FORENSIC TOXICOLOGY ASPECTS OF ALCOHOL

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Introduction

- Alcohols as Chemical Organic Compounds (R-OH).
- Three common aliphatic alcohols often encountered in forensic and clinical toxicology are: Methanol, Ethanol and Ethylene glycol
- In general, alcohol refer to Ethanol in the medical literatures.

Ethanol

- Ethanol (Ethyl Alcohol,C_2H_5OH) is derived from fermentation of sugars in fruits, cereals, and vegetables.
- Ethanol has had a historical role in mankind's medical, social and religious rituals.
- Commercial beer, wine and liquors contain various amounts of ethanol.
- Ethanol is also found in variety of colognes, perfumes, after-shaves, mouthwashes, some rubbing alcohols, pharmaceutical preparations (elixirs) and may other products.
- Ethanol used as a solvent and antiseptic in industry and medicine.

Forensic and Clinical Aspects of Alcohol

- Heavy drinking and drunkenness constitute major public health problems for both individual and society.
- Clinical Medicine: Burden of diseases (Abuse/Addiction (Alcoholism) and Psychological disorders, CVS, CNS, GI, Hematologic, Endocrine diseases, Malnutrition, Cancers, Maternal Malformations, Acute and Chronic Poisoning, etc.)

Alcohol Use/Abuse from Forensic Medicine Viewpoint

- High blood alcohol concentration (BAC) are a common finding in many crimes and accidents such as:
- *Car Accidents (DUI and Legal limits of BAC in Driving)*
- *Transport Accidents (Aviation, Railway, Marine,…)*
- *Drowning*
- *Falling*
- *Workplace Accidents*
- *Suicide*
- *Homicidal and Drug Facilitated Crimes*
- *Poisoning and Drug Overdose (Faked Alcohol Drinks (Methanol)Poisoning*

- From this view, alcohol analysis in body fluids is the most frequent requested service from forensic science and toxicology labs worldwide.
- In the Islamic countries, as the alcohol drinking is a punishable act, the legal aspects of this crime is very important.

Ethanol Products

Beer 3-6%	Antiseptic 10-70%
Wine 16%	Perfume 40-80%
Whisky 40%	Aftershave 40-80%
Vodka 60-90%	Mouthwash 15-25%

Alcoholic Beverages

An **alcoholic beverage** is a drink which contains a substantial amount of the ethanol (0.5-95% V/V).
Alcoholic beverages are typically divided into three classes—beers, wines, and spirits—and typically contain between 3% and 40% alcohol by volume.
Also, they classified as fermented (beers and wines) and distilled (liquors) alcoholic beverages.

Fermented beverages

- Beers
- Wines (Red wine, White wine and Fortified wines)
- Cider

Beer

- Beer is a beverage fermented from grain mash. It is made from barley or a blend of several grains.
- If the fermented mash is distilled, then the beverage is a spirit. Beer is the most consumed alcoholic beverage in the world.
- Beer alcohol content is 3-6 % V/V.

Types of Beer

- **Ale** – This type of beer is brewed from malted barley by mixing certain amount of yeast. The yeast helps in fermenting the beer and giving a fruit flavor to the beer.
- **Fruit Beer** – Fruits like cherry, raspberry and peach are commonly used in brewing this type of beer. Most of the breweries add a flavor of these fruits instead of fermenting these fruits.
- **Lager** – This is another kind of beer that is brewed and stored at low temperatures. It is the most widely brewed and consumer beer in the world. It had its origins in Germany.
- **Wheat Beer** – This type of beer is produced by mixing a larger proportion of wheat when compared to the malted barley content. This type of beer had its origins in Austria and Germany.

Wine

- Wine is a fermented beverage produced from fermentation of fruits such as grapes, apples, cherries, plums.
- Wine involves a longer fermentation process than beer and also a long aging process (months or years), resulting in an alcohol content of 9%–16% ABV.
- Sparkling wine can be made by means of a secondary fermentation.
- "*Fruit wines*" are made from fruits such as plums, cherries, or apples.

Cider

- Cider or cyder is a fermented alcoholic beverage made from any fruit juice; apple juice (traditional and most common), peaches, pears ("Perry" cider) or other fruit.
- Cider alcohol content varies from 1.2% - 8.5% or more in traditional English ciders. In some regions, cider may be called "apple wine".

Chicha

- This is a type of fermented beverage that is used more in the central and the South American Continents. There are both fermented and non fermented chicha that are made out of Maize.

Sake

- This fermented Alcoholic beverage is made in Japan by fermenting rice at a particular temperature (18-20% ABV).

Distilled beverages

- A distilled beverage or liquor is an alcoholic beverage produced by distilling ethanol produced by means of fermenting grain, fruit, or vegetables.
- Unsweetened, distilled, alcoholic beverages that have an alcohol content of at least 20% ABV are called *spirits*. For the most common distilled beverages, such as whiskey and vodka, the alcohol content is around 40%.
- Vodka, Gin, Tequila, Whiskey, Rum and Brandy are examples of distilled beverages. Distilling concentrates the alcohol and eliminates some of the congeners.

- Fortified wine is wine, such as port or sherry, to which a distilled beverage (usually brandy) has been added.
- Fortified wine is distinguished from spirits made from wine in that spirits are produced by means of distillation, while fortified wine is simply wine that has had a spirit added to it.

