Ethers, Amines, Amides & Thiols

BIOB111
CHEMISTRY & BIOCHEMISTRY

Session 10
Key concepts: session 10

From this session you are expected to develop an understanding of the following concepts:

Concept 1: Halogenated ethers

Concept 2: Ether connections in carbohydrates

Concept 3: Covalent bonding of nitrogen

Concept 4: Identifying primary, secondary and tertiary amines

Concept 5: Amines in acid-base reactions

Concept 6: Cyclic amine: haeme

Concept 7: Identifying primary, secondary and tertiary amides

Concept 8: Amide formation in proteins

Concept 9: Disulfide bonding by thiols

Concept 10: How do disulfide bonds contribute to the shape of a protein?

These concepts are covered in the Conceptual multiple choice questions of tutorial 10.
Session Overview

Part 1: The ether functional group
• Hydrocarbon derivatives
• Chemical properties of ethers
• Chemical properties of cyclic ethers

Part 2: The amine functional group
• Chemical bonding of nitrogen atoms
• Chemical properties of amines
• Chemical properties of cyclic amines

Part 3: The role of functional groups in protein structure
• Chemical properties of amides
• Amino acids connect together via amide links
• Formation and hydrolysis of amides
• Chemical properties of thiols
• Formation and breakdown of disulfide bonds
• Role of disulfide bonds in protein structure
Part 1: The ether functional group

- Hydrocarbon derivatives
- Chemical properties of ethers
- Chemical properties of cyclic ethers
Hydrocarbon derivatives

Life on earth would not exist without organic compounds that contain carbon atoms

- Our genetic material (DNA) contains many carbon atoms
- Our bodies rely on the organic compounds below to function:
  - Proteins are made up of amino acids
  - Lipids are often made up of fatty acids (long hydrocarbons) and glycerol
  - Carbohydrates are made up of one or more monosaccharide (sugar) units
Hydrocarbon derivatives

Hydrocarbon derivatives are:

- Hydrocarbon compounds that contain atoms such as oxygen, nitrogen, fluorine or chlorine as well as carbon and hydrogen atoms

  - The location within the hydrocarbon derivative that has atoms other than just carbon and hydrogen is where the functional group is located

Ethanol: present in alcoholic beverages
Hydrocarbon derivatives

**What are functional groups?**

- A functional group is a group of atoms within a compound that provides chemical reactivity.
  
  - The functional group is usually the part of the compound that is involved in chemical reactions.
  
  - All compounds with a particular functional group will behave similarly in chemical reactions.

- To find a functional group within a compound, look for atoms other than just carbon and hydrogen atoms.

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**Ethanol: present in alcoholic beverages**

![Ethanol molecule diagram](image)
# Chemical properties of ethers

<table>
<thead>
<tr>
<th>Functional Group: Ether</th>
</tr>
</thead>
<tbody>
<tr>
<td>Functional group formula:</td>
</tr>
<tr>
<td>Naming convention: Ether compounds have (-oxy-) in the middle of their name e.g. methoxyethane</td>
</tr>
<tr>
<td>Example compound: methoxyethane</td>
</tr>
</tbody>
</table>

The ether functional group is an oxygen atom attached to two R-groups.

The ether functional group is located in the middle of compounds, as it contains two R-groups.
Chemical properties of ethers

Functional groups can have one or two R-groups attached

- Single R-group functional groups are always found at the end of a compound or at a branch point within a compound
  - Example: R-OH = alcohol functional group

- Two R-group functional groups are always found in the middle of a compound and are often used to connect two compounds together
  - Example: R-O-R = ether functional group

### 1 R-group functional group: alcohol

![Diagram of alcohol functional group](image)

- R represents any atom or group of atoms capable of attaching to the functional group
- OH is the group of atoms within the alcohol functional group

### 2 R-group functional group: ether

![Diagram of ether functional group](image)

- R represents any atom or group of atoms capable of attaching to the functional group
- O is the atom that makes up the ether functional group

1 R-group functional group: alcohol

\[
\text{R} - \text{OH}
\]

- **R** represents any atom or group of atoms capable of attaching to the functional group.
- **OH** is the group of atoms within the alcohol functional group.

