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**Glycerol** [Template:IPAc-en](/wiki/Template:IPAc-en)[[1]](#cite_note-1) (also called **glycerine** or **glycerin**; see [spelling differences](/wiki/American_and_British_English_spelling_differences)) is a simple [polyol](/wiki/Polyol) ([sugar alcohol](/wiki/Sugar_alcohol)) compound. It is a colorless, odorless, [viscous](/wiki/Viscous) liquid that is sweet-tasting and non-toxic. It is widely used in the food industry as a sweetener and [humectant](/wiki/Humectant) and in [pharmaceutical formulations](/wiki/Pharmaceutical_formulation). Glycerol has three [hydroxyl groups](/wiki/Hydroxyl_group) that are responsible for its [solubility](/wiki/Solubility) in [water](/wiki/Water) and its [hygroscopic](/wiki/Hygroscopy) nature. The glycerol backbone is central to all [lipids](/wiki/Lipid) known as [triglycerides](/wiki/Triglycerides).

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## Production[[edit](/index.php?title=(none)&action=edit&section=1)]

Glycerol can be either [synthetic](/wiki/Organic_compound#Synthetic_compounds), or derived from plants (usually [soybeans](/wiki/Soybeans) or [palm](/wiki/Arecaceae)) or animals (usually [tallow](/wiki/Tallow)). Approximately 950,000 tons per year are produced in the United States and Europe; 350,000 tons of glycerol were produced per year in the United States alone from 2000 to 2004.[[2]](#cite_note-2) Production will increase as the [EU directive 2003/30/EC](/wiki/Directive_on_the_Promotion_of_the_use_of_biofuels_and_other_renewable_fuels_for_transport) is implemented, which required the replacement of 5.75% of petroleum fuels with [biofuel](/wiki/Biofuel) across all [member states](/wiki/Member_state_of_the_European_Union) by 2010, as glycerol is a byproduct in the production of biodiesel. It was projected in 2006 that by the year 2020, production would be six times more than demand.[[3]](#cite_note-3)[Template:Update needed](/wiki/Template:Update_needed)

### From fats and oils[[edit](/index.php?title=(none)&action=edit&section=2)]

[Triglycerides](/wiki/Triglyceride) found in fats and oils are by definition [esters](/wiki/Ester) of glycerol with long-chain carboxylic acids; the hydrolysis ([saponification](/wiki/Saponification)) or [transesterification](/wiki/Transesterification) of these triglycerides produces [stoichiometric](/wiki/Stoichiometry) quantities of glycerol. In this scheme, glycerol is produced as a co-product in the production of long-chain carboxylate salts used as soaps (see [soap-making](/wiki/Soap-making)):

[400px](/wiki/File:SaponificationGeneral.svg)

It is also a byproduct of the production of [biodiesel](/wiki/Biodiesel) via [transesterification](/wiki/Transesterification). This form of crude glycerol is often dark in appearance with a thick, syrup-like consistency. Triglycerides (**1**) are treated with an alcohol such as ethanol (**2**) with catalytic base to give ethyl esters of fatty acids (**3**) and glycerol (**4**):

[400px](/wiki/File:Transesterification_of_triglycerides_with_ethanol.png)

Glycerol from triglycerides is produced on a large scale, but the crude product is of variable quality, with a low selling price of as low as 1–8 U.S. cents per pound in 2011. It can be purified, but the process is expensive. As a result, a good fraction of crude glycerol is disposed of as waste. Some glycerol is burned for energy, but the heat value is low.[[4]](#cite_note-4) Crude glycerol from the hydrolysis of triglycerides can be purified by treatment with [activated carbon](/wiki/Activated_carbon) to remove organic impurities, alkali to remove unreacted glycerol esters, and [ion exchange](/wiki/Ion_exchange) to remove salts. High purity glycerol (> 99.5%) is obtained by multi-step distillation; vacuum is helpful due to the high boiling point of glycerol (290 °C).<ref name = Ullmann/>

### Synthetic glycerol[[edit](/index.php?title=(none)&action=edit&section=3)]

Synthetic glycerol refers to material obtained from non-triglyceride sources. Glycerol may also be produced by various routes from [propylene](/wiki/Propylene). The [epichlorohydrin](/wiki/Epichlorohydrin) process is the most important; it involves the chlorination of propylene to give [allyl chloride](/wiki/Allyl_chloride), which is oxidized with [hypochlorite](/wiki/Hypochlorite) to dichlorohydrins, which reacts with a strong base to give epichlorohydrin. This epichlorohydrin is then hydrolyzed to give glycerol. Chlorine-free processes from propylene include the synthesis of glycerol from [acrolein](/wiki/Acrolein) and [propylene oxide](/wiki/Propylene_oxide).[[3]](#cite_note-3)

