Adapting to a Warmer World

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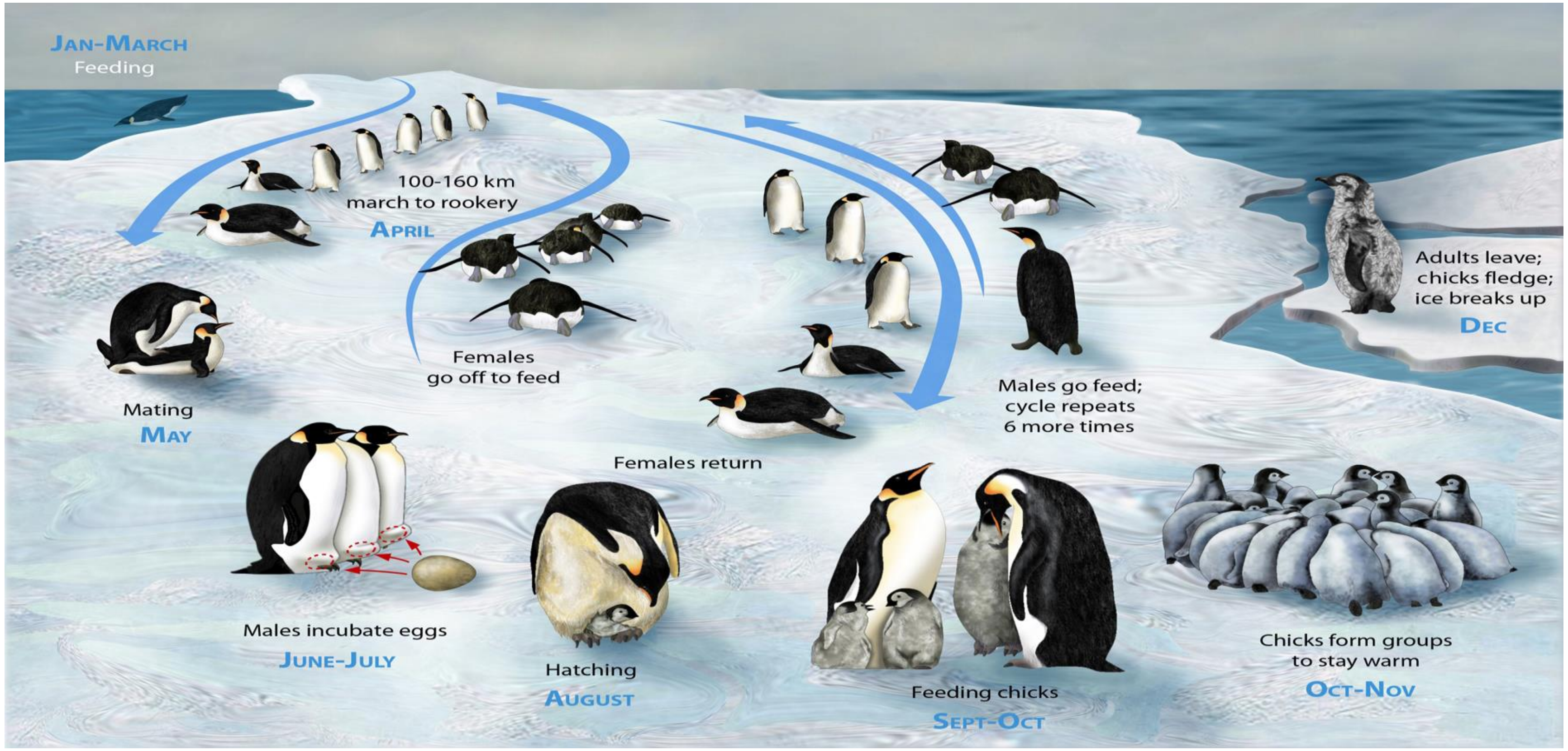
Caution! This presentation may be more about penguins than you really wanted to know.



There are at least three major aspects involved in dealing with and adapting to an increase in environmental temperature (a warmer world). These are: physiological, behavioral and genetic. This presentation will go into each of these in some detail which will, in all likelihood, be more about penguins than what you had in mind for this topic. Nonetheless, I hope you enjoy and obtain some useful information to boot.