2 R-group functional group: ether

\[
\text{R} - \text{O} - \text{R}
\]

- **R** represents any atom or group of atoms capable of attaching to the functional group.
- **O** is the atom that makes up the ether alcohol functional group.
- **R** represents any atom or group of atoms capable of attaching to the functional group.

Functional group in the middle of a compound between two R-groups.
Chemical properties of ethers

- In the past, ethoxyethane was used as an anaesthetics but it had strong side effects (e.g. nausea)

- Halogenated derivatives of ethers are commonly used as anaesthetics today
  - Have less side effects

- Ethers can be converted into halogenated ethers via halogenation reactions
  - Hydrogen atoms are replaced by halogen atoms
Chemical properties of cyclic ethers

- The ether functional group can exist in straight-chain and ring structures.

- In a cyclic ether an oxygen atom connects to two different carbon atoms, which are both part of the ring.  
  - Furan and pyran are cyclic ethers.

- Cyclic sugar compounds such as glucose and fructose are cyclic ethers.
Chemical properties of cyclic ethers

- The ether functional group contains two R-groups
  - Allows the ether to connect two small compounds together to create a larger compound

- The ether functional group can connect two single sugar units to create a compound that contains two sugar units
  - Example: glucose + fructose → Sucrose
  - An ether that is used to connect two sugar units together is called a glycosidic bond
Glycosidic bond

Glycosidic bond connecting the two glucose units together

Maltose disaccharide

Once a hydrogen atom detaches from one glucose and an OH group detaches from the other glucose, the lost atoms come together to form H₂O. The oxygen atom from one glucose forms a new bond with the carbon atom from the other glucose unit, which forms the ether and links the two glucose units.
Attempt Socrative questions: 1 and 2

Google Socrative and go to the student login

Room name:

City name followed by 1 or 2 (e.g. PERTH1)

1 for 1\textsuperscript{st} session of the week and 2 for 2\textsuperscript{nd} session of the week
Part 1: The ether functional group

• Hydrocarbon derivatives
  – Hydrocarbon derivatives are compounds that contain atoms such as oxygen, nitrogen, fluorine or chlorine as well as carbon and hydrogen atoms

• Chemical properties of ethers
  – The ether functional group is an oxygen atom attached to two R-groups
  – The ether functional group is located in the middle of compounds, as it contains two R-groups
  – Ether compounds have -oxy- in the middle of their names e.g. methoxymethane
  – Ethers were previously used as anaesthetics but now halogenated ethers anaesthetics are preferred, as they have less side effects

• Chemical properties of cyclic ethers
  – In a cyclic ether an oxygen atom connects to two different carbon atoms, which are both part of the same ring structure
  – Carbohydrates such as the ring structured versions of glucose and fructose contain the ether functional group
  – The ether functional group can connect two sugar units together to form a two unit carbohydrate such as sucrose (glucose + fructose)
Part 2: The amine functional group

• Chemical bonding of nitrogen atoms
• Chemical properties of amines
• Chemical properties of cyclic amines
Chemical properties of amines

**Functional Group: Amine**

- Functional group formula: $\text{R} \text{--} \text{NH}_2$
- The amine functional group is a nitrogen connected to one, two or three R-groups.

**Naming convention:** Amine compounds have –amine at the end of their name e.g. propanamine.

**Example compound:**

```
H     H     H
H     C     C     N
H     H     H     H
```

Propanamine
Chemical bonding of nitrogen atoms

Nitrogen
Contains 3 unpaired valence electrons

Nitrogen forms 3 covalent bonds to obtain 8 valence electrons

- Nitrogen belongs to Group V (A), meaning it has 5 valence electrons
  - Nitrogen shares its unpaired valence electrons with other atoms to acquire 3 shared pairs of electrons = 3 covalent bonds
  - Once nitrogen has formed 3 covalent bonds:
    - It has 8 valence electrons and has satisfied the octet rule
Chemical bonding of nitrogen atoms

Electron

Paired valence electrons = non-bonding electrons

Unpaired valence electrons = bonding electron

Covalent bond = 2 electrons shared between the 2 participating atoms

NH₃ is the compound ammonia

Simplified representation

Nitrogen forms 3 single covalent bonds with 3 separate hydrogen atoms
Double Covalent bond = 4 electrons shared between the 2 participating atoms in two separate covalent bonds