Type of Distilled Alcoholic Beverages

- **Arrack** – This distilled Alcohol is mainly produced in South Asia and South East Asia. This is produced by mixing fermented sap of coconut flower with sugar cane.
- **Awamori** – This distilled Alcoholic beverage is a Japanese production and made in Okinawa in Japan. This is actually made by fermenting rice and then distilling the fermented rice.
- **Gin** – This is a type of distilled spirit that is made from Juniper Berries. There are different types of gin like Damson Gin and Sloe Gin. Damson gin is hugely popular in Britain.
- **Rum** – Though consumed in different parts of the globe, rum is extremely popular in Caribbean region and Latin America. This is made by fermenting sugar cane juice or by fermenting molasses, one of the byproducts of sugarcane.

- **Vodka** – Vodka is a distilled spirit made by distilling fermented grain like wheat, corn or potatoes. It has an alcoholic content of 40%.
- **Whiskey** – This distilled alcoholic beverage is made by fermenting a combination of different grains including barley, malted barley, Rye, Corn and Wheat. The fermented whisky is then allowed to age in wooden casks.
  - **Bourborn Whiskey** – This is usually referred to as American Whiskey and is made from Corn.
  - **Scotch Whisky** – This type of Whisky is made by distilling fermented malt barley and had its origin in Scotland.
- **Brandy** – This distilled beverage is made by distilling wine. It has an alcoholic content that ranges between 30% and 60%
- **Tequila** – This is a distilled beverage that is prepared from Blue Agave plant. It is named after a city in Mexico

Beer

Ale vs Lager

German Dunkel beer (Dark Lager)

Red wine

White wine

Rosé Wine


ECHO FALLS
CALIFORNIA
Fresh Strawberries & Cherries
ROSÉ WINE

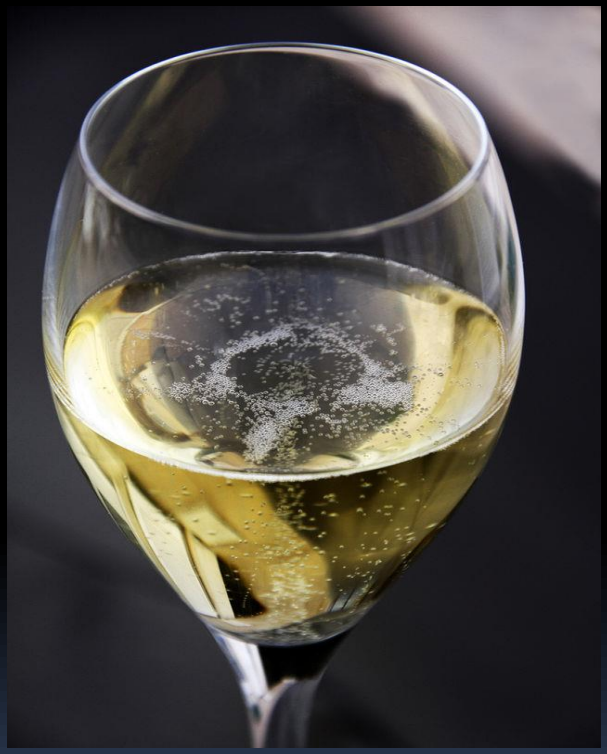
Cider

Port Wine


KEDEM
מבושל
כשר לפסח
NEW YORK STATE
PORT WINE
ALCOHOL 18% BY VOLUME
PRODUCED AND BOTTLED BY ROYAL WINE CORP
BAYONNE, N.J. U.S.A
תחת השגחת הרה"ג מצעהלים שליט"א
750 mL
CONTAINS SULFITES

Sherry (Spanish wine) of 1775 – the oldest wine in the Massandra winery collection, Crimea

Champagne



Sake (rice wine)

Nigori, or unfiltered sake

Sake barrel offerings at the Shinto shrine

Rum


ESTD 1920
THE REAL McCOY
Prohibition Tradition
RUM
aged 3 years
in SELECT AMERICAN OAK BOURBON BARRELS
ESTD 1920
THE REAL McCOY
RUM
aged 5 years
in SELECT AMERICAN WHITE OAK CASKS of the THE REAL McCOY
IMPORTED EXCLUSIVELY BY REAL McCOY SPIRITS, STONINGTON, CT, USA
ESTD 1920
THE REAL McCOY
Prohibition Tradition
RUM
in SELECT AMERICAN OAK BOURBON BARRELS

Vodka


IGANOFF
42 BELOW
BELVEDERE
VODKA
VERMONT WHITE
KARLOFF
MEDEA
ABSOLUT
VODKA
IMPORTED

Whiskey


CLAESSENS
2001 DESIGN
CLAESSENS
2007 DESIGN
No.1 McDowell's
A BLEND OF THE FINEST SELECTED IMPORTED SCOTCH AND INDIAN MALT WHISKIES
WHISKY
McDowell's
No1
RESERVE WHISKY
BLENDED WITH SCOTCH AND SELECT INDIAN MALTS
McDowell's
No1
RESERVE WHISKY

Gin


CADENHEAD'S
OLD RAJ
DRY GIN
55% alc/vol
CADENHEAD'S
OLD RAJ
DRY GIN
46% alc/vol
ROGUE
SPRUCE
GIN
SARTICIOUS
GIN
DESERT JUNIPER
BOMBAY
SAPPHIRE
DRY GIN
Citadelle
GIN
MARTIN MILLER'S
IMPORTED
ROGUE
Rogue Spruce Gin
BEST AMERICAN GIN
BEEFEATER
BOMBAY
DRY GIN
1761
GORDON'S
LONDON DRY GIN
Seagram's
VIBOVICE
PLYMOUTH
ENGLISH GIN
Tanqueray
IMPORTED
SAVE $1.00
SAVE $3.00
$39.99
$22.99
$19.99
$26.99
$38.99

Gin


okanagan spirits
GIN
Craft Distillery
HAND-CRAFTED IN BC
750 mL 40% alc./vol.

