chapter 7 Sea Urchin Development

Effects of Ultraviolet Radiation [1]

Ultraviolet Radiation in Earth's Atmosphere

What could be more enticing than a sun-drenched beach? Yet that inviting sunlight harbors great potential harm for us, as well as any organism exposed to the damaging ultraviolet rays that pass through our atmosphere. It has been known for some time that ultraviolet light is damaging, and indeed you may have already used it in the laboratory as a germicidal agent. Ultraviolet light kills—and it does so primarily by damaging DNA. So how does any organism survive exposure to ultraviolet light? And how much of a threat are the increasing levels of ultraviolet radiation that are reaching Earth's surface because of the damage we have caused to the protective atmospheric ozone layer?

The damage caused by **ultraviolet** (UV) radiation depends on its wavelength (Figure 7.1). UV wavelengths fall between 200 and 400 nanometers (nm). Above this is visible light, also called **PAR** (photosynthetically active radiation; **400–700 nm**) that is not considered harmful. Within the UV range, the longest wavelengths, which constitute **UV-A** (**320–400 nm**), are the least harmful to biological systems. They are also the type of UV radiation that passes most easily through Earth's atmosphere. Only about 3% of the sunlight reaching Earth's surface is in the ultraviolet range, and most of this is in the UV-A range. **UV-B** (**280–320 nm**; though some sources use 290–320 nm) is significantly more harmful, but most of the UV-B coming from the sun (especially wavelengths below 295 nm) is blocked by the ozone in Earth's upper atmosphere (the stratosphere). Only about 0.25% of the sun's light reaching Earth's surface is UV-B. **UV-C** (**200–280 nm**) is the most highly dangerous to organisms; however, because of its absorption by oxygen in the atmosphere, UV-C never reaches Earth's surface. It is UV-B radiation, therefore, that is of primary concern to biological organisms, and anything that would shift the absorption of UV-B to allow more of this wavelength to reach the Earth's surface should be of major concern to us.

This is precisely what has been happening due to a reduction in the protective ozone shield of the upper atmosphere. This shield has been reduced in recent years by the production of **chlorofluorocarbons** (**CFCs**; these include freon, chloroform, carbon tetrachloride, various cleaning agents of computer circuit boards, and propellants for aerosol cans). CFCs carry chlorine into the upper atmosphere where the chlorine destroys ozone. The increase in CFCs has created such severe ozone depletion that as much as 5% of the ozone shield has disappeared in less than a 10-year period. Even if we were to completely stop the production of CFCs today, it would still take 30 years before the CFCs that are presently in the lower atmosphere finally worked their way into the upper atmosphere. And it would take 70 years beyond that before the ozone levels were restored just to

[1] With thanks to Nikki Adams, Department of Biology, University of California, for her help in developing this chapter.