NHO is the compound nitroxyl

Nitrogen forms 1 double covalent bond with oxygen and 1 single covalent bond with a hydrogen atom
Chemical bonding of nitrogen atoms

Nitrogen forms 1 triple covalent bond with another nitrogen atom

Triple Covalent bond = 6 electrons shared between the 2 participating atoms in three separate covalent bonds
Amine

Functional group

**Primary (1°) Amine**

- **Definition**: The nitrogen atom is bonded to one carbon atom.
- **Example**: $\text{CH}_3\text{-N-CH}_3$

**Secondary (2°) Amine**

- **Definition**: The nitrogen atom is bonded to two carbon atoms.
- **Example**: $\text{CH}_3\text{-N-CH}_3$

**Tertiary (3°) Amine**

- **Definition**: The nitrogen atom is bonded to three carbon atoms.
- **Example**: $\text{CH}_3\text{-N-CH}_3\text{-CH}_3$

---

**The Nitrogen Atom**

- **Definition**: The nitrogen atom is bonded to:
  - One carbon atom in the case of primary amines.
  - Two carbon atoms in the case of secondary amines.
  - Three carbon atoms in the case of tertiary amines.
Chemical properties of amines

How to work out whether an amine is 1°, 2° or 3°:

- **Step 1:** Identify the nitrogen atom that is part of the amine group

  \[
  \text{CH}_3\text{NCH}_3
  \]

  \[
  \text{CH}_3\text{NCH}_3\text{H}
  \]

- **Step 2:** Count the number of carbon atoms attached to the nitrogen atom identified in step 1

- **Step 3:** The number of attached carbons identified in step 2 specifies whether it is a primary, secondary or tertiary amine

  - 1 attached carbon = 1° amine
  - 2 attached carbon = 2° amine
  - 3 attached carbon = 3° amine
Classify the following compounds as either a 1°, 2° or 3° amine:

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image1.png" alt="Image" /></td>
</tr>
<tr>
<td>2.</td>
<td><img src="image2.png" alt="Image" /></td>
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<tr>
<td>3.</td>
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</tr>
<tr>
<td>4.</td>
<td><img src="image4.png" alt="Image" /></td>
<td><img src="image4.png" alt="Image" /></td>
</tr>
</tbody>
</table>
Chemical properties of amines

- The odour of an amine resembles the smell of raw fish

- Trimethylamine produced in spoiling seafood contributes to the fishy smell
  - Other amines are released as fish decay which also contribute to the fishy smell

- Amines can be converted to amine salts via an acid-base reaction
  - Amine salts do not have a fishy odour

- Lemon juice is often added to fish
  - Results in an acid-base reaction between the amines the lemon juice (acid)
    - Reduces the fishy smell

https://www.freeimages.com/photo/smoked-mackerel-1057358

Trimethylamine
Chemical properties of amines

- Amines are weak bases that accept $\text{H}^+$ from an acid about $\sim$5% of the time.

- Nitrogen atoms have an unshared electron pair.
  - Nitrogen’s unshared pair of electrons can accept a $\text{H}^+$ (lacks electrons) from an acid in an acid-base reaction.

- Trimethylamine reacts with citric acid (in lemon juice) to create an odourless amine salt.
  - Reduces the fishy smell of dead fish.

\[
\text{CH}_3\text{N(CH}_3\text{)}_3 + \text{C}_6\text{H}_8\text{O}_7 \rightarrow \text{CH}_3\text{N(CH}_3\text{)}_3\text{H}^+ + \text{C}_6\text{H}_7\text{O}_7^- \text{ (Conjugate base of citric acid)}
\]
Chemical properties of amines

- Amine functional groups are found in important compounds including drugs
- Amine compounds are often insoluble in water
  - Difficult for amine drugs to be absorbed
- Amine containing drugs are usually converted into amine salts via an aid-base reaction
  - Amine salts have increased solubility in water making it easier for them to be absorbed
  - Amine salts have a longer shelf life, as they are more resistant to oxidation
Chemical properties of cyclic amines

