **Mechanism of action of drugs*** **transporter inhibition**
* **non-specific drug action**
* **gene expression modulation**
 | **1** | By the end of the lesson students should: * understand the general steps in the mechanism of action of drugs
* know examples of drugs from each category of mechanism of action
* understand the advantages and disadvantages of each drug action
 | **Example 1 ideas/activities**Flipped learning: students present their findings from the flipped learning task in previous lesson researching two different mechanisms of action of drugs.Show the video on antisense oligotides as an emerging area of drug development.Discuss the student responses and if required, consolidate the information using a further example of a drug which acts via each pathway.**Transporter inhibition**: Fluoxetine inhibits the serotonin transporter in the brain, preventing reuptake.**Gene expression modulation:** Fexaramine affects genes responsible for cholesterol metabolism (it should be noted that this is still experimental).Students construct a table evaluating the advantages and disadvantages of each mechanism of action.Assess student understanding with a short quiz on the key terms from the previous lessons: receptor, agonist, antagonist, inhibition, transporter, signal transduction. | [Gene expression as a target for drug discovery](https://pmc.ncbi.nlm.nih.gov/articles/PMC6134365/)The article from NIH provides information on this emerging category of drug treatment to inform the discussion and provide further examples.[Antisense oligotides: an emerging area of drug development](https://www.youtube.com/watch?v=jgnDXfm2cnA)This video can be used as part of the discussion to introduce an emerging technology which modulates the expression of genes. |  |
| **7** | **1.4 Drug Delivery:** * **routes of administration**
* **influence of chemical properties**
 | **2** | By the end of the lesson students should:* know the routes of drug delivery
* understand how the chemical properties of the drug determine the route of administration
 | **Example 1 ideas/activities**Students watch the MSJ Chem video on routes of administration and answer focused questions based on this.Define the key terms for broad classification of drug delivery:* **enteral**
* **parenteral**
* **topical and transdermal**
* **inhalation**
* **systemic and local**

Discussion/teacher led section on the different routes of drug administration. This should focus on expanding the key terms already defined to know the different ways that drugs can be introduced into the body.Routes of administration:* **entera**l - oral
* **parenteral** - intravenous, intramuscular, subcutaneous, intradermal
* **topical** (dermal, vaginal, nasal, optic and ophthalmic) and **transdermal**
* **inhalation** (inhalers, nebulisers and gaseous anaesthetics)
* **intraosseous** (directly into bone marrow)

The difference between **nasal** (topical) and **transnasal** (administered to the nasal cavity for systemic administration) should be highlighted.Students label a diagram of the body with each of the routes of administration along with a short description.**Example 2 ideas/activities**Independent research task - students to describe the chemical properties of an example drug administered by each of the different routes.The students could choose their own examples or could be provided with drugs to research.Complete the ‘Drug Delivery’ worksheet from the Teach Engineering website. | [Routes of administration](https://www.youtube.com/watch?v=4wg3BSRyK3k)A short video from MSJ Chem providing a brief introduction to different methods of administration to use for a starter activity with focused questions.[Teach Engineering](https://www.teachengineering.org/lessons/view/uoh_body_lesson01)A website with teaching resources for drug delivery. The site includes slide presentations and student worksheets.The drug delivery worksheet can be used to assess student understanding at the end of the lesson. | [MSD Manual Drug administration](https://www.msdmanuals.com/home/drugs/administration-and-kinetics-of-drugs/drug-administration)The MSD Manual provides examples of drugs administered by each route for students to use in the independent research task. |
| **8** | **1.4 Drug Delivery:*** **bioavailability**
* **advantages and disadvantages of each route**
 | **1** | By the end of the lesson students should:* know how the route of administration affects the concentration of the drug at the site of action
* understand the advantages and disadvantages of each route of administration
 | **Example 1 ideas/activities**Define the key terms students need to understand:* **bioavailability** (to refer to the concentration of the drug at the site of action)
* **clearance**
* **first pass metabolism**