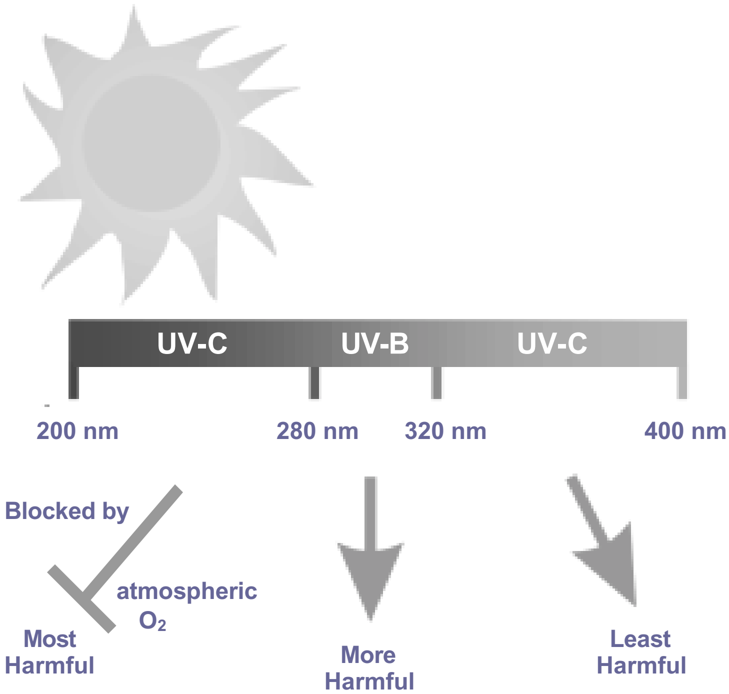

Figure 7.1
The damage caused by ultraviolet radiation depends on its wavelength. UV-C (200-280 nm) is the most harmful, but it doesn't reach Earth's surface, since it is blocked by atmospheric oxygen. UV-B (280-320 nm) is more harmful than UV-A (320-400 nm).

present-day levels. Major efforts toward the elimination of CFCs were made in 1987 when 24 countries signed the Montreal Protocol, and additional countries have signed since then. Even so, there are major **ozone "holes"** that have developed in the upper atmosphere, and these grow and shrink in size with seasonal regularity, becoming their largest in the winter months. Ozone depletion is a global problem, although it is most severe over Antarctica where one ozone "hole" at its largest is the size of the United States.

The effects of this ozone depletion are likely to be most devastating to organisms that are exposed to sunlight during their developmental stages. These include many freshwater and marine species, as well as terrestrial species such as amphibians that return to water for reproduction. Although it used to be thought that UV-B couldn't penetrate into water very far, it has since been learned that UV-B radiation can reach to depths of 20 meters, and UV-A radiation can penetrate even farther. So, many of the organisms that we used to think were protected from increased UV exposure instead are found to be threatened.

Biological Effects of UV Radiation

The damage caused by UV radiation that is environmentally relevant includes that caused by UV-A and UV-B. On an organismal level, this damage results in inhibition of photosynthesis, sunburn, photoaging of the skin, skin cancer, cataracts, damage to the neural retina, and depression of the immune system. On a cellular level, the damage can cause the alteration of DNA, proteins, and lipids, either through direct or indirect effects.

UV-A radiation causes damage indirectly by creating **reactive oxygen species**, such as superoxide anions (O_2^-) and hydrogen peroxide (H_2O_2). These highly reactive molecules cause damage by oxidizing proteins, lipids, and DNA. This oxidation can cause poorly functioning enzymes and structural elements of the cell, and it can result in mutations through alteration of the DNA, which can ultimately lead to cancer.

UV-B radiation causes direct damage to proteins and DNA by creating the formation of **pyrimidine dimers** and **crosslinks** between DNA and protein. This form of radiation causes significant DNA damage, delayed cell divisions, and is responsible for most of the ill effects listed above as the effects of UV light on organisms.

Researchers are beginning to investigate the extent of the effects of increased UV radiation caused by the thinning of our protective atmospheric ozone layer. Already, it has been shown that increased levels of UV-B radiation can be particularly damaging to gametes and embryos. Any organism whose gametes or embryos are exposed to sunlight are likely to be susceptible and at risk.

Mechanims That Protect Against Damage from UV

Organisms are not completely unprotected against the damage caused by UV light, and some have greater amounts of protection than others. Protective mechanisms include natural sunscreens, such as **blue pigments,** which reflect short-wavelength radiation, and pigments and other compounds that absorb UV-B, such as **mycosporine-like amino acids** (**MAAs**). MAAs are found in photosynthetic algae, fungi, and bacteria, and they can accumulate in non-photosynthetic organisms that feed on the MAA-rich organisms.

Physiological mechanisms also exist for repairing the DNA damage inflicted by UV light; these rely on DNA repair enzymes such as **photolyase**. These enzymes repair the UV-induced DNA dimers. Interestingly, these are **photorepair mechanisms**, being activated by light in the visible range and down into the UV-A range. Eggs and embryos can vary in the amounts of photolyase they contain, and these variations can be species-specific. In several amphibian species from the western United States, the species that showed the most deformities induced by UV-B radiation exposure were also the species with the lesser amounts of photolyase (Blaustein et al., 1994; Blaustein et al., 1998).