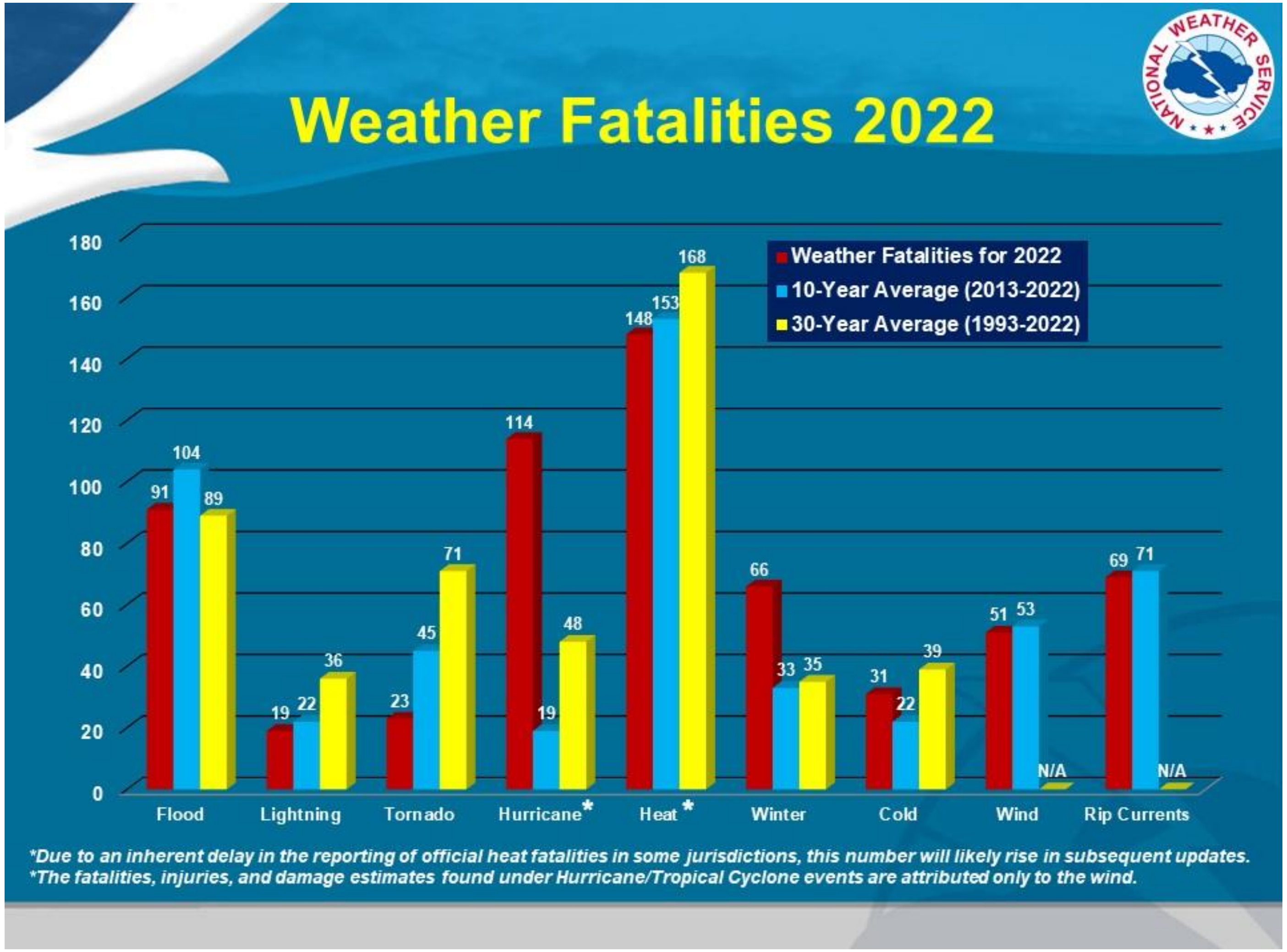


Figure 3: The bar graph shown here presents weather-related fatalities for a single year (2022) and for 10 and 30 year averages. Note that all three time frames show that heat is our most lethal weather-related phenomenon.

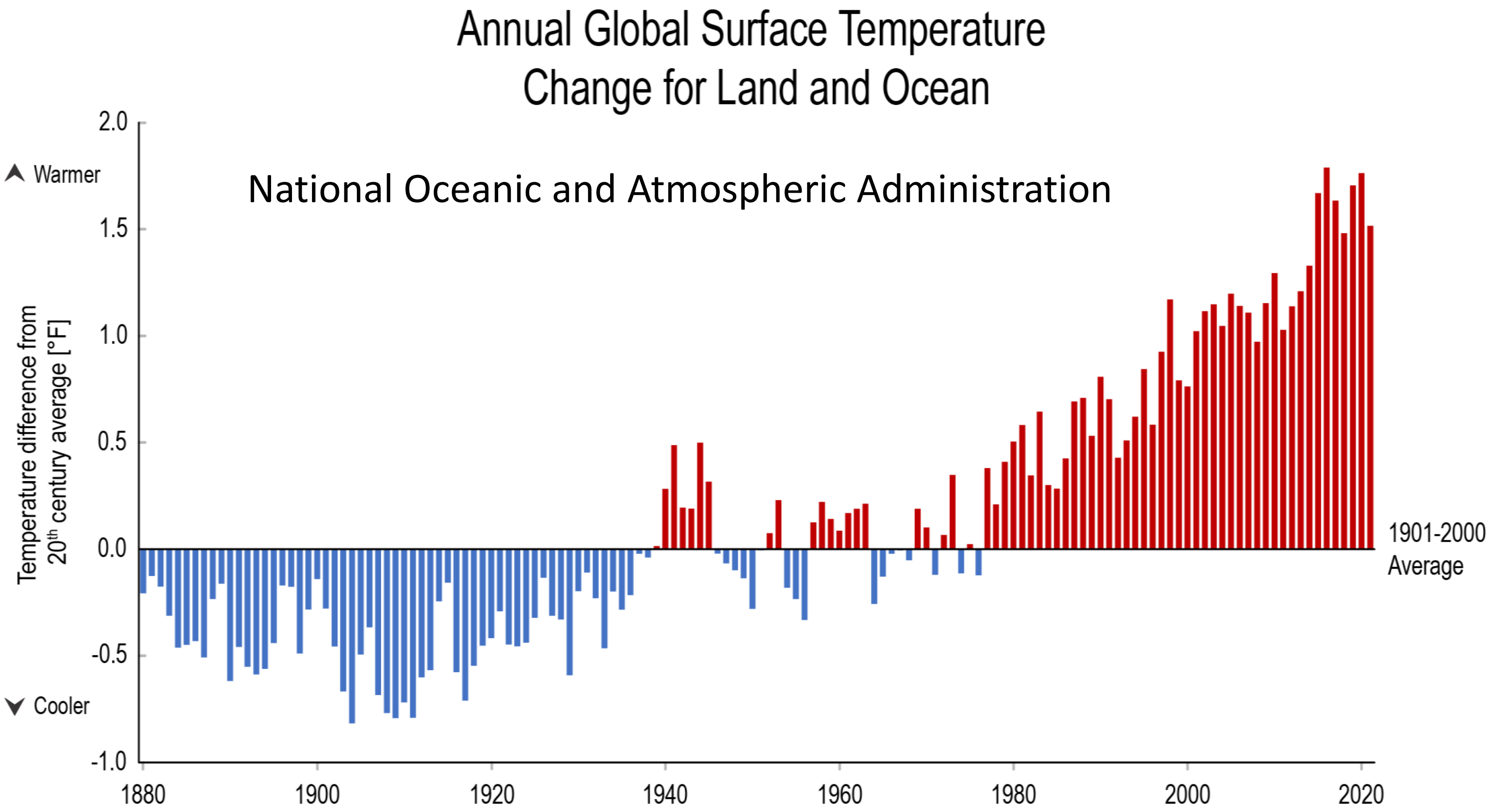


Figure 4: This graph of annual global surface temperatures for land and ocean combined was obtained by first taking the average daily surface temperature year-round for the entirety of the 20th century. That value was then used as a zero baseline to determine the annual change in temperature from the years 1880 to 2020. Note that starting at about 1980 there has been a steady rise in average year-round temperature.

