Ablation

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*Not to be confused with*[*oblation*](http://en.wikipedia.org/wiki/Oblation)*or*[*ablution*](http://en.wikipedia.org/wiki/Ablution)*.*

**Ablation** is removal of material from the surface of an object by [vaporization](http://en.wikipedia.org/wiki/Vaporization), chipping, or other [erosive](http://en.wikipedia.org/wiki/Erosion) processes. Examples of ablative materials are described below and include [spacecraft](http://en.wikipedia.org/wiki/Spacecraft) material for ascent and [atmospheric reentry](http://en.wikipedia.org/wiki/Atmospheric_reentry), ice and snow in [glaciology](http://en.wikipedia.org/wiki/Glaciology), biological tissues in [medicine](http://en.wikipedia.org/wiki/Medicine), and [passive fire protection](http://en.wikipedia.org/wiki/Passive_fire_protection) materials.

[](http://en.wikipedia.org/wiki/File:Ablation_of_quartz_glass_in_a_flashtube.JPG)

[http://bits.wikimedia.org/static-1.23wmf9/skins/common/images/magnify-clip.png](http://en.wikipedia.org/wiki/File:Ablation_of_quartz_glass_in_a_flashtube.JPG)

Ablation near the electrode in a[flashtube](http://en.wikipedia.org/wiki/Flashtube). The high energy electrical arc slowly erodes the glass, leaving a frosted appearance.

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Spaceflight[[edit](http://en.wikipedia.org/w/index.php?title=Ablation&action=edit&section=1)]

*Main article:*[*atmospheric reentry#Ablative*](http://en.wikipedia.org/wiki/Atmospheric_reentry#Ablative)

In [spacecraft](http://en.wikipedia.org/wiki/Spacecraft) design, ablation is used to both cool and protect mechanical parts and/or payloads that would otherwise be damaged by extremely high temperatures. Two principal applications are [heat shields](http://en.wikipedia.org/wiki/Heat_shield) for spacecraft entering a[planetary atmosphere](http://en.wikipedia.org/wiki/Atmosphere) from space and cooling of [rocket engine nozzles](http://en.wikipedia.org/wiki/Rocket_engine_nozzle). Examples include the [Apollo Command Module](http://en.wikipedia.org/wiki/Apollo_Command/Service_Module) that protected astronauts from the [heat](http://en.wikipedia.org/wiki/Heat) of [atmospheric reentry](http://en.wikipedia.org/wiki/Atmospheric_reentry) and the [Kestrel](http://en.wikipedia.org/wiki/Kestrel_(rocket_engine)) [second stage](http://en.wikipedia.org/wiki/Multistage_rocket) [rocket engine](http://en.wikipedia.org/wiki/Rocket_engine)designed for exclusive use in an environment of [space vacuum](http://en.wikipedia.org/wiki/Outer_space#Environment) since no [heat convection](http://en.wikipedia.org/wiki/Convection) is possible.

In a basic sense, ablative material is designed to slowly burn away in a controlled manner, so that heat can be carried away from the spacecraft by the gases generated by the ablative process; while the remaining solid material insulates the craft from superheated gases. There is an entire branch of [spaceflight](http://en.wikipedia.org/wiki/Spaceflight) research involving the search for new [fireproofing](http://en.wikipedia.org/wiki/Fireproofing) materials to achieve the best ablative performance; this function is critical to protect the spacecraft occupants and payload from otherwise excessive heat loading.[[1]](http://en.wikipedia.org/wiki/Ablation#cite_note-1) The same technology is used in some [passive fire protection](http://en.wikipedia.org/wiki/Passive_fire_protection) applications, in some cases by the same vendors, who offer different versions of these [fireproofing](http://en.wikipedia.org/wiki/Fireproofing) products, some for aerospace and some for structural [fire protection](http://en.wikipedia.org/wiki/Fire_protection).