(اُرس)Juniper berry

Blue Agave Plant (Tequila)

Brandy

Brandy Barrels

Turkish Raki (Arrack)

عرق سگی


شرکت سهامی
میکده
قزوین
عرق کشمش اعلا
شماره ۵۵


شرکت سهامی
میکده
قزوین
عرق کشمش اعلا
شماره ۵۵

Persian Arak

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Persian Arak

The famous persian arak is the pure essence of thompsons grapes which are nourished by enriched soil and dried by the gentle strokes of california sunshine. these sun roasted raisins are fermented by their own natural inherited yeasts, therefore producing a taste which cannot be found in any other brand.

(red label) 40%alc./vol 80 proof 750 ml
(black label) 50 %alc./vol 100 proof

Recorded vs. Unrecorded Alcoholic Products

- Recorded alcohol is that part of alcohol which is consumed globally and is reflected in the official statistics on production, cross-border trade and sales figures of the country of production.

- **Unrecorded alcohol** is a summary term for a number of categories not registered in the country where it was consumed. Four main categories can be distinguished :
- **Illegally produced or smuggled alcohol products** (including illegal homemade alcohol).
- **Surrogate alcohol:** non-beverage alcohol products not intended officially for human consumption (such as industrial alcohol, mouthwash or eau de cologne).
- Alcohol products that are recorded, but not in the jurisdiction of consumption (e.g. cross-border shopping).
- **Legal but unrecorded alcohol products** (homemade or other).
- *In 2000, 30% of global alcohol consumption was estimated to be unrecorded .*

Pharmacokinetics

- Ethanol is readily absorbed (peak 30-120 min.) and distributed into the body water (Vd=0.5-0.7L/kg).
- It is rapidly absorbed by diffusion across the lipid membranes of the stomach and small intestine.
- Co-ingestion of food or decreased GI motility produces a delay in absorption and increases the gastric metabolism of ethanol.

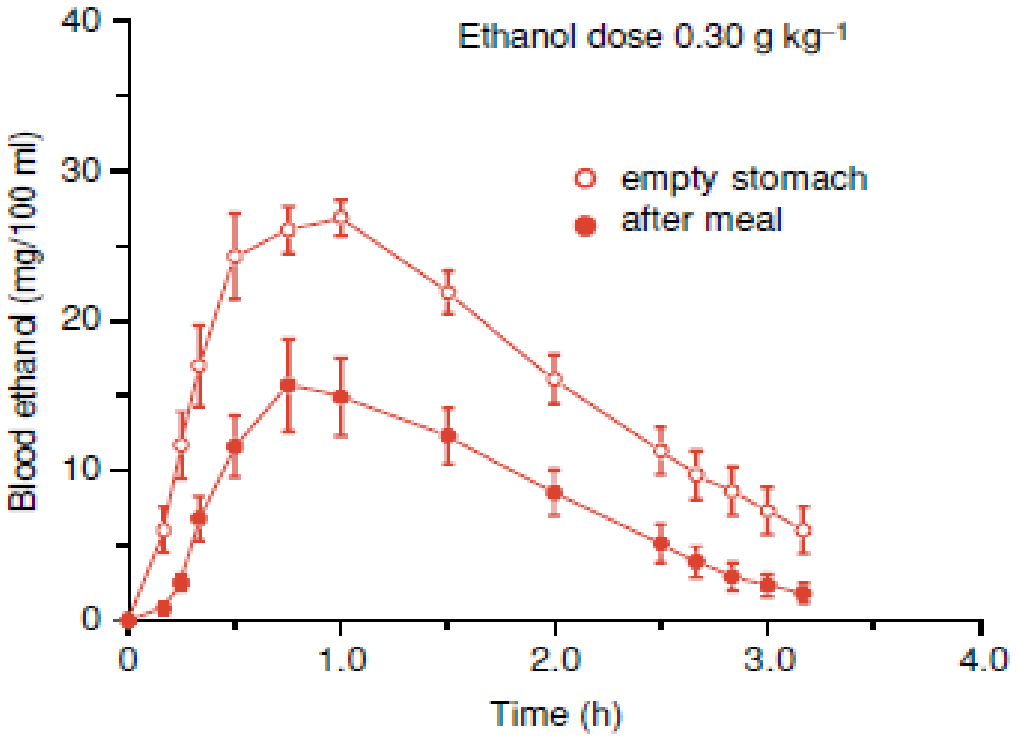

Figure 1 Comparison of the concentration–time profiles of ethanol in blood after drinking a moderate dose of alcohol (0.3 g kg^{-1}) on an empty stomach (10-h fast) or after eating a meal.