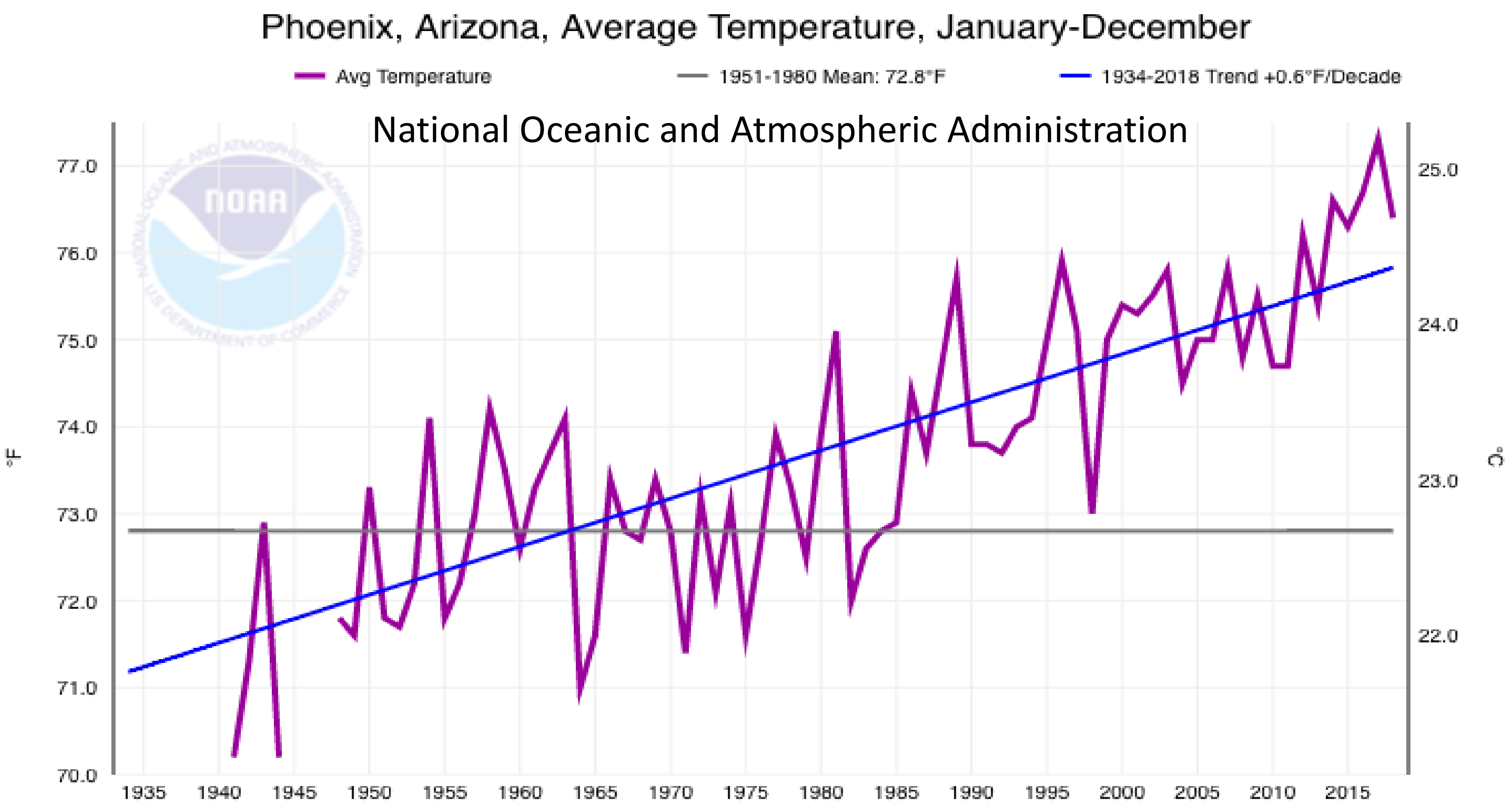


Figure 5: This graph shows average annual temperatures for Phoenix, AZ in both degrees Fahrenheit and Celsius (purple lines). The black line gives the 30-year average from 1951 through 1980. Ignoring the blue line, it can be seen that starting about 1980 temperature began to rise in a manner similar to that for global temperature seen in Figure 4.