- The amine functional group can exist in straight-chain and ring structures

- In a cyclic amine a nitrogen atom connects to two different carbon atoms, which are both part of the same ring
  - The nitrogen bases present in DNA and RNA are cyclic amines
  - The two most widely used central nervous system stimulants, caffeine and nicotine, are cyclic amines

Guanine

Cytosine

Caffeine

Nicotine

Stoker 2014, p552-555
Chemical properties of cyclic amines

- Haeme is a compound that contains four cyclic amines
  - The cyclic amines work together to hold an Fe ion in the centre
  - Haeme binds to the haemoglobin protein present within red blood cells

Stoker 2014, p553
Chemical properties of cyclic amines

- Haeme binds to the haemoglobin protein present within red blood cells
  - Haemoglobin functions to bind oxygen molecules
    - Oxygen actually binds to the Fe atom in the centre of the haeme ring within the haemoglobin protein
  - Once bound to haemoglobin, oxygen is transported to the cells
    - Cells require oxygen to create cellular energy (ATP)
      - Required in the electron transport chain
Chemical properties of cyclic amines

Red blood cells contain many haemoglobin proteins.

Many haemoglobin proteins within the red blood cells.

Oxygen molecule bound to the haeme ring inside a haemoglobin protein.
## Biochemically Important Amines

<table>
<thead>
<tr>
<th>Name</th>
<th>Chemical Structure</th>
<th>Description</th>
</tr>
</thead>
</table>
| Dopamine | ![Dopamine Structure](image) | – A natural stimulant, produced in the brain, which provides feelings of enjoyment  
– Dopamine deficiency may cause Parkinson’s disease  
– Cocaine and amphetamines inhibit the reuptake of dopamine, resulting in a longer lifetime in synapse, providing long-lived feelings of enjoyment |
| Adrenalin | ![Adrenalin Structure](image) | – Functions as a hormone and a neurotransmitter  
– Hormone during the “fight-or-flight” response  
  • CNS stimulant |
| Histamine | ![Histamine Structure](image) | – A potent pro-inflammatory mediator, involved with allergic reactions  
– Antihistamines are drugs that counter act the effect of histamines by preventing binding to histamine receptors on cells |
Key concept: role of haeme in oxygen transport

What type of functional group is present in the haeme ring?

What is the importance of the functional group in the haeme ring?

What role do the red blood cell, haemoglobin protein and haeme play in the transport of oxygen in the body?

Why do the cells require oxygen? What would happen if the body’s cells were starved of oxygen?
Attempt Socrative questions: 3 to 6

Google Socrative and go to the student login

Room name:

City name followed by 1 or 2 (e.g. PERTH1)

1 for 1\textsuperscript{st} session of the week and 2 for 2\textsuperscript{nd} session of the week
Part 2: The amine functional group

• **Chemical bonding of nitrogen atoms**
  – A nitrogen atom contains three unpaired valence electrons which allows it to form three covalent bonds
  – Nitrogen atoms form a combination of single, double and triple covalent bonds to obtain eight electrons in their valence shell to satisfy the octet rule

• **Chemical properties of amines**
  – The amine functional group is a nitrogen connected to one, two or three R-groups
  – Compounds that contain the amine functional group have —amine at the end of their name
  – The number of carbons attached to the nitrogen within the amine group specifies whether the amine is primary, secondary or tertiary:
    • 1 attached carbon = 1° amine
    • 2 attached carbon = 2° amine
    • 3 attached carbon = 3° amine
  – The odour of an amine resembles the smell of raw fish
  – Amines can react with the acids in lemon juice to be converted to amine salts which do not have a fishy odour
  – Drugs that contain the amine functional group are converted into amine salts to increase their solubility and give them a longer shelf life
Part 2: The amine functional group

• Chemical properties of cyclic amines
  – In a cyclic amine, a nitrogen atom connects to two different carbon atoms which are both part of the same ring
  – The nitrogen bases in DNA and RNA are both cyclic amines
  – Haeme is a compound that contains four cyclic amine rings
  – Haeme binds to the haemoglobin protein present within red blood cells
  – Oxygen actually binds to the Fe atom in the centre of the haeme ring within haemoglobin
  – The haemoglobin protein transports oxygen to the cells where it is used in metabolic pathways to generate cellular energy (ATP)
Part 3: The role of functional groups in protein structure