- The relationship between a person's BAC and the amount of alcohol absorbed and distributed in all body fluids and tissues is given by the following simple equation:

$$A = BAC \times Vd \times \text{body weight}$$

- A= amount of alcohol in grams absorbed and distributed in all body fluids at the time of sampling blood,
- BAC= Blood Alcohol Concentration in units of g /L (not mg /dL),
- Body weight= as Kg
- Vd = volume of distribution of alcohol as liters per kilogram (L/Kg)
- Body weight as (Kg)

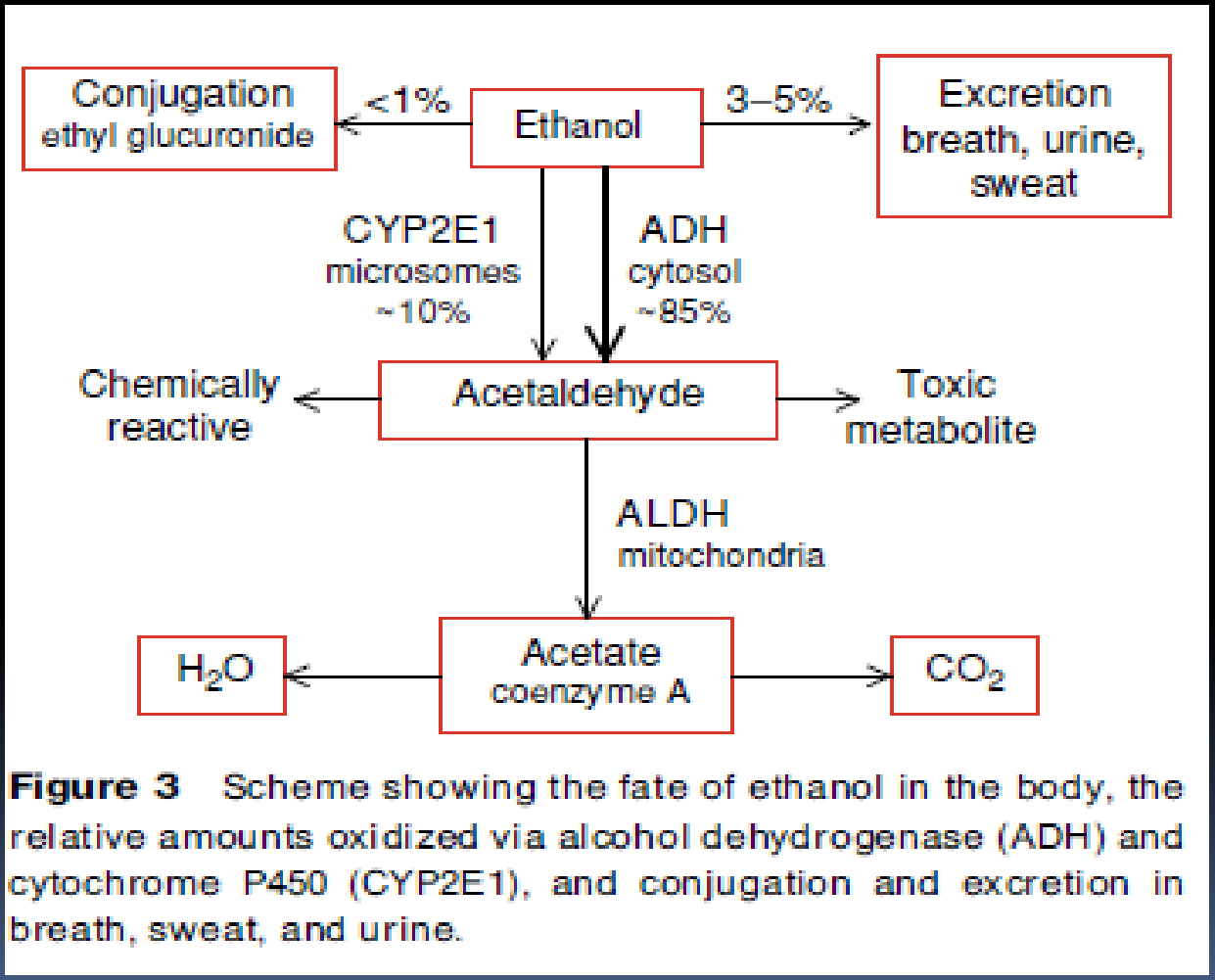

Figure 3 Scheme showing the fate of ethanol in the body, the relative amounts oxidized via alcohol dehydrogenase (ADH) and cytochrome P450 (CYP2E1), and conjugation and excretion in breath, sweat, and urine.