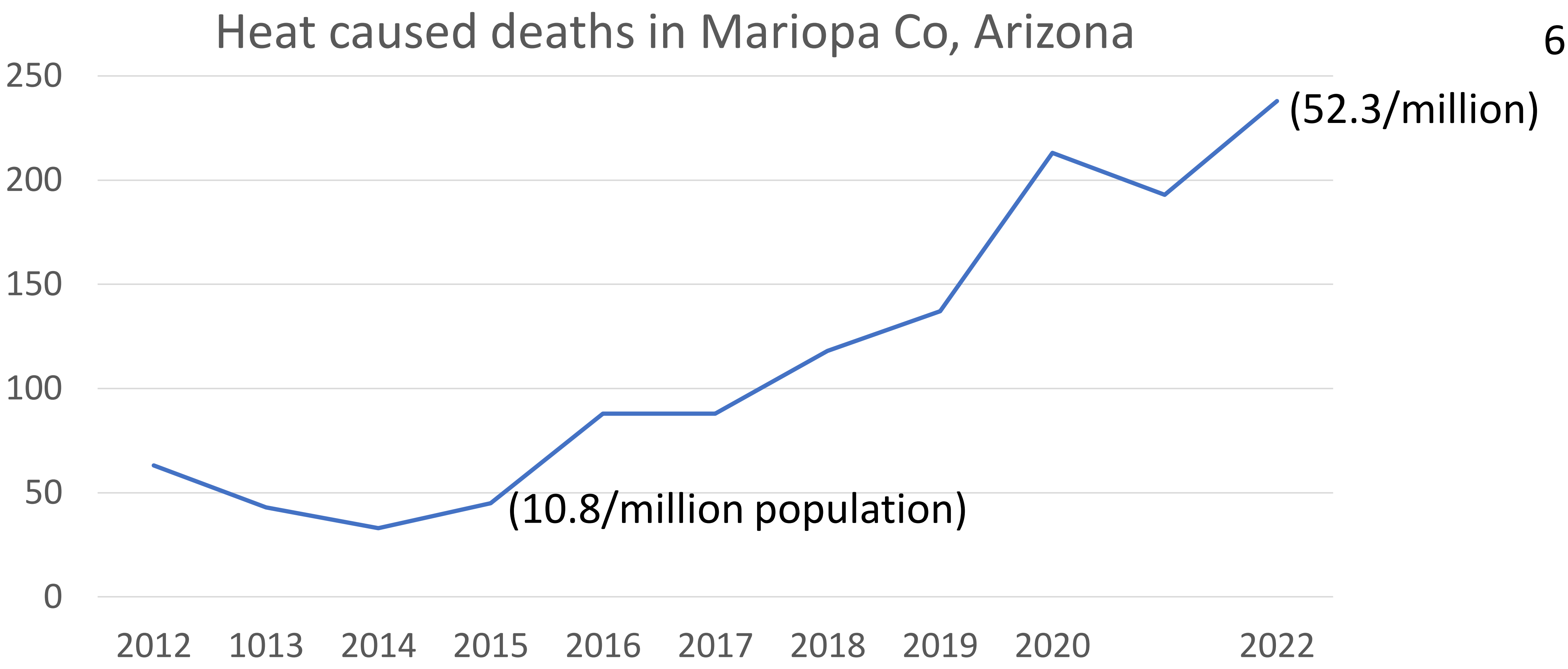


Figure 6: Shown here are the number of heat-caused deaths in Maricopa County, AZ from 2012 to and including 2022. The numbers in brackets are the absolute values factored by population which indicate that the rise in the number of deaths is not simply due to population growth. The term "heat-caused" means that death was directly due to the condition of hyperthermia, the salient features of which are given in the next figure.

Heat caused = Hyperthermia (aka heat stroke)*

- high body temperature
- hot dry skin
- little or no sweating
- nausea
- decreased skin turgor

*a life threatening condition (call 911)

Figure 7: This figure gives the descriptive features of hyperthermia. Of these, the hot dry skin, little or no sweating and reduced skin turgor are unique to this condition. Turgor, or turgidity, is a condition of rigidity in tissues. When skin with normal turgor is deformed, as with pinching, it will return to its original shape when the deforming force is removed. This indicates that the skin is properly hydrated. With dehydration the skin will remain deformed when the force is removed, as is the case with a person experiencing hyperthermia. As noted, hyperthermia is a life-threatening condition. If and when encountering a person in this condition, call 911 and they will, or should, tell you what to do until help arrives. A good reason to carry a cellphone when out in summer heat.

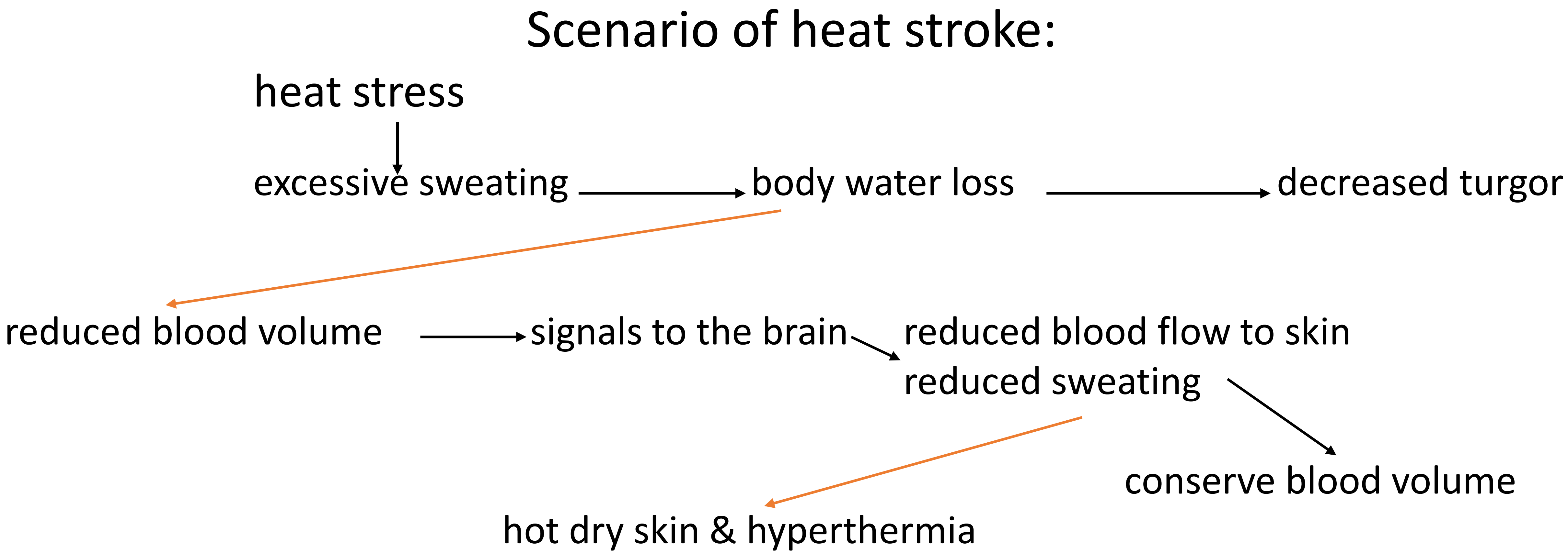


Figure 8: Shown here is the sequence of events resulting in hyperthermia. The key factor is that excessive sweating causes a loss of body water sufficient to significantly reduce the plasma (watery) component of blood volume. Since the heart can't properly function without adequate blood volume, regulatory mechanisms in the body attempt to arrest the continual loss of blood plasma by considerably reducing, or altogether stopping, sweat production which, in turn, throws the person into the condition of hyperthermia.