[600px](/wiki/File:Synthetic_routes_to_glycerol.png)

Because of the emphasis on [biodiesel](/wiki/Biodiesel), where glycerol is a waste product, the market for glycerol is depressed, and these old processes are no longer economical on a large scale. Due to the glycerol glut, efforts are being made to convert glycerol to its precursors, such as acrolein and epichlorohydrin.[[5]](#cite_note-5) (See the [Chemical intermediate](/wiki/#Chemical_intermediate) section of this article.)

## Applications[[edit](/index.php?title=(none)&action=edit&section=4)]

### Food industry[[edit](/index.php?title=(none)&action=edit&section=5)]

In food and beverages, glycerol serves as a [humectant](/wiki/Humectant), [solvent](/wiki/Solvent), and [sweetener](/wiki/Sweetener), and may help [preserve foods](/wiki/Food_preservative). It is also used as filler in commercially prepared [low-fat](/wiki/Low-fat) foods (e.g., [cookies](/wiki/Cookie)), and as a [thickening agent](/wiki/Thickening_agent) in [liqueurs](/wiki/Liqueur). Glycerol and water are used to preserve certain types of plant leaves.[[6]](#cite_note-6) As a [sugar substitute](/wiki/Sugar_substitute), it has approximately 27 [kilocalories](/wiki/Food_energy) per [teaspoon](/wiki/Teaspoon) (sugar has 20) and is 60% as [sweet](/wiki/Sweetness) as [sucrose](/wiki/Sucrose). It does not feed the [bacteria](/wiki/Bacteria) that form [plaques](/wiki/Dental_plaque) and cause [dental cavities](/wiki/Dental_cavities). As a [food additive](/wiki/Food_additive), glycerol is labeled as [E number](/wiki/E_number) E422. It is added to icing (frosting) to prevent it from setting too hard.

As used in foods, glycerol is categorized by the [Academy of Nutrition and Dietetics](/wiki/Academy_of_Nutrition_and_Dietetics) as a [carbohydrate](/wiki/Carbohydrate). The U.S. [Food and Drug Administration](/wiki/Food_and_Drug_Administration) (FDA) carbohydrate designation includes all caloric [macronutrients](/wiki/Macronutrient) excluding protein and fat. Glycerol has a caloric density similar to table sugar, but a lower [glycemic index](/wiki/Glycemic_index) and different [metabolic pathway](/wiki/Metabolic_pathway) within the body, so some dietary advocates[Template:Who](/wiki/Template:Who) accept glycerol as a sweetener compatible with [low carbohydrate diets](/wiki/Low_carbohydrate_diet).

It is also recommended as an additive when using polyol sweeteners such as [erythritol](/wiki/Erythritol) and [xylitol](/wiki/Xylitol) which have a cooling effect, due to its heating effect in the mouth, if the cooling effect is not wanted.[[7]](#cite_note-7)

### Pharmaceutical and personal care applications[[edit](/index.php?title=(none)&action=edit&section=6)]

[thumb|right|Glycerol suppositories used as laxatives](/wiki/File:Glycerin_suppositories.jpg) Glycerol is used in [medical](/wiki/Medicine) and [pharmaceutical](/wiki/Pharmaceutical) and [personal care](/wiki/Personal_care) preparations, mainly as a means of improving smoothness, providing [lubrication](/wiki/Lubrication) and as a [humectant](/wiki/Humectant). It is found in allergen immunotherapies, [cough syrups](/wiki/Cough_syrup), elixirs and [expectorants](/wiki/Expectorant), [toothpaste](/wiki/Toothpaste), [mouthwashes](/wiki/Mouthwash), [skin care](/wiki/Skin_care) products, shaving cream, [hair care](/wiki/Hair_care) products, [soaps](/wiki/Soap) and water-based [personal lubricants](/wiki/Personal_lubricant). In solid dosage forms like tablets, glycerol is used as a tablet holding agent. For human consumption, glycerol is classified by the U.S. FDA among the [sugar alcohols](/wiki/Sugar_alcohol) as a caloric macronutrient.