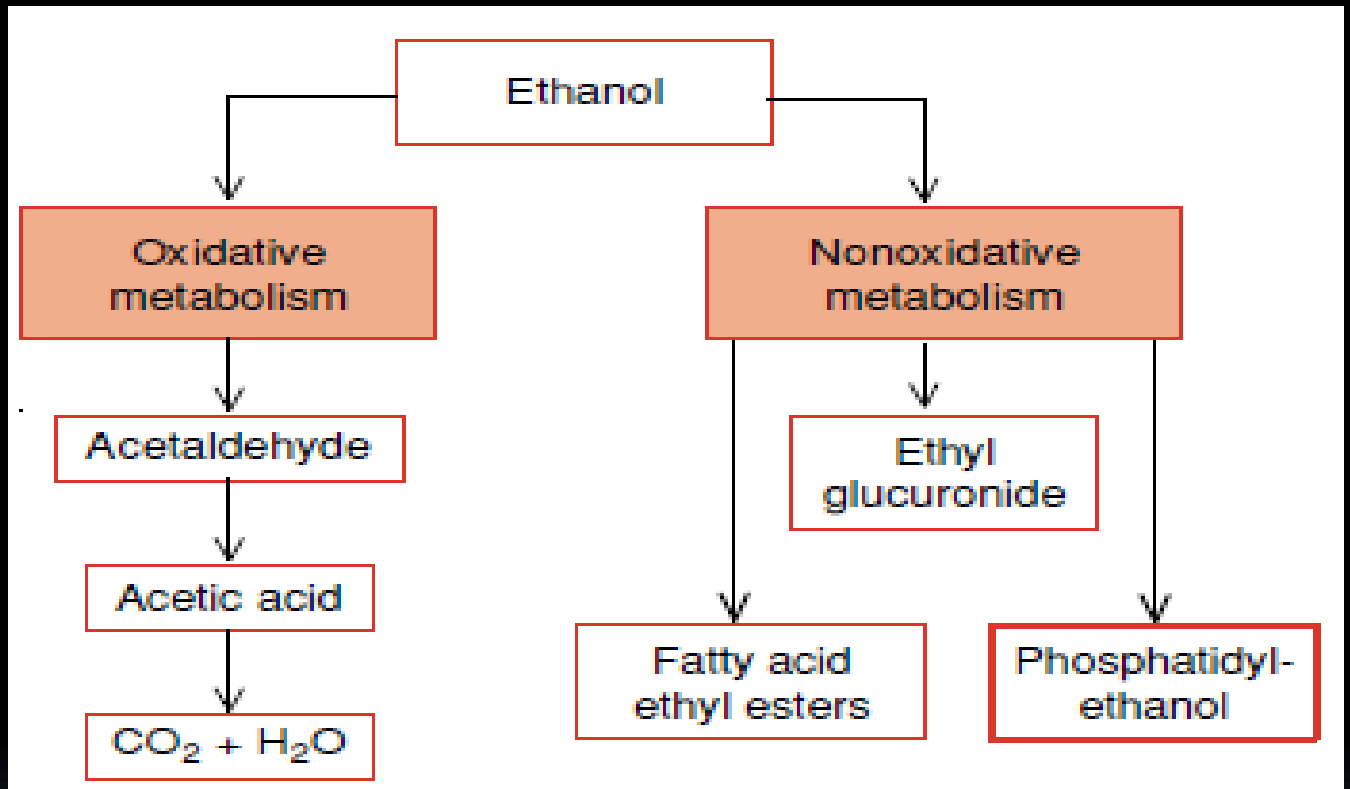

Figure 4 Comparison of the metabolites of ethanol produced by oxidative and nonoxidative metabolic pathways.

- Elimination:
- Elimination is mainly by oxidation in the liver and follows zero-order kinetics.
- The average elimination rate in non-drinkers to be 12-24mg/dl/h; in social drinkers 15mg/dl/h and higher ,and in alcoholics 15-49mg/dl/h.

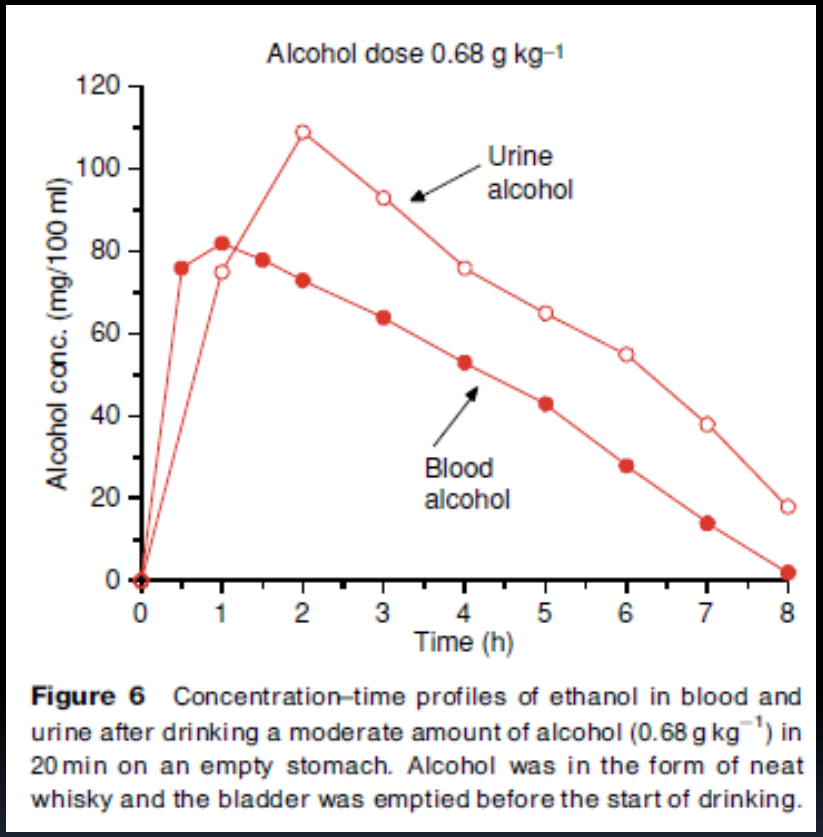

Figure 6 Concentration–time profiles of ethanol in blood and urine after drinking a moderate amount of alcohol (0.68 g kg^{-1}) in 20 min on an empty stomach. Alcohol was in the form of neat whisky and the bladder was emptied before the start of drinking.