Review of body temperature regulation in response to heat:

Physiological

Maintains body temp in warm environments

Behavioral (dressing for hot weather) & Physiological

Maintains body temp in warm to hot environments

Figure 9: The two means by which body temperature is maintained within a range conducive to life, physiological mechanisms and behavioral decisions, are interactive and mutually interdependent. It was the latter that enabled our prehistoric ancestors to migrate from temperate regions of Africa into colder regions of the world.

Two main physiological/physical mechanisms

Evaporation

Body heat is carried away as water vapor.

Occurs mainly, *but not exclusively*, by sweating.

Convection

Air currents carry away heat from the surface(skin) of the body including the heat in water vapor produced by sweating.

Figure 10: The two physiological means by which body temperature is regulated both utilize certain physical properties. With evaporative cooling, body heat provides the energy necessary to vaporize watery sweat on the surface of the skin. That heat is then carried away from the body as vaporized water. Convection is the process by which heat and/or water vapor on the surface of the skin is carried away by air currents. That's how fans and a breezy day serve to keep us cool.

General Scheme of Response to Heat

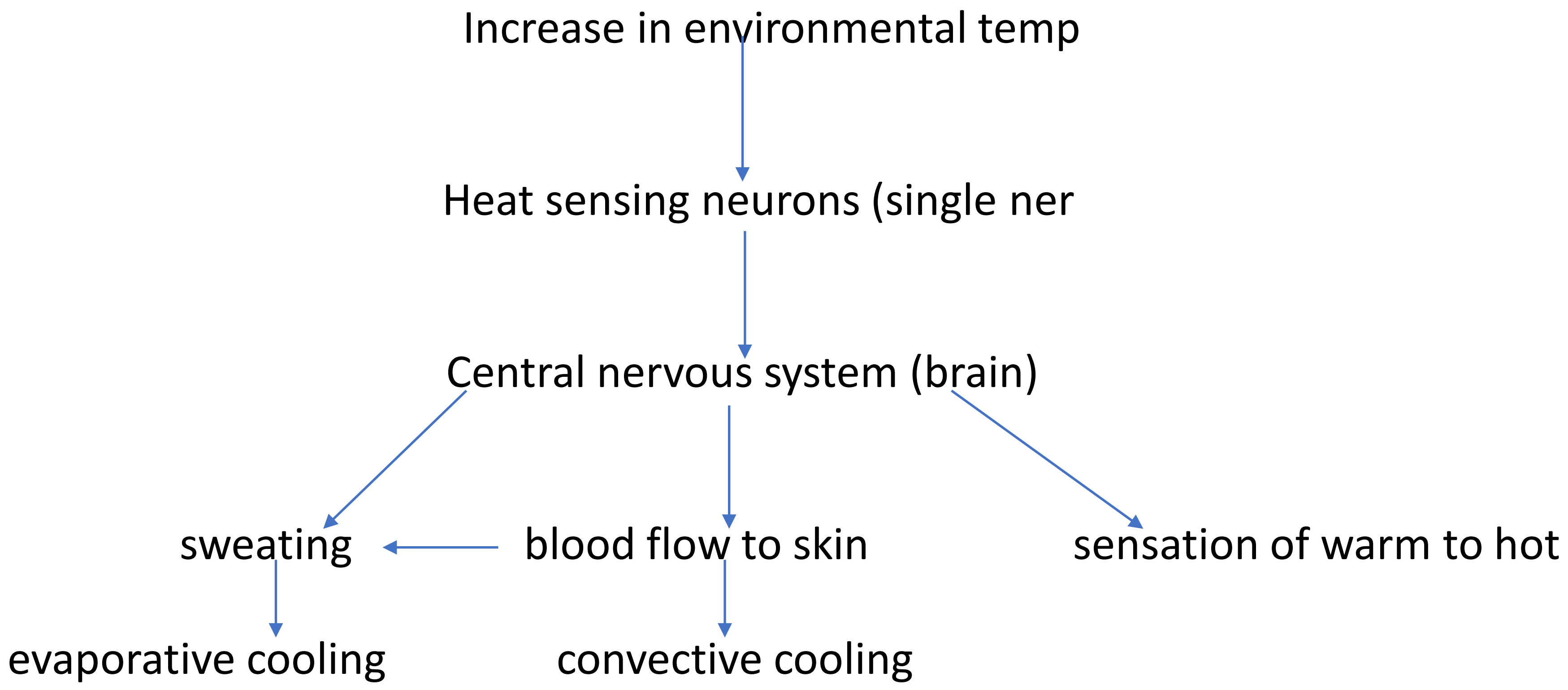


Figure 11: This chart points out the importance of the nervous system in both physiological and behavioral means of body temperature regulation. As noted, the sweating mechanism itself is under neural control as is blood flow to the skin. When the body gains heat either through a rise in environmental temperature and/or physical activity, cutaneous blood flow rises conveying heat to the surface of the skin for convective cooling as well as providing water to sweat glands for evaporative cooling. Finally, our ability to sense heat is necessary for behaviorally avoid getting over heated.