Glaciology[[edit](http://en.wikipedia.org/w/index.php?title=Ablation&action=edit&section=2)]

In glaciology and meteorology, ablation—the opposite of accumulation—refers to all processes that remove snow, ice, or water from a glacier or snowfield.[[2]](http://en.wikipedia.org/wiki/Ablation#cite_note-2) Ablation refers to the melting of snow or ice that runs off the glacier,[evaporation](http://en.wikipedia.org/wiki/Evaporation), [sublimation](http://en.wikipedia.org/wiki/Sublimation_(chemistry)), [calving](http://en.wikipedia.org/wiki/Ice_calving), or erosive removal of snow by wind. Air temperature is typically the dominant control of ablation with precipitation exercising secondary control. In a temperate climate during ablation season, ablation rates typically average around 2 mm/hr.[[3]](http://en.wikipedia.org/wiki/Ablation#cite_note-3) Where solar radiation is the dominant cause of snow ablation (e.g., if air temperatures are low under clear skies), characteristic ablation textures such as [suncups](http://en.wikipedia.org/wiki/Suncup_(snow)" \o "Suncup (snow)) and [penitentes](http://en.wikipedia.org/wiki/Penitentes" \o "Penitentes) may develop on the snow surface.[[4]](http://en.wikipedia.org/wiki/Ablation#cite_note-Betterton-4)

Ablation can refer either to the processes removing ice and snow or to the quantity of ice and snow removed.

Medicine[[edit](http://en.wikipedia.org/w/index.php?title=Ablation&action=edit&section=3)]

In medicine, ablation is the same as removal of a part of [biological tissue](http://en.wikipedia.org/wiki/Biological_tissue), usually by [surgery](http://en.wikipedia.org/wiki/Surgery). Surface ablation of the [skin](http://en.wikipedia.org/wiki/Skin) ([dermabrasion](http://en.wikipedia.org/wiki/Dermabrasion" \o "Dermabrasion), also called resurfacing because it induces [regeneration](http://en.wikipedia.org/wiki/Regeneration_(biology))) can be carried out by chemicals (which cause peeling) or by lasers. Its purpose is to remove skin spots, [aged skin](http://en.wikipedia.org/wiki/Aging), [wrinkles](http://en.wikipedia.org/wiki/Wrinkles), thus [rejuvenating](http://en.wikipedia.org/wiki/Rejuvenation_(aging)) it. Surface ablation is also employed in [otolaryngology](http://en.wikipedia.org/wiki/Otolaryngology) for several kinds of surgery, such as for [snoring](http://en.wikipedia.org/wiki/Snoring). Ablation therapy using radio frequency waves on the heart is used to cure a variety of cardiac arrhythmia such as [supraventricular tachycardia](http://en.wikipedia.org/wiki/Supraventricular_tachycardia" \o "Supraventricular tachycardia), [Wolff–Parkinson–White syndrome](http://en.wikipedia.org/wiki/Wolff%E2%80%93Parkinson%E2%80%93White_syndrome) (WPW), ventricular tachycardia, and more recently as [management of atrial fibrillation](http://en.wikipedia.org/wiki/Management_of_atrial_fibrillation). The term is often used in the context of [laser ablation](http://en.wikipedia.org/wiki/Laser_ablation), a process in which a [laser](http://en.wikipedia.org/wiki/Laser) dissolves a material's [molecular bonds](http://en.wikipedia.org/wiki/Covalent_bond). For a laser to ablate tissues, the power density or [fluence](http://en.wikipedia.org/wiki/Fluence" \o "Fluence) must be high, otherwise thermocoagulation occurs, which is simply thermal vaporization of the tissues.

Rotoablation is a type of arterial cleansing that consists of inserting a tiny, diamond-tipped, drill-like device into the affected artery to remove fatty deposits or plaque. The procedure is used in the treatment of [coronary heart disease](http://en.wikipedia.org/wiki/Coronary_heart_disease) to restore blood flow.

[Radiofrequency ablation](http://en.wikipedia.org/wiki/Radiofrequency_ablation) (RFA) is a method of removing aberrant tissue from within the body via minimally invasive procedures. I.e., RFA in an [electrophysiology study](http://en.wikipedia.org/wiki/Electrophysiology_study) to remove cells that are issuing abnormal electrical activity leading to arrhythmia.