Glycerol is a component of [glycerin soap](/wiki/Glycerin_soap). [Essential oils](/wiki/Essential_oil) are added for [fragrance](/wiki/Fragrance). This kind of soap is used by people with sensitive, easily irritated [skin](/wiki/Skin) because it prevents skin dryness with its [moisturizing](/wiki/Moisturizer) properties. It draws moisture up through skin layers and slows or prevents excessive drying and evaporation.[Template:Citation needed](/wiki/Template:Citation_needed)

Glycerol can be used as a [laxative](/wiki/Laxative) when introduced into the rectum in [suppository](/wiki/Suppository) or small-volume (2–10 ml) ([enema](/wiki/Enema)) form; it irritates the anal mucosa and induces a [hyperosmotic effect](/wiki/Osmotic_laxative).[[8]](#cite_note-8) Taken orally (often mixed with fruit juice to reduce its sweet taste), glycerol can cause a rapid, temporary decrease in the [internal pressure](/wiki/Intraocular_pressure) of the eye. This can be useful for the initial emergency treatment of severely elevated eye pressure.[[9]](#cite_note-9)

### Botanical extracts[[edit](/index.php?title=(none)&action=edit&section=7)]

When utilized in "tincture" method extractions, specifically as a 10% solution, glycerol prevents tannins from precipitating in ethanol extracts of plants ([tinctures](/wiki/Tinctures)). It is also used as an "alcohol-free" alternative to ethanol as a solvent in preparing herbal extractions. It is less extractive when utilized in a standard tincture methodology. Alcohol-based tinctures can also have the alcohol removed and replaced with glycerol for its preserving properties. Such products are not "alcohol-free" in a scientific sense, as glycerol contains three hydroxyl groups. [Fluid extract](/wiki/Fluid_extract) manufacturers often extract herbs in hot water before adding glycerol to make [glycerites](/wiki/Glycerites).[[10]](#cite_note-10)[[11]](#cite_note-11) When used as a primary "true" alcohol-free botanical extraction solvent in non-tincture based methodologies, glycerol has been shown to possess a high degree of extractive versatility for botanicals including removal of numerous constituents and complex compounds, with an extractive power that can rival that of alcohol and water/alcohol solutions.[Template:Citation needed](/wiki/Template:Citation_needed) That glycerol possesses such high extractive power assumes it is utilized with dynamic methodologies as opposed to standard passive "tincturing" methodologies that are better suited to alcohol. Glycerol possesses the intrinsic property of not denaturing or rendering a botanical's constituents inert (as alcohols – i.e. ethyl (grain) alcohol, methyl (wood) alcohol, etc., do). Glycerol is a stable preserving agent for botanical extracts that, when utilized in proper concentrations in an extraction solvent base, does not allow inverting or reduction-oxidation of a finished extract's constituents, even over several years.[Template:Citation needed](/wiki/Template:Citation_needed) Both glycerol and ethanol are viable preserving agents. Glycerol is [bacteriostatic](/wiki/Bacteriostatic) in its action, and ethanol is bactericidal in its action.[[12]](#cite_note-12)[[13]](#cite_note-13)[[14]](#cite_note-14)

### Electronic cigarette liquid[[edit](/index.php?title=(none)&action=edit&section=8)]

Vegetable glycerin is a common component of [e-liquid](/wiki/Construction_of_electronic_cigarettes#E-liquid), a solution used with electronic vaporizers ([electronic cigarettes](/wiki/Electronic_cigarettes)), that is heated with an atomizer to produce a vapor in order to deliver flavors and optionally nicotine.

### Antifreeze[[edit](/index.php?title=(none)&action=edit&section=9)]

[Template:Main](/wiki/Template:Main) Like [ethylene glycol](/wiki/Ethylene_glycol) and [propylene glycol](/wiki/Propylene_glycol), glycerol is a non-ionic [kosmotrope](/wiki/Kosmotropic) that forms strong hydrogen bonds with water molecules, competing with water-water [hydrogen bonds](/wiki/Hydrogen_bonds). This disrupts the crystal lattice formation of ice unless the temperature is significantly lowered. The minimum freezing point temperature is at about −36 °F / −37.8 °C corresponding to 70% glycerol in water.

Glycerol was historically used as an anti-freeze for automotive applications before being replaced by [ethylene glycol](/wiki/Ethylene_glycol), which has a lower freezing point. While the minimum freezing point of a glycerol-water mixture is higher than an ethylene glycol-water mixture, glycerol is not toxic and is being re-examined for use in automotive applications.[[15]](#cite_note-15)[[16]](#cite_note-16) In the laboratory, glycerol is a common component of solvents for [enzymatic](/wiki/Enzyme) reagents stored at temperatures below 0 °C due to the [depression of the freezing temperature](/wiki/Freezing-point_depression). It is also used as a [cryoprotectant](/wiki/Cryoprotectant) where the glycerol is dissolved in water to reduce damage by ice crystals to laboratory organisms that are stored in frozen solutions, such as [bacteria](/wiki/Bacteria), [nematodes](/wiki/Nematode), and mammalian embryos.

### Internal Combustion Fuel[[edit](/index.php?title=(none)&action=edit&section=10)]

Used to power diesel generators supplying electricity for the [FIA](/wiki/FIA) [Formula E](/wiki/Formula_E) series of electric race cars.[[17]](#cite_note-17)

### Chemical intermediate[[edit](/index.php?title=(none)&action=edit&section=11)]

Glycerol is used to produce [nitroglycerin](/wiki/Nitroglycerin), which is an essential ingredient of various explosives such as [dynamite](/wiki/Dynamite), [gelignite](/wiki/Gelignite), and propellants like [cordite](/wiki/Cordite). Reliance on soap-making to supply co-product glycerol made it difficult to increase production to meet wartime demand. Hence, synthetic glycerol processes were national defense priorities in the days leading up to World War II. Nitroglycerin, also known as glyceryl trinitrate (GTN) is commonly used to relieve [*angina pectoris*](/wiki/Angina_pectoris), taken in the form of sub-lingual tablets, or as an aerosol spray.

[Allyl iodide](/wiki/Allyl_iodide), a chemical building block for [polymers](/wiki/Polymers), [preservatives](/wiki/Preservative), [organometallic catalysts](/wiki/Allyl_complex#Metal_allyl_complexes), and [pharmaceuticals](/wiki/Pharmaceuticals), can be synthesized by using elemental [phosphorus](/wiki/Phosphorus) and [iodine](/wiki/Iodine) on glycerol.[[18]](#cite_note-18) A great deal of research is being conducted to try to make value-added products from crude glycerol (typically containing 20% water and residual [esterification](/wiki/Esterification) catalyst) obtained from biodiesel production.[[19]](#cite_note-19) The use of crude glycerol as an additive to biomass for a renewable energy source when burned or gasified is also being explored.

* [Hydrogen](/wiki/Hydrogen) [gas](/wiki/Gas) production unit[[20]](#cite_note-20)\* [Glycerine acetate](/wiki/Glycerine_acetate) (as a potential fuel additive)[[21]](#cite_note-21)\*Conversion to [propylene glycol](/wiki/Propylene_glycol)[[22]](#cite_note-22)\* Conversion to [acrolein](/wiki/Acrolein)[[23]](#cite_note-23)[[24]](#cite_note-24)\* Conversion to [ethanol](/wiki/Ethanol)[[25]](#cite_note-25)\* Conversion to [epichlorohydrin](/wiki/Epichlorohydrin),[[26]](#cite_note-26) a raw material for [epoxy resins](/wiki/Epoxy_resins)

### Film Industry[[edit](/index.php?title=(none)&action=edit&section=12)]

Glycerol is used by the film industry when filming scenes involving water in order to stop areas from drying out too quickly.[[27]](#cite_note-27)

## Metabolism[[edit](/index.php?title=(none)&action=edit&section=13)]

Glycerol is a precursor for synthesis of [triacylglycerols](/wiki/Triacylglycerol) and of [phospholipids](/wiki/Phospholipid) in the liver and [adipose tissue](/wiki/Adipose_tissue). When the body uses stored fat as a source of energy, glycerol and [fatty acids](/wiki/Fatty_acid) are released into the bloodstream. Circulating glycerol does not [glycate](/wiki/Glycate) proteins as do glucose or fructose, and does not lead to the formation of [advanced glycation endproducts](/wiki/Advanced_glycation_endproduct) (AGEs). In some[Template:Which](/wiki/Template:Which) organisms, the glycerol component can enter the glycolysis pathway directly and, thus, provide energy for cellular metabolism (or, potentially, be converted to glucose through gluconeogenesis).