Evaporation and Convection both occur on the surface of the skin

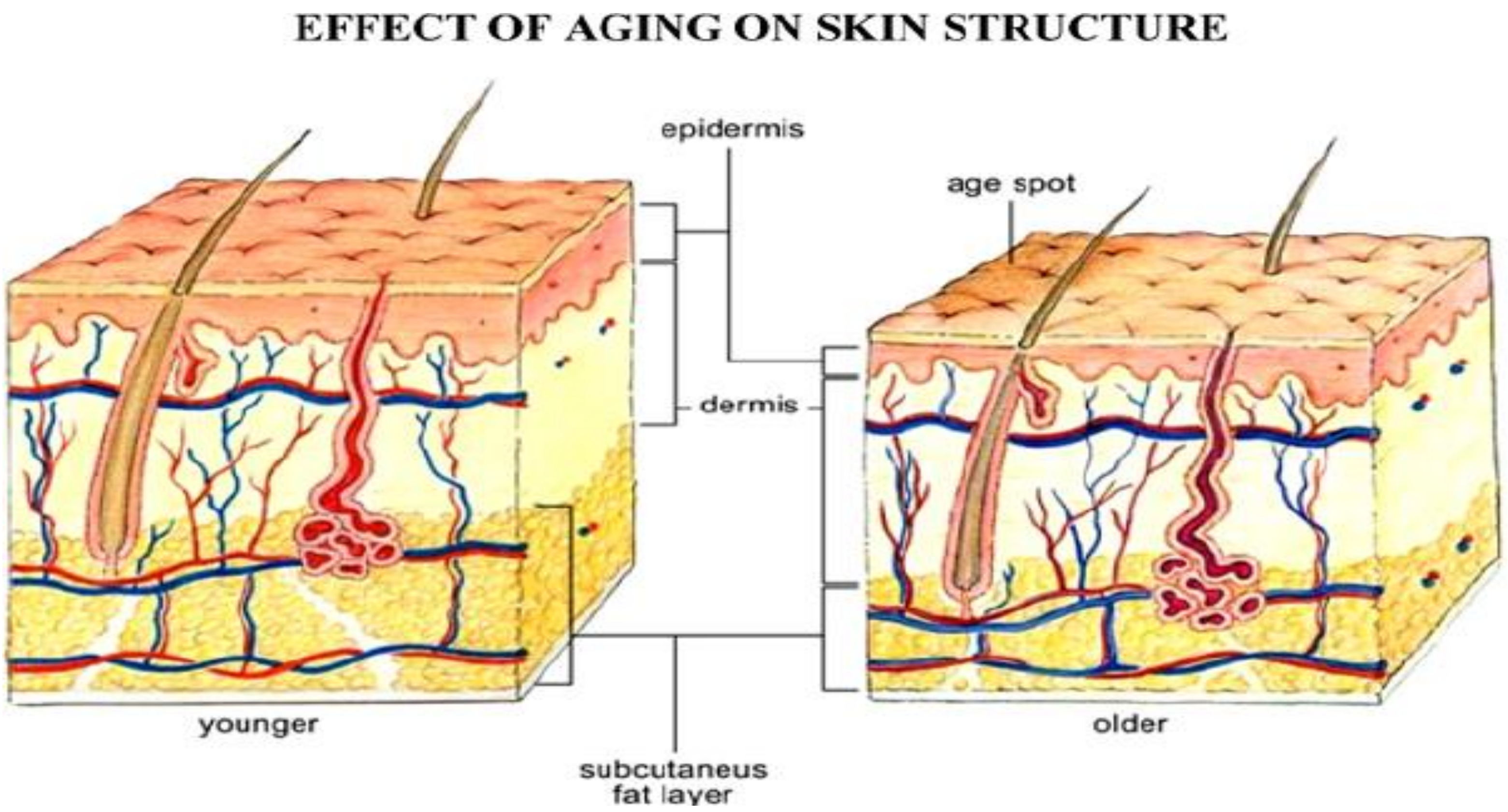


Figure 12: The thing to notice about this figure is that the epidermis (upper layer of skin) becomes thinner as a person ages. This cause of this as well as its impact on temperature regulation in the heat are given in the following figure.

Decrease in thickness of epidermis with age:

- Due to decrease in metabolism of basal cells of the epidermis
  - Results in decrease in epidermis turnover
    - *Exfoliation exceeds formation of new basal cells*

Effects of a thinner epidermis on temperature regulation:

- Results in sub-epidermal blood vessels being closer to the surface
  - Assists in convective cooling in warm environments
    - Partially compensates for age related loss of sweat glands

Figure 13: Basal cells are the metabolically active cells at the bottom (base) of the epidermis. With age basal cell metabolism slows resulting in the sluffing off (exfoliation) of spent layers of skin on the surface getting ahead of the formation of new basal cells. As a result, the epidermis becomes thinner. A thinner epidermis brings sub-epidermal blood vessels, and the body heat they carry, closer to the surface of the skin thereby assisting in convective cooling.

Detection of Environmental Temperature

Temperature sensing neurons
(aka thermoreceptors)
also exist in:
parts of the brain
and skeletal muscles