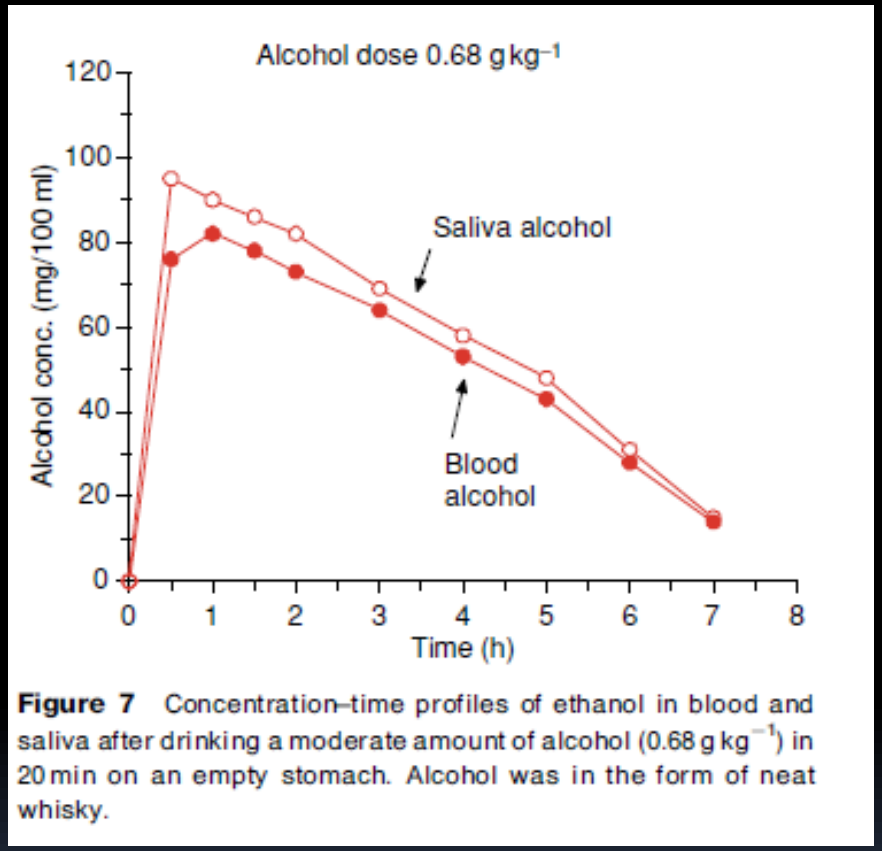

Figure 7 Concentration–time profiles of ethanol in blood and saliva after drinking a moderate amount of alcohol (0.68 g kg^{-1}) in 20 min on an empty stomach. Alcohol was in the form of neat whisky.

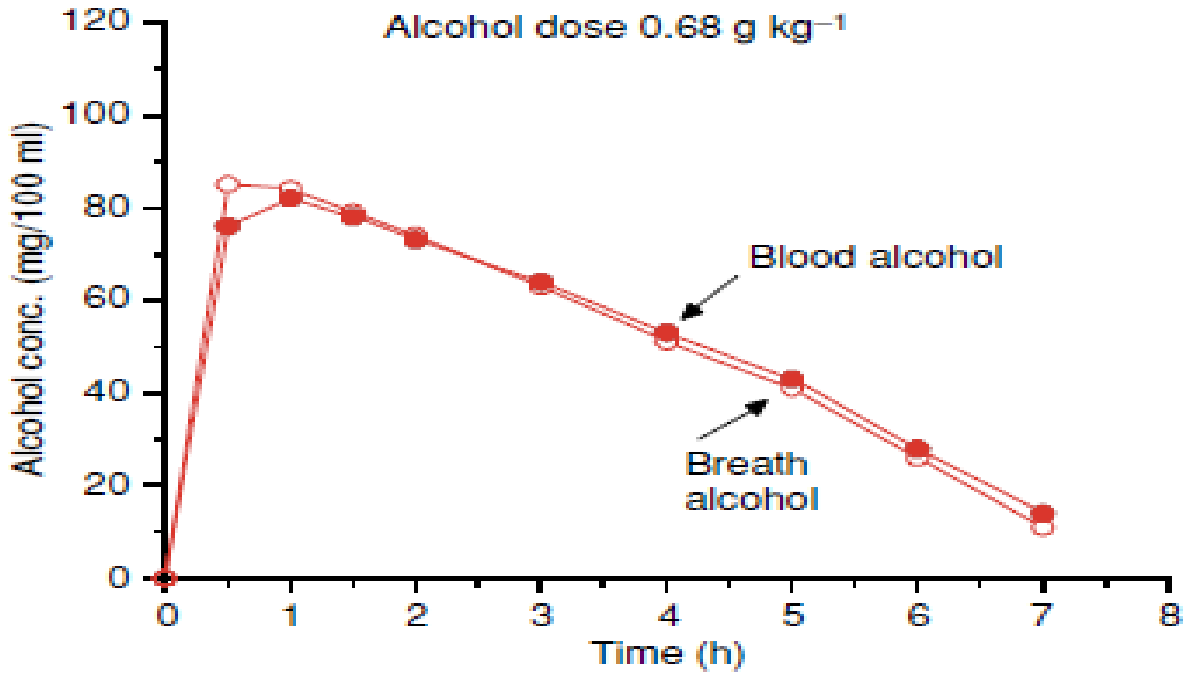

Figure 8 Concentration–time profiles of ethanol in blood and breath after drinking a moderate amount of alcohol (0.68 g kg^{-1}) in 20 min on an empty stomach. Alcohol was in the form of neat whisky and the breath alcohol analyzer was Intoxilyzer 5000 based on infrared analysis.