- Chemical properties of amides
- Amino acids connect together via amide links
- Formation and hydrolysis of amides
- Chemical properties of thiols
- Formation and breakdown of disulfide bonds
- Role of disulfide bonds in protein structure
### Chemical properties of amides

#### Functional Group: Amide

<table>
<thead>
<tr>
<th>Functional group formula:</th>
<th>Naming convention: Amide compounds have –amide at the end of their name e.g. propanamide</th>
<th>Example compound: Propanamide</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{R} \text{–CONH}_2$</td>
<td>The amide functional group is a carbonyl connected to a nitrogen which attaches to zero, one or two R-groups</td>
<td><img src="image" alt="Propanamide structure" /></td>
</tr>
</tbody>
</table>

Example compound: Propanamide

R—CONH₂

The amide functional group is a carbonyl connected to a nitrogen which attaches to zero, one or two R-groups.

**Functional group formula:**

- First degree: $\text{R–CONH}_2$
- Second degree: $\text{R–CONH–R}$
- Third degree: $\text{R–CONH–R–R}$
Amide Functional group

**PRIMARY (1°) AMIDE**
- Definition: The amide group is bonded to one carbon atom.
- Example: \( \text{CH}_3\text{C}=\text{N} \)

**SECONDARY (2°) AMIDE**
- Definition: The amide group is bonded to two carbon atoms.
- Example: \( \text{CH}_3\text{C}=\text{N} \)

**TERTIARY (3°) AMIDE**
- Definition: The amide group is bonded to three carbon atoms.
- Example: \( \text{CH}_3\text{C}=\text{N} \)
Classify the following compounds as either a 1°, 2° or 3° amide:

1. \( \text{CH}_3 - \text{CH}_2 - \text{C} - \text{N} - \text{H} \)

2. \( \text{H} - \text{N} - \text{C} - \text{C} - \text{N} - \text{C} - \text{C} - \text{O} \)

3. \( \text{H} - \text{N} - \text{C} - \text{C} - \text{N} - \text{C} - \text{C} - \text{O} \)

4. \( \text{CH}_3 - \text{C} - \text{N} - \text{H} - \text{CH}_3 \)
Chemical properties of amides

How to work out whether an amine is 1°, 2° or 3°:

- **Step 1:** Identify the position of the amide group within the compound

- **Step 2:** Count the number of carbon atoms attached to the amide group identified in step 1 (both sides)

- **Step 3:** The number of attached carbons identified in step 2 specifies whether it is a primary, secondary or tertiary amide

  - 1 attached carbon = 1° amide
  - 2 attached carbon = 2° amide
  - 3 attached carbon = 3° amide
Chemical properties of amides

- Cyclic amides where the amide is part of the four-membered ring are called β-lactams
  - The antibiotic penicillin contains a β-lactam ring

Stoker 2014, p566
https://www.freeimages.com/photo/pill-1565001
Chemical properties of amides

- **Paracetamol**
  - Common over the counter pain medication
    - Top-selling over the counter pain reliever

- **Urea**
  - Urea is one of the major products of amino acid metabolism
    - Amino acids that are not required by the body are metabolised into urea
      - Urea is removed from the body via urination to maintain nitrogen balance and avoid nitrogen toxicity
Functional groups can have one or two R-groups attached

- Single R-group functional groups are always found at the end of a compound or at a branch point within a compound
  - Example: R-OH = alcohol functional group

- Two R-group functional groups are always found in the middle of a compound and are often used to connect two compounds together
  - Example: R-O-R = ether functional group

1 R-group functional group: alcohol

R – OH

| R represents any atom or group of atoms capable of attaching to the functional group |
| OH is the group of atoms within the alcohol functional group |

2 R-group functional group: ether

R – O – R

| R represents any atom or group of atoms capable of attaching to the functional group |
| O is the atom that makes up the ether functional group |
| R represents any atom or group of atoms capable of attaching to the functional group |
1 R-group functional group: alcohol

\[ \text{R} - \text{OH} \]

- \( \text{R} \) represents any atom or group of atoms capable of attaching to the functional group.
- \( \text{OH} \) is the group of atoms within the alcohol functional group.

2 R-group functional group: ether

\[ \text{R} - \text{O} - \text{R} \]

- \( \text{R} \) represents any atom or group of atoms capable of attaching to the functional group.
- \( \text{O} \) is the atom that makes up the ether alcohol functional group.

Functional group in the middle of a compound between two R-groups.
Amino acids connect together via amide links

- Proteins are chains of 100 or more amino acids
  - Amino acids link together by forming an amide connection
    - Aka a peptide bond

- The specific sequence of amino acids in a protein dictates the shape and function of the protein
  - Example: the haemoglobin protein functions to bind and transport oxygen within the red blood cells
Amino acids connect together via amide links

- Each amino acid contains the amine and carboxylic acid functional groups

![Amino acid: alanine](image)

- Amine
- Carboxylic acid
Amide formation:
• Two amino acids connect together in a chemical reaction where the carboxylic acid of one amino acid reacts with the amine of a second amino acid to create an amide
  
  \[ \text{Amine} + \text{carboxylic acid} \rightarrow \text{Amide} \]
Formation and hydrolysis of amides

The covalent bonds connecting the OH group to one amino acid and a hydrogen atom to a second amino acid are broken. The OH forms a new bond to the hydrogen atom to create $H_2O$. The carbonyl group from one amino acid forms a new bond to the nitrogen atom from the second amino acid to create an amide link and the larger two amino acid compound.
Formation and hydrolysis of amides

Amide hydrolysis:
- A two amino acid compound is broken into two smaller compounds
- The atoms from H₂O allow a carboxylic acid group to form in one amino acid and an amine functional group to form in a second amino acid
  - Amide $\rightarrow$ amine + carboxylic acid

![Diagram of amide hydrolysis](image)
The covalent bond connecting the nitrogen to the carbonyl group (within the amide link) is broken. A hydrogen atom (from H₂O) bonds to the nitrogen to create an amine functional group in the alanine amino acid. An OH group (from H₂O) bonds to the carbonyl group to create a carboxylic acid group in the serine amino acid.
Attempt Socrative questions: 7 and 8

Google Socrative and go to the student login

**Room name:**

City name followed by 1 or 2 (e.g. PERTH1)

1 for 1\textsuperscript{st} session of the week and 2 for 2\textsuperscript{nd} session of the week
# Chemical properties of thiols

## Functional Group: Thiol

### Functional group formula:

\[ \text{R} \text{—S} \text{H} \]

The thiol functional group is also known as the sulfhydryl group.

### Naming convention:

Thiol compounds have –thiol at the end of their name. E.g. propanethiol

#### Example compound:

[Chemical structure of propanethiol]

The thiol functional group is located at the end of a compound (or a branch point), as it contains one R-group.
Chemical properties of thiols

Thiols have strong disagreeable odours

- **Examples:**
  - Methanethiol
    - Smell of rotten cabbage and “bad breath”
  - Essence of skunk contains two thiol compounds below
    - Skunks use the thiols as a defense mechanism to ward off predators

![Chemical structures of thiols](image)
Formation and breakdown of disulfide bonds

Formation of the disulfide bond between cysteine amino acids
• The thiol groups within the two cysteine amino acids are oxidised as they lose a hydrogen atom
  – To satisfy the bonding arrangements of the sulfur atoms within the two cysteine amino acids, the sulfur atoms connect by forming a disulfide bond
• The hydrogen atoms lost from the cysteine amino acids are accepted by the glutathione units to form the thiol functional group.

[Diagram showing the formation of disulfide bond between cysteine amino acids and glutathione units]
Formation and breakdown of disulfide bonds

The cysteine amino acids are oxidised losing hydrogen atoms, which are accepted by two separate glutathione units (reduced). The two cysteine units form a disulfide bond which creates a two amino acid compound.
Formation and breakdown of disulfide bonds

Breakage of a disulfide bond between cysteine amino acids

- The disulfide bond between two cysteine units is broken when the compound is reduced by accepting hydrogen atoms, which creates the thiol functional group
  - The hydrogen atoms come from the oxidised two glutathione unit compound
Formation and breakdown of disulfide bonds

The two cysteine amino acid compound is reduced by gaining hydrogen atoms, which allows the thiol groups to form. The oxidised glutathione units come together to form a disulphide bond to satisfy the bonding requirements of the sulfur atoms.
Role of disulfide bonds in protein structure

- Proteins are chains of 100 or more amino acids
  - Amino acids link together by forming an amide connection
    - Aka a peptide bond

- The specific sequence of amino acids in a protein dictates the shape and function of the protein
  - Example: the haemoglobin protein functions to bind and transport oxygen within the red blood cells
Role of disulfide bonds in protein structure

- Interactions and chemical bonds between non-adjacent amino acids give proteins their specific 3D arrangement and shape
  - The shape of the protein is vital to the function of the protein
  - Without interactions between non-adjacent amino acids the protein chain would be a long string of amino acids with no function

Protein with non-adjacent interactions or bonds between amino acids
Role of disulfide bonds in protein structure

Animation of the formation of a disulphide bond which gives the protein a specific shape

The disulphide bond which forms between two thiol containing amino acids (once the hydrogen atoms have been lost) gives the protein a specific three-dimensional shape.
How is a disulfide bond formed between two different cysteine amino acids?

Is it possible for a disulfide bond to be broken? If so how?

Why is a disulfide bond between two non-adjacent cysteine amino acids within a protein chain important?

Key concept: thiol group, disulfide bond
Attempt Socrative questions: 9 and 10

Google Socrative and go to the student login

Room name:

City name followed by 1 or 2 (e.g. PERTH1)

1 for 1st session of the week and 2 for 2nd session of the week
### Part 3: The role of functional groups in protein structure

**Chemical properties of amides**
- The amide functional group is a carbonyl connected to a nitrogen which attaches to zero, one or two R-groups.
- Compounds that contain the amide functional group have –amide at the end of their name.
- The number of carbons attached to the amide group specifies whether the amide is primary, secondary or tertiary:
  - 1 attached carbon = 1° amide
  - 2 attached carbon = 2° amide
  - 3 attached carbon = 3° amide
- Urea is a product of amino acid metabolism that contains the amide group.
- Urea must be removed from the body via urination to prevent nitrogen toxicity.

**Amino acids connect together via amide links**
- When the nitrogen within the amide functional group is attached to 2 R-groups, it can be used to connect two amino acids together.
- When an amide link connects two amino acids together it is called a peptide bond.
- Proteins are made up of hundreds of amino acids, with the adjacent amino acids in the chain connected by peptide bonds.
Part 3: The role of functional groups in protein structure

- **Formation and hydrolysis of amides**
  - Amide formation: Two amino acids connect together in a chemical reaction where the carboxylic acid of one amino acid reacts with the amine of a second amino acid to create an amide
  - Amine + carboxylic acid → Amide
  - Amide hydrolysis: A two amino acid compound is broken into two smaller compounds
  - After the amide link has broken, the atoms from \( \text{H}_2\text{O} \) allow a carboxylic acid group to form in one amino acid and an amine functional group to form in a second amino acid
  - Amide → amine + carboxylic acid
Part 3: The role of functional groups in protein structure

• **Chemical properties of thiols**
  – Compounds that contain the thiol functional group have –thiol at the end of the name
  – The thiol functional group is located at the end of a compound (or a branch point), as it contains one R-group
  – Thiols have strong disagreeable odours e.g. skunk smell

• **Formation and breakdown of disulfide bonds**
  – The thiol groups within the two cysteine amino acids are oxidised when they lose a hydrogen atom, before the sulfur atoms connect by forming a disulfide bond
  – The disulfide bond between two cysteine units is broken when the compound is reduced by accepting hydrogen atoms, which creates the thiol functional group

• **Role of disulfide bonds in protein structure**
  – Interactions and chemical bonds between non-adjacent amino acids gives proteins their specific 3D arrangement and shape
  – Proteins rely on their specific shape to function
  – Without interactions between non-adjacent amino acids the protein chain would be a long string of amino acids with no function
  – A disulfide bond that forms between two non-adjacent cysteine amino acids contributes to the 3D shape of the protein
Readings & Resources


• Stoker, HS 2004, *General, Organic and Biological Chemistry*, 3rd edn, Houghton Mifflin, Boston, MA.

• Timberlake, KC 2014, *General, organic, and biological chemistry: structures of life*, 4th edn, Pearson, Boston, MA.


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