[Bone marrow](http://en.wikipedia.org/wiki/Bone_marrow) ablation is a process whereby the human bone marrow cells are eliminated in preparation for a [bone marrow transplant](http://en.wikipedia.org/wiki/Bone_marrow_transplant). This is performed using high-intensity [chemotherapy](http://en.wikipedia.org/wiki/Chemotherapy) and [total body irradiation](http://en.wikipedia.org/wiki/Total_body_irradiation). As such it has nothing to do with the vaporization techniques described in the rest of this article.

[Ablation of brain tissue](http://en.wikipedia.org/wiki/Ablative_brain_surgery) is used for treating certain [neurological disorders](http://en.wikipedia.org/wiki/Neurological_disorder), particularly [Parkinson's disease](http://en.wikipedia.org/wiki/Parkinson%27s_disease), and sometimes for [psychiatric disorders](http://en.wikipedia.org/wiki/Psychiatric_disorder) as well.

Recently, some researchers reported successful results with genetic ablation. In particular, genetic ablation is potentially a much more efficient method of removing unwanted cells, such as [tumor](http://en.wikipedia.org/wiki/Tumor) cells, because large numbers of animals lacking specific cells could be generated. Genetically ablated lines can be maintained for a prolonged period of time and shared within the research community. Researchers at Columbia University report of reconstituted[caspases](http://en.wikipedia.org/wiki/Caspases) combined from [*C. elegans*](http://en.wikipedia.org/wiki/Caenorhabditis_elegans) and humans, which maintain a high degree of target specificity. The genetic ablation techniques described could prove useful in battling cancer.[[5]](http://en.wikipedia.org/wiki/Ablation#cite_note-5)

Biology[[edit](http://en.wikipedia.org/w/index.php?title=Ablation&action=edit&section=4)]

**Biological ablation** is the removal of a biological structure or functionality.

Genetic ablation is another term for [gene silencing](http://en.wikipedia.org/wiki/Gene_silencing), in which [gene expression](http://en.wikipedia.org/wiki/Gene_expression) is abolished through the alteration or deletion of [genetic sequence](http://en.wikipedia.org/wiki/Genetic_sequence) information. In cell ablation, individual cells in a population or culture are destroyed or removed. Both can be used as experimental tools, as in [loss-of-function](http://en.wikipedia.org/wiki/Loss-of-function) experiments.[[6]](http://en.wikipedia.org/wiki/Ablation#cite_note-6)

Laser ablation[[edit](http://en.wikipedia.org/w/index.php?title=Ablation&action=edit&section=5)]

*Main article:*[*laser ablation*](http://en.wikipedia.org/wiki/Laser_ablation)

[](http://en.wikipedia.org/wiki/File:SSY1_Military_Surplus_Nd-YAG_Laser_Firing.JPG)

[http://bits.wikimedia.org/static-1.23wmf9/skins/common/images/magnify-clip.png](http://en.wikipedia.org/wiki/File:SSY1_Military_Surplus_Nd-YAG_Laser_Firing.JPG)

An [Nd:YAG](http://en.wikipedia.org/wiki/Nd:YAG" \o "Nd:YAG) laser drills a hole through a block of [nitrile](http://en.wikipedia.org/wiki/Nitrile_rubber" \o "Nitrile rubber). The intense burst of infrared radiation ablates the highly absorbing rubber, releasing an eruption of [plasma](http://en.wikipedia.org/wiki/Plasma_(physics)).

[Laser ablation](http://en.wikipedia.org/wiki/Laser_ablation) is greatly affected by the nature of the material and its ability to absorb energy, therefore the wavelength of the ablation laser should have a minimum absorption depth. While these lasers can average a low power, they can offer peak intensity and fluence given by:

\text{Intensity } (\mathrm{W}/\mathrm{cm}^2) = \frac{\text{average power } (\mathrm{W})}{\text{focal spot area } (\mathrm{cm}^2)}

\text{Peak intensity } (\mathrm{W}/\mathrm{cm}^2) = \frac{\text{peak power } (\mathrm{W})}{\text{focal spot area } (\mathrm{cm}^2)}

\text{Fluence } (\mathrm{J}/\mathrm{cm}^2) = \frac{\text{laser pulse energy } (\mathrm{J})}{\text{focal spot area } (\mathrm{cm}^2)}

while the peak power is

\text{Peak power } (\mathrm{W}) = \frac{\text{pulse energy } (\mathrm{J})}{\text{pulse duration } (\mathrm{s})}