Factors affecting blood Ethanol

- Sex
- Age
- Adiposity
- Smoking
- Delayed gastric empting

Ethanol Toxic Dose

Adult : 6-10 ml/kg

Children : 4 ml/kg

Intoxication signs

<150 mg%	150-300 mg%	300-500 mg%
Warmth Well-being Talketive Self-confidence Coordination Decrease reflex	Ataxia Diplopia Flushing Sweating Tachycardia	Hypothermia Drowsiness Coma Metabolic acidosis Respiratory depression

Blood Ethanol Level > 500 mg%

Hypotension
Hypothermia
Coma
Convulsion
Respiratory Arrest

Table 10 Typical signs and symptoms of acute alcohol influence as a function of a person's blood alcohol concentration when observations were made close to the maximum value after a single oral dose

Blood-alcohol (mg per 100 ml)	*Signs and symptoms of alcohol influence*[a]
<20	No untoward effects or outward signs
30–50	Mild euphoria and impairment of certain skilled tasks that require divided attention
50–100	Reduced inhibitions, increased talkativeness, sensory and motor disturbances, slower reaction time, especially in choice situations
100–150	Lack of coordination, unsteady gait, slurred speech, prolonged reaction to sights and sounds
150–200	Obvious drunkenness, significantly slower reaction time even for simple tasks, nausea and vomiting in some people, ataxia, aggressiveness
200–300	Inability to stand upright and walk without support, incoherent speech, motor areas of the brain severely depressed with distorted perception and judgment
300–400	Confusion, stupor, or coma with shallow breathing and risk of death
>400	Heightened risk of death through respiratory paralysis and cardiopulmonary arrest

[a]Large intersubject variations exist within each blood-alcohol concentration range owing to different drinking patterns and the development of tolerance to alcohol, and individuals may exhibit very different effects.

Table 8 Examples of biological specimens used for determination of alcohol in forensic casework when dealing with living and dead subjects

Living subjects	*Deceased subjects (postmortem)*
Whole blood	Whole blood
Cubital vein[a]	Cubital or jugular vein
Radial artery	Femoral vein[a]
Capillary or fingertip sample	Cardiac (heart) blood
Plasma or serum[a]	Stomach contents
Freshly voided urine[a]	Bladder urine[a]
Tears	Vitreous humor[a]
Cerebrospinal fluid	Cerebrospinal fluid
Saliva	Bile
Sweat	Bone marrow or synovial fluid
Breath	Various tissues
Free-expired	Brain
End-expired[a]	Muscle
Rebreathed	Liver

[a]Recommended specimens if available.

Table 4 Summary of the analytical methods used to determine ethanol in body fluids

Method of analysis	*Basic principle of the analytical method*
Chemical oxidation	The ethanol is first separated from the biological matrix by distillation, diffusion, aeration, or protein precipitation. The resulting aqueous ethanol is then oxidized, usually with a mixture of potassium dichromate and sulfuric acid, and the reaction endpoint is determined by volumetric titration or by spectrophotometry
Enzymatic oxidation	Ethanol is first separated from the biological matrix as above; the pH of the aqueous distillate is adjusted to between 8 and 9 with semicarbizide buffer, and the coenzyme (NAD^+) is added. Oxidation of ethanol is achieved by adding the enzyme alcohol dehydrogenase derived from yeast and the reaction is monitored by formation of the reduced coenzyme (NADH) at 340 nm by ultraviolet spectrometry
Gas chromatography using liquid injection	An aliquot of blood or other body fluid is diluted 1:5 or 1:10 with an aqueous solution of internal standard (either *n*-propanol or *t*-butanol). About 1–5 μl of the diluted specimen is injected into the gas chromatograph fitted with a polar stationary phase (e.g., polyethylene glycol) and a flame ionization detector is used for quantitation
Gas chromatography using headspace analysis	An aliquot of blood or other body fluid is diluted 1:5 or 1:10 with an aqueous internal standard as above. The diluted specimen is allowed to equilibrate in an airtight glass vial for 20 min before an aliquot of the vapor phase (called the headspace) is removed with a gastight syringe or other means (instruments fitted with automated injectors are common) and transferred into a gas chromatograph for analysis
Infrared spectrometry	Ethanol in the vapor phase (e.g., breath) is quantitatively determined by infrared spectrometry according to the Lambert–Beer law. Ethanol absorbs infrared radiation at wavelengths of 3.4 μm corresponding to the C-H stretch and at 9.5 μm corresponding to the C-O stretch
Electrochemical oxidation	Ethanol in the vapor phase (e.g., breath) is quantitatively determined by electrochemical oxidation with a platinum black catalyst and an acid electrolyte mounted with electrical connections to form a fuel cell. The ethanol molecules enter one side of the cell and are oxidized via acetaldehyde to acetic acid; the current produced is proportional to the concentration of ethanol in the sample

Table 12 Biochemical markers or indicators of acute and chronic intake of alcohol

Biochemical marker	*Specimen for analysis*	*Comments*
Ethanol (EtOH)	Blood, breath, saliva, urine	Highly specific and useful to prove acute alcohol intake; sensitivity depends on amount of alcohol consumed
Ethyl glucuronide (EtG)	Blood or urine	More sensitive than analysis of ethanol, this metabolite is a useful marker for recent drinking up to 24 h after a drinking spree
5-hydroxytryptophol (5-HTOL)	Urine	The predominant urinary metabolite of serotonin is 5-hydroxyindoleacetic acid (5-HIAA), although this shifts towards 5-HTOL during catabolism of alcohol. This leads to an increased ratio of 5-HTOL:5-HIAA, which remains elevated for 10–20 h after end of drinking
γ-glutamyl transferase (GGT)	Serum	This serum marker is elevated after chronic drinking and although fairly sensitive it lacks specificity because other factors can elevate the readings and cause positive results (e.g., various drugs, other liver diseases)
Carbohydrate-deficient transferrin (CDT)	Serum	A widely used marker with good specificity for detecting long-standing heavy drinking
Mean corpuscular volume (MCV)	Red blood cells	Routine clinical laboratory test
Transaminases (AST, ALT)	Serum	Routine clinical laboratory tests, although not very sensitive or specific for alcohol abuse

METHANOL

- Methanol (wood alcohol, methyl alcohol, CH_3OH), is a common ingredient in many solvents, washing solutions and paint removers.

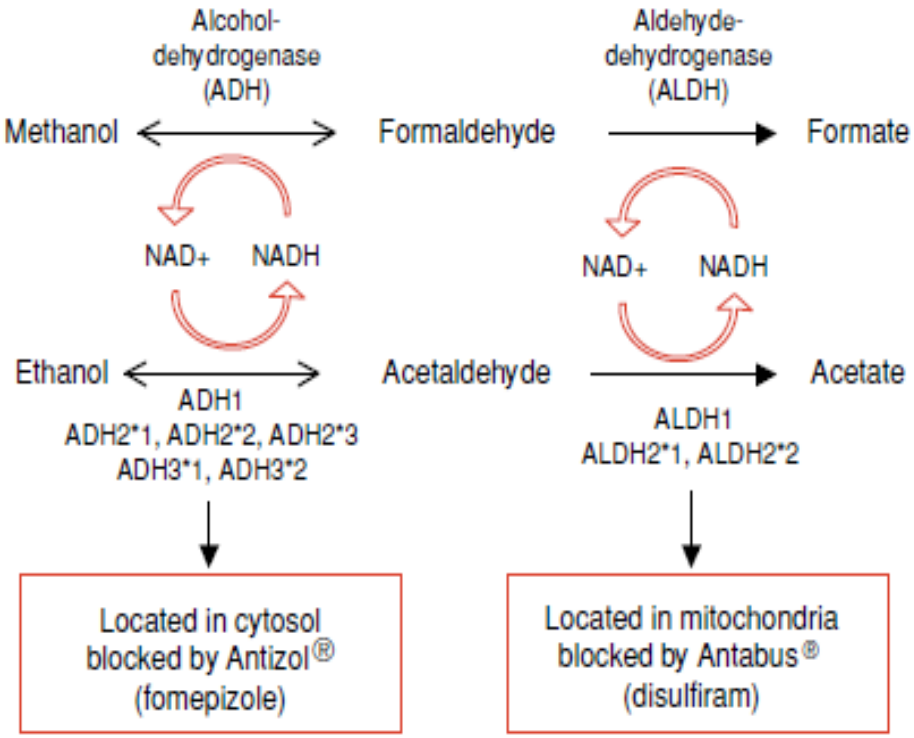

Figure 2 Scheme showing the enzymatic oxidation of ethanol and methanol via alcohol dehydrogenase (ADH) and aldehyde dehydrogenase (ALDH) and the various isozymes involved and examples of drugs that inhibit ADH (fomepizole or 4-methylpyrazole) and ALDH (disulfiram).

Methanol

Toxic dose > 10ml

Fatal dose : 60-240 ml

Clinical features

- **30`- 2h**

  resemble mild ethanol intoxication

- **6 – 30h**

  dizziness, drowsiness, vomiting diarrhea, abdominal pain

Other effects

Hyperglycemia

Mydriasis without light reflex

Blurred or snowfield vision-blindness

Delay in Treatment

Coma

Convulsion

Metabolic acidosis

Acute renal failure

Treatment

- Supportive care
- Gastric lavage
- Na Bicarbonate
- Folic acid
- Antidotes
- Hemodialysis

Antidotes

Ethanol

Fomepizole

Ethanol therapy

- ***Loading dose***

Infusion : 7 ml/kg of ethanol 10% , 30min

Oral : 4ml/kg of ethanol 20% , 30min

Ethanol therapy

- **Maintenance dose**

  ml/kg/h of ethanol 10% (oral , IV)

  - Non-drinker/child 0.88
  - Average adult 1.4
  - Chronic drinker 2

- Ethanol conc. to 100-150 mg%

Fomepizole

L.D. = 15mg/kg (IV)

M.D. = 10mg/kg , q12h , 4 doses

then 15mg/kg , q12h

Fomepizole

- **Contraindication:**

  Hypersensitivity to fomepizole or other pyrazoles.

- **Precautions:**

  Do not give undiluted or bolus injection.

  In children less than 5 years old

  Liver disease

  Renal impairment

Indications for Hemodialysis

- Sever Metabolic Acidosis
- Visual Abnormalities
- Osmolar gap >10 mOsm/L
- Methanol Concentration > 25 mg/dl

ETHYLENE GLYCOL

Ethylene glycol

- Products
- Kinetic
- E.G → … → glyoxalate → oxalate

ADH

Itself is non-toxic

Toxicity being to…

Fatal Dose of Ethylene glycol

Fatal dose in adult : 100ml

Clinical features

- **30’- 1h**

  Resemble ethanol intoxication

  CNS

- **4-12h**

  Drowsiness, tachycardia, hypertension,CHF

- **24-72h**

  Acute R.F, coma ,convulsion,myocard dep.

Other effects

- Hypocalcemia
  - Tetani
  - Arrhythmia
  - Convulsion
- Hypoglycemia
- Hyperkalemia
- Severe metabolic acidosis