Before glycerol can enter the pathway of [glycolysis](/wiki/Glycolysis) or [gluconeogenesis](/wiki/Gluconeogenesis) (depending on physiological conditions), it must be converted to their intermediate [glyceraldehyde 3-phosphate](/wiki/Glyceraldehyde_3-phosphate) in the following steps:

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Glycerol | [Glycerol kinase](/wiki/Glycerol_kinase) | | [Glycerol-3-phosphate](/wiki/Glycerol-3-phosphate) | [Glycerol-3-phosphate dehydrogenase](/wiki/Glycerol-3-phosphate_dehydrogenase) | | [Dihydroxyacetone phosphate](/wiki/Dihydroxyacetone_phosphate) | [Triosephosphate isomerase](/wiki/Triosephosphate_isomerase) | | [Glyceraldehyde 3-phosphate](/wiki/Glyceraldehyde_3-phosphate) |
| [100px](/wiki/Image:Glycerin_Skelett.svg) | ATP | ADP | [100px](/wiki/Image:Glycerol-3-phosphate.png) | NAD+ | NADH | [125px](/wiki/Image:DHAP_struct.svg) |  |  | [150px](/wiki/Image:G3P-2D-skeletal.png) |
| [60px](/wiki/Image:Biochem_reaction_arrow_forward_YYNN_horiz_med.svg) | | [60px](/wiki/Image:biochem_reaction_arrow_reversible_YYYY_horiz_med.svg) | | [60px](/wiki/Image:Biochem_reaction_arrow_reversible_NNNN_horiz_med.svg) | |
|  |  | NAD+ | NADH |  |  |  |

The enzyme [glycerol kinase](/wiki/Glycerol_kinase) is present mainly in the liver and kidneys, but also in other body tissues, including muscle and brain.[[28]](#cite_note-28)[[29]](#cite_note-29)[[30]](#cite_note-30) In adipose tissue, glycerol 3-phosphate is obtained from [dihydroxyacetone phosphate](/wiki/Dihydroxyacetone_phosphate) (DHAP) with the enzyme [glycerol-3-phosphate dehydrogenase](/wiki/Glycerol-3-phosphate_dehydrogenase).

Glycerol has very low toxicity when ingested; its [LD50](/wiki/LD50) oral dose for rats is 12600 mg/kg and 8700 mg/kg for mice.

## Historical cases of contamination with diethylene[[edit](/index.php?title=(none)&action=edit&section=14)]

On 4 May 2007, the US [Food and Drug Administration](/wiki/Food_and_Drug_Administration) advised all US makers of medicines to test all batches of glycerol for the toxic [diethylene glycol](/wiki/Diethylene_glycol).[[31]](#cite_note-31) This followed an occurrence of [hundreds of fatal poisonings in Panama](/wiki/Toxic_cough_syrup) resulting from a falsified import customs declaration by Panamanian import/export firm Aduanas Javier de Gracia Express, S. A. The cheaper diethylene glycol was relabeled as the more expensive glycerol.[[32]](#cite_note-32)[[33]](#cite_note-33)

## See also[[edit](/index.php?title=(none)&action=edit&section=15)]

* [Epichlorohydrin](/wiki/Epichlorohydrin)
* [Nitroglycerin](/wiki/Nitroglycerin)
* [Oleochemicals](/wiki/Oleochemical)
* [Saponification](/wiki/Saponification)/Soap making
* [Solketal](/wiki/Solketal)
* [Sugar alcohol](/wiki/Sugar_alcohol)
* [Transesterification](/wiki/Transesterification)

## References[[edit](/index.php?title=(none)&action=edit&section=16)]

[Template:Reflist](/wiki/Template:Reflist)

## External links[[edit](/index.php?title=(none)&action=edit&section=17)]

* [Glycerin MS Spectrum](http://gmd.mpimp-golm.mpg.de/Spectrums/06a47467-ce25-4606-9d46-01ca6d04585f.aspx)
* [CDC – NIOSH Pocket Guide to Chemical Hazards – Glycerin (mist)](http://www.cdc.gov/niosh/npg/npgd0302.html)

[Template:Sugar alcohols](/wiki/Template:Sugar_alcohols) [Template:Authority control](/wiki/Template:Authority_control)

[Category:Polyols](/wiki/Category:Polyols) [Category:Food additives](/wiki/Category:Food_additives) [Category:Household chemicals](/wiki/Category:Household_chemicals) [Category:Cosmetics chemicals](/wiki/Category:Cosmetics_chemicals) [Category:Alcohol solvents](/wiki/Category:Alcohol_solvents) [Category:Laxatives](/wiki/Category:Laxatives) [Category:Glassforming liquids and melts](/wiki/Category:Glassforming_liquids_and_melts) [Category:Demulcents](/wiki/Category:Demulcents) [Category:Commodity chemicals](/wiki/Category:Commodity_chemicals)