Surface ablation of the [cornea](http://en.wikipedia.org/wiki/Cornea) for several types of eye [refractive surgery](http://en.wikipedia.org/wiki/Refractive_surgery) is now common, using an [excimer laser](http://en.wikipedia.org/wiki/Excimer_laser" \o "Excimer laser) system ([LASIK](http://en.wikipedia.org/wiki/LASIK) and [LASEK](http://en.wikipedia.org/wiki/LASEK)). Since the cornea does not grow back, laser is used to remodel the cornea [refractive](http://en.wikipedia.org/wiki/Refraction" \o "Refraction)properties to correct [refraction errors](http://en.wikipedia.org/wiki/Refraction_error), such as [astigmatism](http://en.wikipedia.org/wiki/Astigmatism_(eye)), [myopia](http://en.wikipedia.org/wiki/Myopia), and [hyperopia](http://en.wikipedia.org/wiki/Hyperopia" \o "Hyperopia). Laser ablation is also used to remove part of the [uterine](http://en.wikipedia.org/wiki/Uterus) wall in women with [menstruation](http://en.wikipedia.org/wiki/Menstruation) and [adenomyosis](http://en.wikipedia.org/wiki/Adenomyosis" \o "Adenomyosis) problems in a process called [endometrial ablation](http://en.wikipedia.org/wiki/Endometrial_ablation).

Recently, researchers have demonstrates a successful technique for ablating subsurface tumors with minimal thermal damage to surrounding healthy tissue using a focused laser beam from an ultra-short pulse diode laser source.[[7]](http://en.wikipedia.org/wiki/Ablation#cite_note-7)

Passive fire protection[[edit](http://en.wikipedia.org/w/index.php?title=Ablation&action=edit&section=6)]

[Firestopping](http://en.wikipedia.org/wiki/Firestop) and [fireproofing](http://en.wikipedia.org/wiki/Fireproofing) products can be ablative in nature. This can mean [endothermic](http://en.wikipedia.org/wiki/Endothermic) materials, or merely materials that are sacrificial and become "spent" over time while exposed to [fire](http://en.wikipedia.org/wiki/Fire) such as [silicone](http://en.wikipedia.org/wiki/Silicone) firestop products. Given sufficient time under fire or heat conditions, these products char away, crumble, and disappear. The idea is to put enough of this material in the way of the fire that a level of [fire-resistance rating](http://en.wikipedia.org/wiki/Fire-resistance_rating) can be maintained, as demonstrated in a[fire test](http://en.wikipedia.org/wiki/Fire_test). Ablative materials usually have a large concentration of organic matter[[*citation needed*](http://en.wikipedia.org/wiki/Wikipedia:Citation_needed)] that is reduced by fire to ashes. In the case of silicone, organic [rubber](http://en.wikipedia.org/wiki/Rubber) surrounds very finely divided [silica](http://en.wikipedia.org/wiki/Silica) [dust](http://en.wikipedia.org/wiki/Dust) (up to 380 m² of combined surface area of all the dust particles per gram of this dust[[*citation needed*](http://en.wikipedia.org/wiki/Wikipedia:Citation_needed)]). When the organic rubber is exposed to fire it burns to ash and leaves behind the silica dust with which the product started.

Marine surface coatings[[edit](http://en.wikipedia.org/w/index.php?title=Ablation&action=edit&section=7)]

[Antifouling](http://en.wikipedia.org/wiki/Biofouling#Anti-fouling) paints and other related coatings are routinely used to prevent the buildup of [microorganisms](http://en.wikipedia.org/wiki/Microorganisms) and other animals, such as [barnacles](http://en.wikipedia.org/wiki/Barnacle) for the bottom hull surfaces of recreational, commercial and military sea vessels. Ablative paints are often utilized for this purpose to prevent the dilution or deactivation of the antifouling agent. Over time, the paint will slowly decompose in the water, exposing fresh antifouling compounds on the surface. Engineering the antifouling agents and the ablation rate can produce long-lived protection from the deleterious effects of biofouling.