Discussion/teacher led section explaining how the concentration of the drug at the site of action is influenced by the route of administration. As a starting point drugs administered intravenously should be considered 100% bioavailable, other injectable methods also have high bioavailability. The impact of first pass metabolism on enteral routes should be explained.Construct a table summarising the key points from the teacher led section for each route of administration.**Example 2 ideas/activities**Students evaluate each route of administration and list the advantages and disadvantages for each route. Knowledge Dose is a good starting point for this, but students should also use their own understanding from the last lesson.Assess students' understanding by showing a variety of chemical structures of drugs and discuss the most appropriate route of administration for each structure based on the structures and functional groups present. | [Bioavailability slides](https://www.slideshare.net/MrunalDhole/bioavailability-137481959#36)The slides provide the percentage availability for different routes of administration along with an explanation for the figures for example the impact of the first pass metabolism. This is a useful resource for informing the teacher led section. | [Knowledge Dose](https://www.knowledgedose.com/routes-of-drug-administration/#jump-section-oral-route)The Knowledge Dose resource will provide information for students in order to effectively evaluate the advantages and disadvantages of each route of administration. |

**Subject knowledge support for this area of study**

| **Subject knowledge enhancement** | **Details** |
| --- | --- |
| **Underlying knowledge and understanding** | In order to effectively engage with lessons on pharmaceutical drugs, students should already have a foundation understanding of several key concepts in both biology and chemistry. This is the prerequisite knowledge and understanding for this area of study:**Basic organic chemistry**: students should be familiar with the structure and properties of basic organic functional groups**Enzymes**: an understanding of the structure of enzymes and the ‘lock and key hypothesis’ and ‘induced fit’ model of enzyme action.**Organ systems**: students should have an understanding of the circulatory and digestive systems and their roles in the transport of substances around the body, and the excretion of waste substances.  |
| **Common misconceptions** | Assumption that all drugs have the same mechanism of action: students may assume that all drugs for a particular condition have the same mechanism of action rather than working via different pathways.That drugs can be taken together with either no interaction or with an increase in efficacy rather than potentially adverse interactions which limit the dosing of certain drugs.Assumption that oral administration is always the most convenient and effective method of administration. |
| **Key concepts** | Drug classification: students should understand the general physiological effects of stimulants, depressants, hallucinogens, cannabinoids and opioids along with specific examples of drugs from each category.Students should understand the general mechanism of action of each category along with potential development of dependency and tolerance. Pharmacodynamics: students should understand the concepts of a dose-response relationship and therapeutic index.Pharmacokinetics: students should understand the pharmacokinetic parameters (absorption, distribution, metabolism and excretion) which determine the dose of a drug.Toxicity: students should know that the therapeutic index is the ratio between the effective and toxic doses of a drug and that a higher therapeutic index means a safer drug.Interactions and adverse reactions: students should understand that some drugs will interact with each other, sometimes adversely and that this can affect dosing regimens, particularly in patients with multiple conditions.Receptors: students should be able to define a receptor agonist and describe the cascade of intracellular actions triggered by receptor binding which are blocked by an antagonist.Enzyme/transporter inhibition: students should be familiar with examples of drugs which have efficacy through the inhibition of an enzyme or a transporter channel.Routes of drug delivery: students should be able to compare the routes of drug delivery in terms of bioavailability and excretion and how pharmacokinetic parameters determine the chosen route of administration. |
| **Subject knowledge enhancement for teachers**  | Read:[Queen Mary University Pharmacology](https://www.qmul.ac.uk/library/academic-skills/online-study-resources/resource-guides-by-subject/biological-sciences/useful-websites/pharmacology---useful-websites/) Queen Mary University Pharmacology website provides links to useful websites covering various aspects of pharmacologyRang and Dale’s Pharmacology 9th Edition ISBN 0702074489Medical Pharmacology at a Glance 9th Edition, Michael J Neal ISBN 1119548012Listen: [Real life Pharmacology](https://podcasts.apple.com/gb/podcast/real-life-pharmacology-pharmacology-education-for-health/id1352791315) The Real Life Pharmacology podcast provides pharmacology education for healthcare professionalsWatch: [Introduction to Pharmacology](https://www.youtube.com/watch?v=JYgdC4EQxUo) |