Using Sea Urchins as a Model Organism for UV Studies

Sea urchins can be used to study damage induced by ultraviolet radiation. They are exposed in nature to UV radiation during all stages of their life cycle, and any analysis of their sensitivity can be used as a measure of the extent of the threat that increased UV-B exposure poses. Although the adults would seem to be well protected from UV radiation by their heavily calcified tests, their gametes and embryos are transparent and poorly protected.

It has long been known that UV radiation is harmful to sea urchin development. As early as 1877 (Downes and Blunt), UV radiation was shown to induce mitotic delay in cells. These results were verified and and shown to apply to sea urchin embryos as well (e.g., Giese, 1946; Rustad, 1971). It has also been shown that UV radiation has adverse effects on sperm, causing sperm to agglutinate, be less motile, and have reduced fertilizing abilities. In most of these earlier studies, however, the emphasis was not on the threats of environmental exposures to UV radiation, and the wavelengths used were often in the UV-C range, a range that isn't environmentally relevant. More recently, however, the ill effects of UV light in environmentally relevant ranges have been documented (e.g., Adams and Shick, 1996; Anderson et al., 1993). These studies show that environmental UV light can cause cleavage delay and a number of developmental abnormalities, such as blastulae that are filled with an abnormally large number of cells, exogastrulae, and bizarrely shaped pluteus larvae with extra spicules. The embryos have proven to be most susceptible to damage when they are exposed during early stages (up to the formation of the blastula) rather than during later stages.

The embryos are not without some protection against UV radiation. Adams and Shick have documented that the accumulation of natural sunscreens (the MAAs discussed earlier) protect the eggs and embryos. These MAAs, found in the algae that is consumed by the adult animal, are stored in the eggs, providing a certain level of protection, depending upon the amounts accumulated. Therefore, by selecting algae high in MAAs, an adult animal can influence the protection from UV radiation that it provides the next generation.

Setting Up Your Experiments

The questions you can ask of sea urchin gametes and embryos about the effects of UV are limited only by your imagination.

- Is the sperm or the egg more susceptible to UV radiation?
- What stages of development are most susceptible to damage by UV radiation?
- Will exposure to differing lengths of daylight affect development?
- Is UV-B or UV-A radiation more harmful to these embryos?
- Is the combined effect of UV-B and UV-A radiation exposure greater than the effect of exposure to only one of these ranges?
- Do antioxidants, such as vitamin C, counteract the effects of UV-A radiation and thus reduce the formation of reactive oxygen species?
- Does exposure to just PAR (visible light) cause any defects?
- Does exposure to PAR mitigate any of the ill effects caused by UV radiation exposure?
- Do the screens for filtering out UV light that we rely on to protect us—such as sunglasses and sunscreen lotions for our skin—actually work?

In getting started, you will want to refer back to Chapter 6, "Echinoid Fertilization and Development," to review how to obtain gametes from the sea urchin, and how to store these gametes until you are ready to use them. Remember that the eggs should be washed several times in seawater to remove any perivisceral fluid and that the sperm should be stored as "dry sperm." Eggs should be maintained at temperatures appropriate for the species. Sperm can be stored in the refrigerator. You should be using these gametes as soon after spawning as possible. Remember that aged eggs (4 hours old or older) are more susceptible to parthenogenesis.

In preparing your cultures, it is best to use artificial or filtered seawater, if possible. This avoids the inclusion of dissolved organic material, which can become oxidized when exposed to UV light, forming reactive oxygen species such as hydrogen peroxide.

You can set up your cultures in petri dishes. You should put no more eggs in a dish than will form a monolayer, since you want to achieve equal exposure to the light conditions. To keep sperm from using up their energy with active swimming, they can be maintained as a thin layer of dry sperm on ice or as diluted sperm in cold (4˚C) seawater. Cultures will have to be kept covered so that they don't lose water to the environment. The cover you choose will depend on the type of light you want to let through.

If you want to test the effects of UV-A and UV-B that are occurring naturally, you can set your cultures up outside to use natural sunlight. Alternatively, you can use a light that mimics the range of light in nature. To test the effects of UV-A and UV-B separately, you can use filters that block certain wavelengths of light, or you can use bulbs that emit only in certain wavelengths. These bulbs are discussed below.

In setting up your exposures, you can use a short exposure period (such as 30 minutes) followed either by dark conditions (to prevent photorepair mechanisms from working) or by visible light conditions that will allow for photorepair. Exposures also can be set to mimic natural light-dark cycles. Using sunlight will automatically give you a natural light-dark cycle. Alternatively, you can choose constant exposure, although you should be aware that some of these exposures could be exceedingly harmful to your embryos and may kill them.

Whatever your setup, remember that you should be keeping your gametes and embryos at a temperature that promotes development. You would have determined this temperature during your previous laboratory on sea urchin development. In many cases, this means that you have to keep your cultures cold. If using natural sunlight, you may need to keep your cultures sitting on ice that you replenish as needed. If using artificial light, again, maintain cultures on ice if needed, or preferably in a cold room or temperature-controlled water bath.

Special lightbulbs that can be used

Everyday room lights Room lighting provides light in the PAR (visible) range. An incandescent bulb emits negligible levels of UV light. Fluorescent bulbs, however, emit measurable levels of UV-B light as well as PAR, and this factor should be considered in your experiments. (You could even test to see if there were any differences between exposure to a fluorescent bulb versus an incandescent bulb.) An unfiltered halogen bulb emits a continuous spectrum that reaches all the way into the UV-C range.

Grow lights A grow light, a light commonly used to enhance growth of house-grown plants, provides light enhanced in the UV-A range without emitting light in the UV-B range.

Sunlamps A sunlamp, such as those sold for home use (e.g., Sylvania FS20 sunlamp), provides light enhanced in the UV-B range. Sunlamps from 20 years ago (275 watts) emit high levels of both UV-A and UV-B radiation.

Black lights A black light, a common accessory to youthful parties (e.g., NEC T10, 20 watts), provides UV-A light.

UV 340 lamps A UV 340 lightbulb supplies light in both the UV-A and UV-B ranges and mimics the light found in nature. These bulbs are commonly used to test paints for weathering in sunlight.

Germicidal lamps A germicidal UV bulb emits light enhanced in the UV-C range. It is therefore not environmentally relevant, but it can be used to show the detrimental effects of this exceedingly harmful radiation.

Filters that can be used to exclude UV-A or UV-B

Whether you are using natural sunlight or a UV 340 bulb, you can test the differing effects of UV-A and UV-B light by filtering out one or the other using various plastics and glass that block specific wavelengths of light. These sheets can be placed over your culture dishes. Alternatively, if you are working out in the field with organisms in their natural environment, you can use containers or bags made from the material. You can place the embryos in the containers or bags and suspend them in the water where they are normally found.

Filters that block UV-B	Allows through UV-A and PAR	glass Xerox transparencies plastic milk bottle Mylar film
Filters that block UV-A and UV-B (UV opaque)	Allows through PAR	standard plexiglass "light-block" plastic milkbottle sunglasses (rated as 100% UV blocking) sunscreens (variable) UV opaque plexiglass
UV transparent filters	Allows through UV-A, UV-B, and PAR	plastic petri dish plastic sandwich bag plastic food wrap UV transparent plexiglass cellulose acetate

Filters that block UV-B

These will test the effects of exposure to UV-A and PAR.

Glass Plate glass blocks almost all UV-B light while allowing through most UV-A light and PAR. For example, 1/8-inch plate glass blocks all UV-B while allowing through 76% of the UV-A light and PAR. A glass slide blocks all of the UV-B while allowing through 85% of the UV-A light and PAR. A finger bowl blocks all of the UV-B while allowing through 61% of the UV-A and PAR. (N.B.: Pyrex glass petri dishes do not block UV-B effectively.)

Xerox transparencies The transparency films that are used for copier machines block 95% of UV-B while allowing through 77% of UV-A and PAR.

Plastic milk bottle An ordinary plastic milk bottle blocks all UV-B light while allowing through 55% of the UV-A and 80% of PAR.

Mylar A special type of Mylar film (Mylar type D fluoropolymer film) blocks all UV-B radiation.

Filters that block both UV-A and UV-B (UV opaque)

These will test the effects of exposure only to PAR (visible light).

Standard plexiglass Standard plexiglass blocks all UV-B and most UV-A radiation while allowing PAR through.

"Light-block" plastic milk bottle The special "light-block" plastic bottles designed to protect the vitamins in milk from breaking down block all UV-B light and virtually all UV-A, while allowing through only 14% of PAR.

Sunglasses Your own sunglasses, if bought recently, come with a rating as to how much UV-A and UV-B they block. It would be interesting to test these as a filter, both for their protective effects on the embryos as well as for the reliability of their advertised claims.

Sunscreens The sunsreens you buy to shield your skin may or may not be effective in blocking UV radiation. You could test them by applying a thin film on a UV-transparent substance such as a plastic petri dish or a plastic sandwich bag.

UV opaque plexiglass A specially formulated plexiglass can be obtained (Plexiglas® G UF-3 acrylic) that blocks all of UV-A and UV-B but allows through PAR.

Filters that do not block either UV-A or UV-B (UV transparent)

These can be used as a control cover, so that all cultures are covered by a plastic sheet.

Plastic petri dish A plastic petri dish allows through most UV-A (81%) and substantial amounts of UV-B (50%) radiation as well as PAR.

Plastic sandwich bag The plastic bags you use for food storage allow through almost all UV-A, UV-B, and PAR.

Plastic food wrap The plastic food wrap that you commonly wrap around your sandwiches allows through virtually all UV-A, UV-B, and PAR.

UV transparent plexiglass A specially formulated plexiglass can be obtained (Plexiglas® G UVT acrylic) that doesn't block PAR, UV-A, or UV-B. It does block UV-C.

Cellulose acetate Cellulose acetate, like UV transparent plexiglass, doesn't block PAR, UV-A, or UV-B, but it does block UV-C. Since it is less expensive than UV transparent plexiglass, it may be a preferred material to use.

Safety first

Remember that any bulb emitting UV light will be damaging to you. UV light is very damaging to your eyes: it can cause cataracts by damaging your lens, and blindness by damaging your retina. You must wear protective glasses, therefore, when exposed to UV light. If possible, avoid having the UV lights on when you are present. UV light also causes **photoaging** of the skin (making your skin leathery and lined), as well as **skin cancer**. So you should wear protective clothing as well whenever you risk exposure to UV light.

Monitoring Your Cultures

In monitoring your cultures, you can look for a number of things: fertilization delays, cleavage delays, and developmental delays, as well as abnormalities in any of the stages.

Record any differences that you see in your cultures as a percent of normal. Count 100 embryos, then record the number of abnormal/normal.

Data simply on the timing of development are valuable. Realize that an alteration in the rate of development can cause embryos to emerge as juveniles when natural conditions may not be optimal for them. You can record when your cultures reach the blastula stage; the appearance of a hatched blastula, early gastrulation, and late gastrulation; the stage of spicule formation; and so on. Always compare your experimental results with a control culture.

Developmental abnormalities are also very likely to occur, especially on exposure to increased levels of UV-B radiation. Look for any developmental abnormalities, such as a blastula stage that fills up with cells, exogastrulae, abnormally long cilia, and extra spicules.

The abnormalities you observe may deal with size differences. You can determine changes in size by measuring the diameters of cleavage-stage embryos and both the outer and inner diameters of blastula stages and later. This will allow you to determine if a smaller blastocoel is caused by a smaller embryo or by taller cells.

Keeping Up with the Issues

When it comes to dealing with the issue of UV radiation, it is important to avoid being part of the problem and to actively be part of the solution. Increased UV radiation levels affect all of us, and already we are experiencing the effects through increased levels of skin cancer and cataracts. One way to participate is to keep informed. Several websites are devoted to ultraviolet radiation monitoring and can keep you up to date on increased levels in your area as well as globally. For the United States, these include the National Ultraviolet Monitoring Center (http://oz.physast.uga.edu/) and the EPA's Ultraviolet Radiation Monitoring Network (www.epa.gov/uvnet). Another EPA site deals specifically with the depletion of the ozone layer (www.epa.gov/docs/ozone). It details how you can avoid adding to the problem by explaining what substances cause ozone depletion and what substances can be used as substitutes. It also lists regulations that are in place. A site that gives information on international efforts to protect the ozone layer, run by the United Nations, can be found at www.undp.org/seed/eanda/montreal.htm.

Accompanying Materials

See *Vade Mecum:* "Sea urchin–UV." This chapter of the CD has interactive units on normal sea urchin development and on the developmental abnormalities in sea urchin embryos caused by UV-B exposure.

Gilbert, S. F. 2003. *Developmental Biology*, 7th Ed. Sinauer Associates, Sunderland, MA. Contains a chapter that discusses the harmful effects of ultraviolet radiation on embryos.

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Adams, N. L. 1999. The green sea urchin, *Strongylocentrotus droebachiensis,* covers itself in response to ultraviolet radiation. *Amer. Zool.* 39: 113A**.** A beautiful study showing that sea urchins protect themselves from UV radiation in part by covering themselves with shells and seaweed, or whatever is available to them.

Adams, N. L. and J. M. Shick. 1996. Mycosporine-like amino acids provide protection against ultraviolet radiation in eggs of the green sea urchin, *Stongylocentrotus droebachiensis*. *Photochem and Photobiol*., 64: 149–158. A detailed analysis of MAAs in sea urchin eggs, this study reports that MAAs do protect these eggs from UV radiation.

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De Gruijl, F. R. and P. D. Forbes. 1995**.** UV-induced skin cancer in a hairless mouse model. *BioEssays* 17 (7): 651–660. This is an excellent discussion of the hazards of UV radiation that humans are commonly exposed to.

Downes, A. and T. P. Blunt. 1877. Researches on the effect of light upon bacteria and other organisms. *Proc. Roy. Soc. Lond.* 26: 488–500. A lesson in history. As early as 1877, these researchers showed that UV radiation induced mitotic delay in cells.

Dunlap, W. C. and J. M. Shick. 1998. Ultraviolet radiation-absorbing mycosporine-like amino acids in coral reef organisms: a biochemical and environmental perspective. *J. Phycol.* 34: 418–430. A superb review of the protective value of MAAs in coral reef organisms.

Epel, D., K. Hemela, J. M. Shick and C. Patton. 1999. Development in the floating world: defenses of eggs and embryos against damage from UV radiation. *Amer. Zool.* 39: 271–278. A well-written article that discusses many of the questions surrounding UV radiation damage to embryos while focusing of the damage and protective devices in tunicate embryos.

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Suppliers

Cadillac Plastic
2855 Coolidge Highway, Suite 300
Troy, MI 48084
1-800-274-1000
www.cadillacplastic.com

Plexiglas® G UVT Acrylic, 6 mm thick (UVT—allows through UV-B, UV-A, and PAR)
Plexiglas® G UF-3 acrylic sheet, 6 mm thick (UVO— blocks all UV, allows through PAR only)

Allied Signal Plastics
P. O. Box 1205
Pottsville, PA 17901
1-800-934-5679
www.honeywell.com

Aclar 33c Fluoropolymer film, 127 microns thick 5 gauge (UVT—allows through UV-B, UV-A, and PAR)

DuPont Teijin Films
Barley Mill Plaza, Bldg 27
Lancaster Pike and Route 141
P. O. Box 80027
Wilmington, DE 19880-0027
www.dupontteijinfilms.com

AIN Plastics
249 E. Sandford Blvd.
P. O. Box 151
Mount Vernon, NY 10550
1-800-431-2451
www.tincna.com/ain1.htm

Mylar type D fluoropolymer film, 127 microns thick (5 mil) (Blocks UV-B—allows through UV-A and PAR)

Polycast Technology Corporation
70 Carlisle Place
Stamford, CT 06902
1-800-243-9002
www.polycast.com

Carolina Biological Supply Company
2700 York Road
Burlington, NC 27215
1-800-334-5551 or
1-910-584-0381
www.carolina.com

UV 340 bulbs (mimic the UV-A and UV-B range of nature)
UV-C (germicidal) lamps—not environmentally relevant

Science supply companies such as:
Ward's Natural Science Establishment, Inc.
P.O. Box 92912
5100 West Henrietta Road
Rochester, NY 14692-9012
1-800-962-2660
www.wardsci.com

UV safety goggles

Glossary

Antioxidant: A substance that neutralizes reactive oxygen species by offering their own electrons and so protect other molecules from harm. Beta-carotene, vitamins A, C and E, and the minerals selenium and zinc are antioxidants.

Archenteron: Literally, ancient gut. The primitive gut formed during gastrulation.

Artificial seawater: A salt solution that can be used instead of sea water. It includes the major salts found in sea water, sodium chloride, potassium chloride, magnesium chloride, magnesium sulfate, and calcium chloride.

Black lights: A blacklight, common at college parties (e.g., NEC T10, 20W), provides UV-A light.

Blastocoel: The cavity within a blastula.

Blastula stage: The stage in embryonic development following cleavage and preceding gastrulation. The embryo may form a hollow blastula (coeloblastula) or a solid blastula (stereoblastula). The cavity formed in a coeloblastula is called the blastocoel.

CFCs: Chlorofluorocarbons.

Chlorofluorocarbons (CFCs): Compounds that can carry chlorine into the upper atmosphere where the chlorine destroys ozone. CFCs include freon, chloroform, carbon tetrachloride, various cleaning agents of computer circuit boards, and propellants for aerosol cans.

Dry sperm: Sperm that have been shed and are kept in this concentrated form, undiluted. In experimental procedures, it is often useful to store sperm as dry sperm, since they survive for longer periods in this form.

Echinopluteus (pluteus) larva: The type of larva typical of echinoids (sea urchins, etc). It consists of a delicate body with long arm-like extensions supported by spicules.

Exogastrula: A deformity in developing embryos in which the archenterons, instead of invaginating, evaginates, forming an external archenteron.

Fertilization: Fusion of egg and sperm.

Gastrulation: The stage in embryonic development that follows cleavage. During gastrulation, cells rearrange themselves, the endoderm and mesoderm cells moving inward and the ectoderm cells spreading around the outside, with some ectoderm invaginating to form such structures as the stomodeum.

Germicidal lamp: A UV-bulb that emits light enhanced in the UV-C range. It is used to sterilize an area. It is dangerous to the eyes and skin, and should be turned off before a person enters the work area.

Grow lights: A light commonly used to enhance growth of house-grown plants. It provides light enhanced in the UV-A range without emitting light in the UV-B range.

Hatched blastula: A term used to describe the echinoid (sea urchin, etc.) embryo when it has hatched out of its fertilization envelope. This occurs early in development, just after primary mesenchyme cells have started to ingress.

Hydrogen peroxide: H_2O_2. A highly reactive compound that can damage biological systems by oxidizing components such as proteins, lipids, and DNA.

Invagination: The folding inward of a sheet of cells. This is a common type of movement during gastrulation. In the sea urchin, for example, the archenteron first forms by an invagination of the vegetal plate.

MAAs: Mycosporine-like amino acids.

Micromeres: Cells in a blastula that are smaller than the others. In the sea urchin embryo, micromeres form at the vegetal pole at the 16-cell stage. These will form the primary mesenchyme.

Mycosporine-like amino acids (MAAs): Amino acids that absorb UV-B radiation and therefore can protect organisms against the harmful effects of UV-B radiation. Found in photosynthetic algae, fungi, and bacteria, and those organisms that accumulate MAAs through their diet. Considered a natural sunscreen.

Ozone: O_3. An allotropic (alternative) form of oxygen. In our upper atmosphere, it protects the Earth's surface from UV-B radiation. In the lower atmosphere, it is a pollutant that is harmful to the health of organisms.

Ozone holes: Holes in the protective ozone shield in the Earth's stratosphere that are allowing greater amounts of the exceedingly harmful UV-B radiation to penetrate to the Earth's surface. As much as 5% of the this ozone shield has disappeared in less than a 10-year period.

PAR: Stands for photosynthetically active radiation. This is the range of wavelengths (400-700 nm) that can activate photosynthetically active pigments. It is not considered harmful.

Parthenogenesis: The development of an egg without fertilization.

Photoaging: Aging of tissues that is induced by UV-radiation. This can be attributed in large part to the cross-linking of collagen. Highly cross-linked collagen in the dermis causes wrinkles. Photoaging of the skin results in leathery-looking skin that is deeply lined.

Photolyase: An enzyme that is activated by light and that repairs UV-induced DNA dimers.

Photorepair mechanisms: Cellular repair mechanisms that are activated by light.

Pluteus larva: The type of larva typical of echinoderms. It consists of a delicate body with long arm-like extensions supported by spicules.

Primary mesenchyme: Mesoderm cells in echinoid embryos (such as those of the sea urchin) derived from the micromeres that are the first cells to enter the blastocoel during gastrulation. They form the spicules of the larva.

Prism larval stage: In an echinoid (sea urchin, etc.) larva, the stage at which the larva is shaped like a prism. It is an early stage in larval development.

Pyrimidine dimers: Dimers of any of the pyrimidine bases, cytosine, thymine, uracil.

Reactive oxygen species: Highly reactive oxygen containing molecules that cause damage to biological systems by oxidizing components such as proteins, lipids, and DNA. Examples are superoxide anions (O_2^-) and hydrogen peroxide (H_2O_2).

Skin cancer: Cancer that starts in the skin. Types include melanoma, a deadly cancer if not caught early, squamous cell carcinoma, and basal cell carcinoma. UV-radiation is thought to be responsible for most incidences of basal cell and squamous cell carcinomas. A reasonable correlation exists between UV-radiation exposure and melanoma, but the relationship is not as clear as with the other two types of cancer.

Spawning: The release of gametes (eggs or sperm).

Spicules: In the echinoid (sea urchin, etc.) larva, these are the calcium carbonate structures that serve as the skeletal supports for the larva. The are laid down by the primary mesenchyme cells.

Standard sperm suspension: The diluted form of sperm that is used for fertilization studies. In the sea urchin, for example, this is 1 drop of dry sperm in 10 ml of seawater.

Stratosphere: The Earth's upper atmosphere. It contains a protective layer of ozone which prevents most of the highly harmful UV-B radiation from penetrating to the Earth's surface.

Sunlamps: A lamp that provides light enhanced in the UV-B range. Sunlamps from 20 years ago emit high levels of both UV-A and UV-B radiation.

Ultraviolet radiation: Radiation of wavelengths that fall between 200 and 400 nanometers (nm).

UV 340 lamps: A light bulb that supplies light in both the UV-A and UV-B ranges and mimics the light found in nature.

UV-A: The longest wavelengths (320-400 nm) within the ultraviolet range. This range is harmful to biological organisms, but is less harmful than UV-B or UV-C. Most of the UV radiation reaching the Earth's surface is in the UV-A range.

UV-B: The range of wavelengths within the ultraviolet that fall between 280-320 nm. (Some sources use 290-320 nm.) UV-B radiation is significantly more harmful to biological organisms than UV-A. Most of the UV-B radiation coming from the sun is blocked by the ozone in the Earth's upper atmosphere. Holes developing in this ozone layer are allowing greater amounts of UV-B radiation to penetrate to the Earth's surface.

UV-B filters: Filters that block UV-B radiation, but allow UV-A radiation and PAR to pass through. Examples include glass, Xerox transparencies, plastic milk bottles, and Mylar film.

UV-C: Ultraviolet radiation in the range of 200-280 nm. This is the most highly dangerous range of UV radiation for biological organisms. It is absorbed by oxygen in the atmosphere, such that it never reaches the Earth's surface.

UV-opaque filters: Filters that block UV-A and UV-B radiation, but allow PAR to pass through. Examples include standard plexiglass, sunglasses rated as 100% UV-blocking, light-block plastic milk bottles, and many cosmetic sunscreens.

UV-transparent filters: Filters that allow UV-A, UV-B radiation and PAR to pass through. Examples include plastic petri dishes, plastic sandwich bags, plastic food wrap, UV-transparent plexiglass, and cellulose acetate.