See also[[edit](http://en.wikipedia.org/w/index.php?title=Ablation&action=edit&section=8)]

* [Ablative armor](http://en.wikipedia.org/wiki/Ablative_armor)

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**Ablative**[[edit](http://en.wikipedia.org/w/index.php?title=Atmospheric_entry&action=edit&section=15)]

[](http://en.wikipedia.org/wiki/File:Apollo_12_heat_shield.JPG)

[http://bits.wikimedia.org/static-1.23wmf10/skins/common/images/magnify-clip.png](http://en.wikipedia.org/wiki/File:Apollo_12_heat_shield.JPG)

Ablative heat shield (after use) on [Apollo 12](http://en.wikipedia.org/wiki/Apollo_12) capsule

The [ablative](http://en.wikipedia.org/wiki/Ablation) heat shield functions by lifting the hot shock layer gas away from the heat shield's outer wall (creating a cooler [boundary layer](http://en.wikipedia.org/wiki/Boundary_layer)). The boundary layer comes from *blowing* of gaseous reaction products from the heat shield material and provides protection against all forms of heat flux. The overall process of reducing the heat flux experienced by the heat shield's outer wall by way of a boundary layer is called *blockage*. Ablation occurs at two levels in an ablative TPS: the outer surface of the TPS material chars, melts, and [sublimes](http://en.wikipedia.org/wiki/Sublimation_(physics)), while the bulk of the TPS material undergoes [pyrolysis](http://en.wikipedia.org/wiki/Pyrolysis" \o "Pyrolysis) and expels product gases. The gas produced by pyrolysis is what drives blowing and causes blockage of convective and catalytic heat flux. [Pyrolysis](http://en.wikipedia.org/wiki/Pyrolysis" \o "Pyrolysis) can be measured in real time using [thermogravimetric analysis](http://en.wikipedia.org/wiki/Thermogravimetric_analysis" \o "Thermogravimetric analysis), so that the ablative performance can be evaluated.[[14]](http://en.wikipedia.org/wiki/Atmospheric_reentry#cite_note-14) Ablation can also provide blockage against radiative heat flux by introducing carbon into the shock layer thus making it optically opaque. Radiative heat flux blockage was the primary thermal protection mechanism of the Galileo Probe TPS material (carbon phenolic). Carbon phenolic was originally developed as a rocket nozzle throat material (used in the [Space Shuttle Solid Rocket Booster](http://en.wikipedia.org/wiki/Space_Shuttle_Solid_Rocket_Booster)) and for re-entry vehicle nose tips.

Early research on ablation technology in the USA was centered at [NASA](http://en.wikipedia.org/wiki/NASA)'s [Ames Research Center](http://en.wikipedia.org/wiki/Ames_Research_Center) located at [Moffett Field](http://en.wikipedia.org/wiki/Moffett_Field), California. [Ames Research Center](http://en.wikipedia.org/wiki/Ames_Research_Center) was ideal, since it had numerous[wind tunnels](http://en.wikipedia.org/wiki/Wind_tunnels) capable of generating varying wind velocities. Initial experiments typically mounted a mock-up of the ablative material to be analyzed within a [hypersonic](http://en.wikipedia.org/wiki/Hypersonic) wind tunnel.[[15]](http://en.wikipedia.org/wiki/Atmospheric_reentry#cite_note-15)

[](http://en.wikipedia.org/wiki/File:Mars_Pathfinder.jpg)

[http://bits.wikimedia.org/static-1.23wmf10/skins/common/images/magnify-clip.png](http://en.wikipedia.org/wiki/File:Mars_Pathfinder.jpg)

Mars Pathfinder during final assembly showing the aeroshell, cruise ring and solid rocket motor

The [thermal conductivity](http://en.wikipedia.org/wiki/Thermal_conductivity) of a TPS material is proportional to the material's density. Carbon phenolic is a very effective ablative material, but also has high density which is undesirable. If the heat flux experienced by an entry vehicle is insufficient to cause pyrolysis then the TPS material's conductivity could allow heat flux conduction into the TPS bondline material thus leading to TPS failure. Consequently for entry trajectories causing lower heat flux, carbon phenolic is sometimes inappropriate and lower density TPS materials such as the following examples can be better design choices: