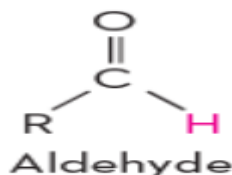


Lecture 4: Aldehydes

The aldehydes is characterized by the presence of the carbonyl group



- The **carbonyl group** of an aldehyde is polar because oxygen is more electronegative than carbon. This produces a dipole in which the oxygen carries a partial negative charge and the carbon carries a partial positive charge.
- Thus, the attractive forces between carbonyl-containing compounds include London dispersion forces between the hydrocarbon chains and dipole-dipole attractions between carbonyl groups.
- As a result, they have higher boiling points than comparable hydrocarbons, but lower boiling points than comparable alcohols.

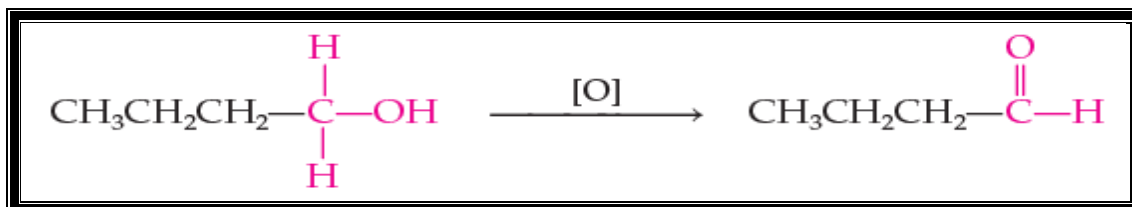
IUPAC Nomenclature and Common Names

aldehydes are named by determining the parent compound and replacing the final -e of the parent alkane with -al.

IUPAC Name	Common Name	Formula
Methanal	Formaldehyde	$\text{H}-\overset{\text{O}}{\parallel}{\text{C}}-\text{H}$
Ethanal	Acetaldehyde	$\text{CH}_3-\overset{\text{O}}{\parallel}{\text{C}}-\text{H}$
Propanal	Propionaldehyde	$\text{CH}_3\text{CH}_2-\overset{\text{O}}{\parallel}{\text{C}}-\text{H}$
Butanal	Butyraldehyde	$\text{CH}_3\text{CH}_2\text{CH}_2-\overset{\text{O}}{\parallel}{\text{C}}-\text{H}$
Pentanal	Valeraldehyde	$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2-\overset{\text{O}}{\parallel}{\text{C}}-\text{H}$

Preparation of Aldehydes

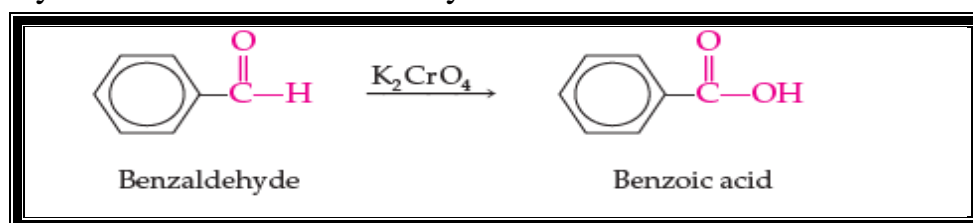
The oxidation of a primary alcohol produces an aldehyde,



Reactions of aldehyde and ketone

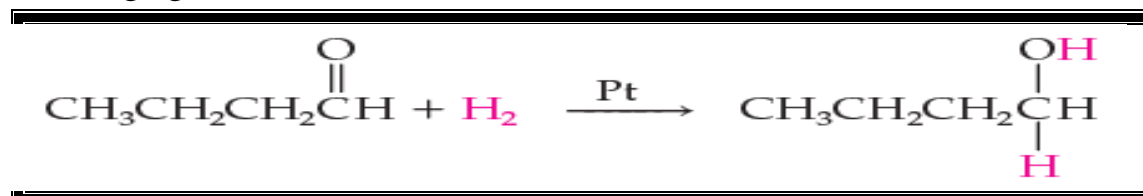
1. Oxidation Reactions

Aldehydes are oxidized to carboxylic acids



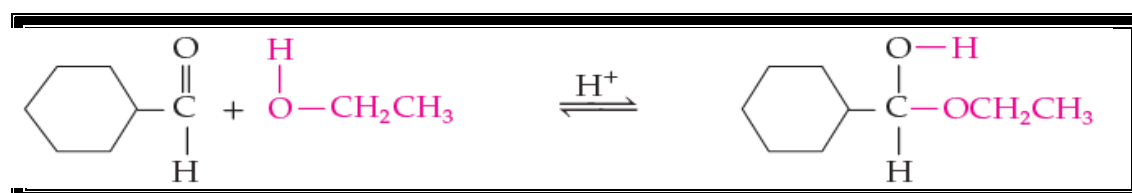
2. Reduction Reactions

Aldehydes are readily reduced to the corresponding alcohol by a variety of reducing agents, the symbol [H] over the reaction arrow represents a reducing agent.



3. Addition reaction

Addition reaction is the reaction of aldehydes with alcohols in the presence of catalytic amounts of acid.



Important Aldehydes

Members of the aldehyde families are important as food and fragrance chemicals, and as medicinal and agricultural chemicals.

- Methanal (formaldehyde) is used to preserve tissue.
- Ethanal (acetaldehyde) is produced from ethanol in the liver. Ethanol is oxidized in this reaction, which is catalyzed by the liver enzyme alcohol dehydrogenase. The ethanal that is produced in this reaction is responsible for many negative effects of alcohol: facial flushing (due to ALDH2 (aldehyde dehydrogenase 2) deficiency in some populations), nausea, headache, and long-term organ damage. As well as, it is oxidized to produce acetic acid commercially.

Aldehydes in Medical Perspective

Aldehydes play paradoxical roles: they are essential endogenous signaling molecules, yet they are also potent toxins implicated in numerous diseases. This duality makes them a critical focus in biochemistry, toxicology, and pharmacology.

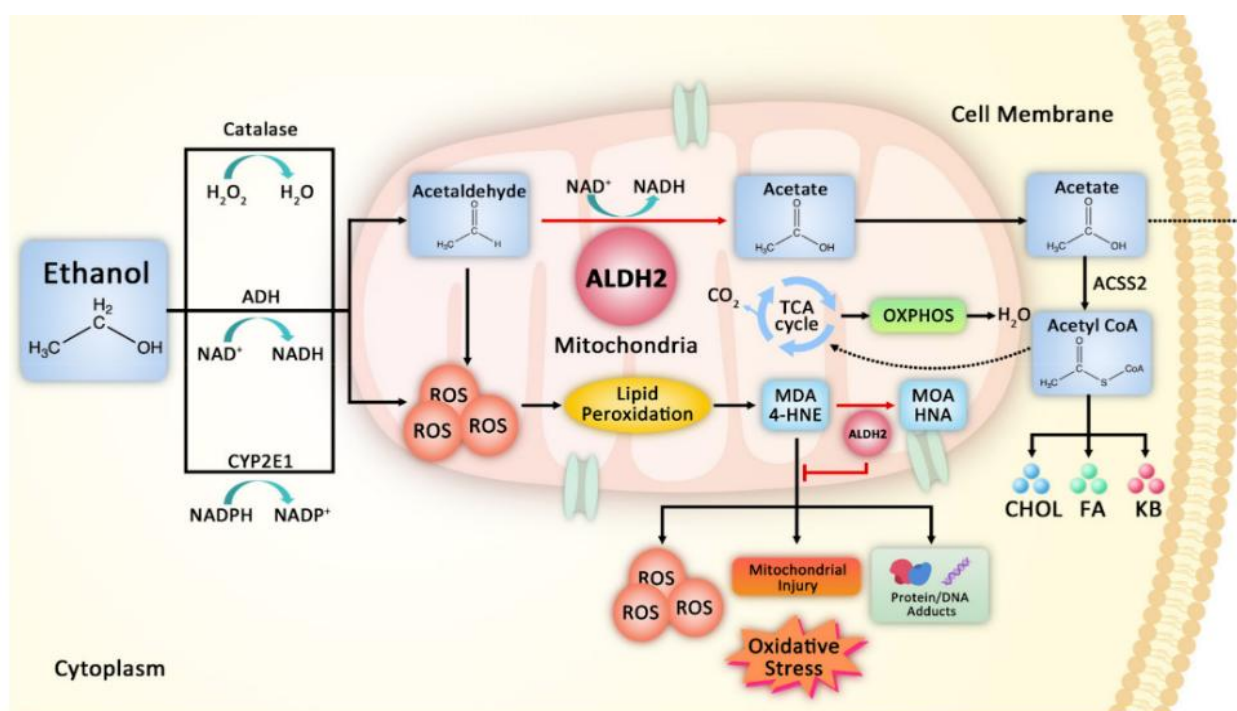
A. Signaling Molecules: Small aldehydes like formaldehyde and acetaldehyde are now recognized as important biological messengers

B. Lipid Peroxidation Products: A major source of pathogenic aldehydes is the peroxidation of polyunsaturated fatty acids in cell membranes. This process, driven by oxidative stress, generates highly reactive aldehydes such as **Malondialdehyde (MDA)**: A classic biomarker for oxidative stress, used in assays to measure lipid peroxidation. **4-Hydroxynonenal (4-HNE)**: Perhaps the most studied toxic aldehyde. It forms protein adducts, disrupts enzyme function, damages mitochondria, and influences cell signaling pathways. At low levels, it can promote cell proliferation; at high levels, it triggers apoptosis (programmed cell death). **Acrolein**: Extremely reactive and cytotoxic. It depletes antioxidants like glutathione and directly damages proteins and DNA.

C. Environmental & Dietary Sources: Present in vehicle exhaust, tobacco smoke, food additives, and even produced during cooking (e.g., acrolein from overheated oils).

D. Chemotherapeutic Agents: Some drugs, like cyclophosphamide, are metabolized into active aldehyde forms that exert cytotoxic effects.

The Body's Defense: Aldehyde Detoxification Systems



Pathway by which aldehyde dehydrogenase 2 (ALDH2) catalyzes aldehyde metabolism in ethanol metabolism. ALDH2 metabolizes acetaldehyde into acetate, metabolizes the malondialdehyde (MDA) into malonic acid (MOA) or acetaldehyde, and metabolizes the 4-hydroxy-2-nonenal (4-NHE) to generate 4-hydroxy-2-nonenic acid (NHA) to reduce the accumulation of toxic aldehydes produced during metabolism. CHOL = cholesterol; FA = fatty acids; KB = ketone bodies.