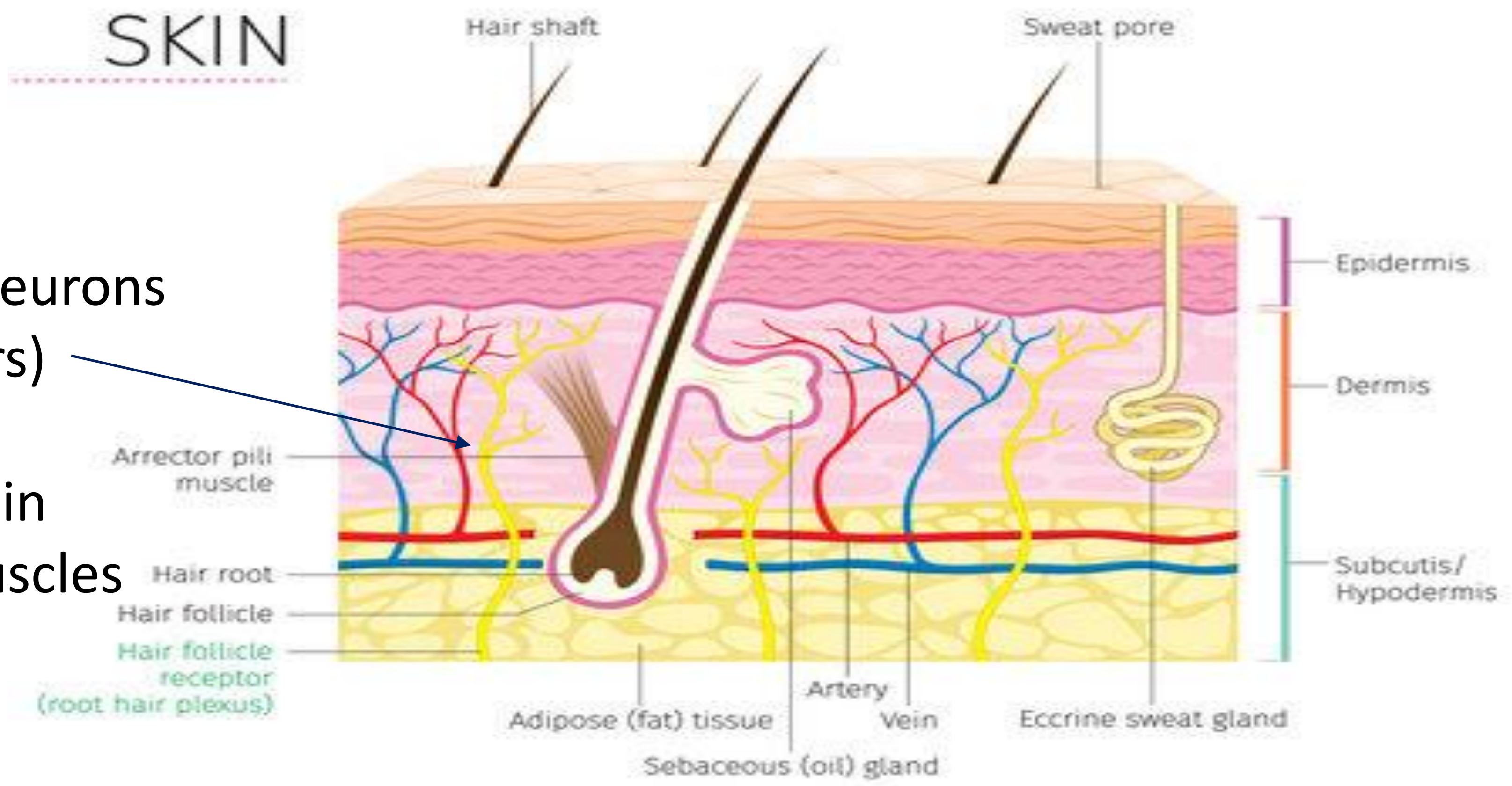
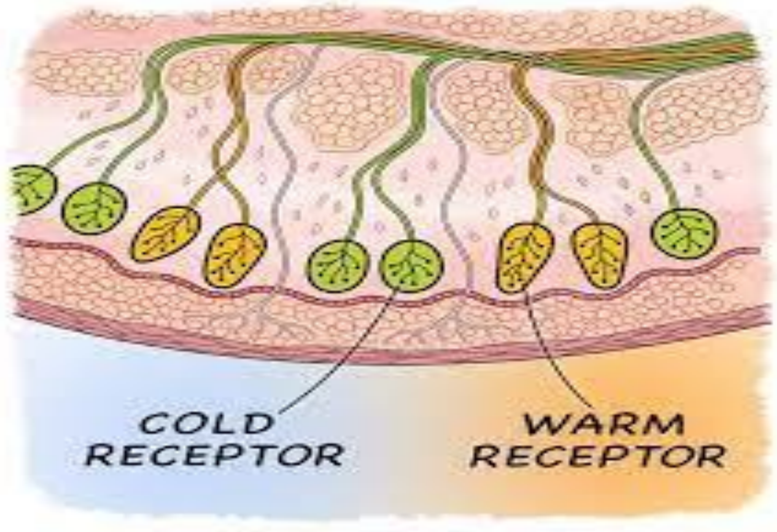


Figure 14: The detection of environmental temperature is carried out by special nerve cells called thermoreceptors. Most, but not all, of these are located in the dermis layer of skin, as shown here.

Thermoreceptors



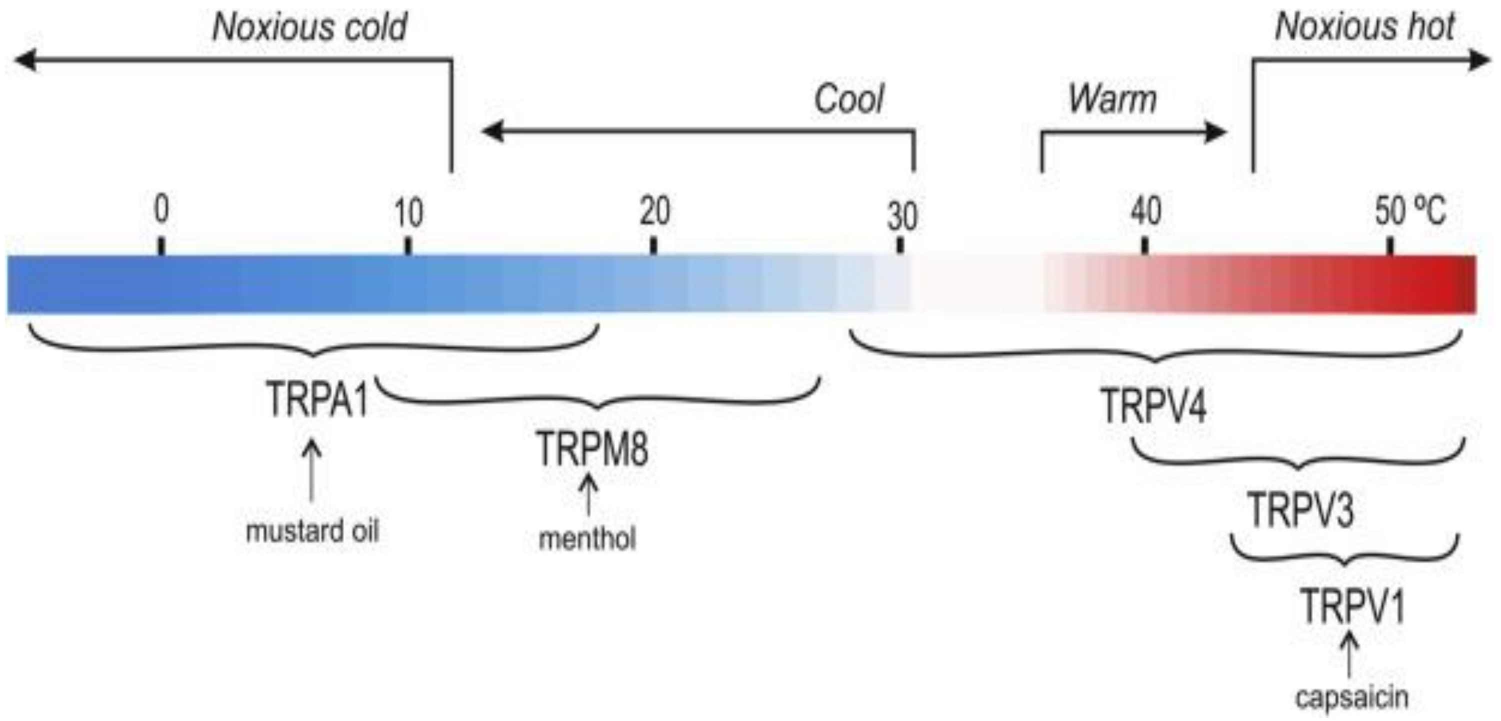
Two types of single neuron endings

Those that respond to cooling temperatures
Range 23 to 82 deg F
Has 2 subtypes each responding to a different Temp range

Those that respond to warming temperatures
Range 82 to 130 deg F
Has 3 subtypes each responding to a different Temp range

Figure 15: There are several sub-types of thermoreceptors divided into two general categories, those that respond to cold and those that respond to heat. Each of these, in turn, consist of sub-types each of which responds to a different temperature range. This arrangement provides a more specific and rapid response to changes in environmental temperature than would be the case if there was only one type of thermoreceptor.

*Temperature response range of thermoreceptors in degrees C (degrees F = 1.8C +32)



Both cold and warm receptors operate by allowing Sodium (Na^+) and/or Calcium (Ca^{++}) to enter the nerve cell attached to the receptor.

*from www.sciencedirect.com

Figure 16: Shown here are the temperature ranges, in degrees Celsius, to which each of the sub-types of thermoreceptors respond. Note that in addition to temperature, these receptors will also respond to certain chemicals which will give the same sensations as environmental temperature itself; mustard oil and menthol for cold receptors and capsaicin for warm receptors. The latter is a common ingredient in heat patches used to relief aching backs, shoulders, etc. Finally, note that thermoreceptors in general operate by opening what are called ion channels which allow sodium and/or calcium to enter the associated nerve cell which then triggers the response.

Sweat glands

Humans have from 2 to 5 million sweat glands

Eccrine glands are the vast majority
Occur throughout the skin
Secrete a watery sweat
About a 15% loss with age

Apocrine glands
Occur in arm pits and genital regions.
Secrete an oily sweat, broken down by bacteria
Produce a musty odor

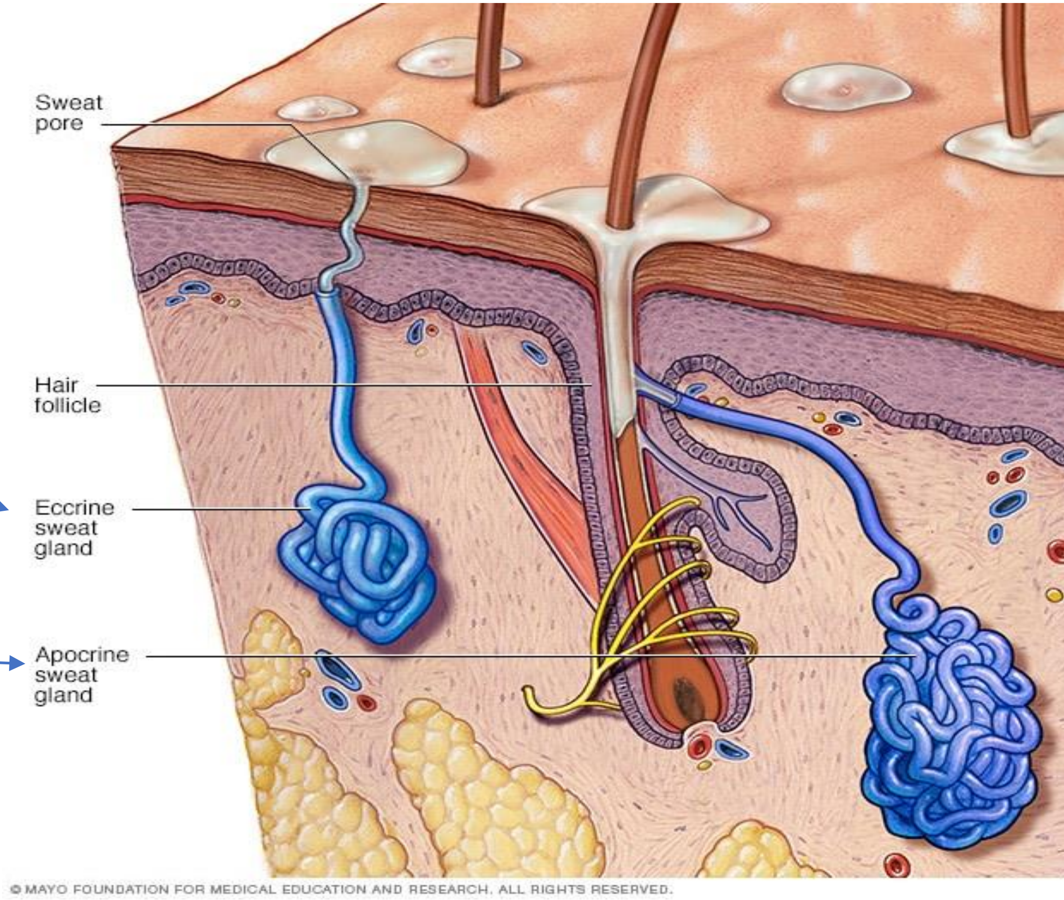


Figure 17: The eccrine glands make up the vast majority of sweat glands in the human body, and are the ones that carry out the process of evaporative cooling. The approximant 15 percent loss of eccrine glands with age is in part compensated by more effective convective cooling due to a thinner epidermis (Who says there's no upside to aging!?).

Sweating initiated when:

Environmental temperature increases

- Usually starts around 80 degrees F

Performing physical work (i.e., physical activity)

- Yes, even in the cold

Experiencing nervous tension

- Individual and highly variable

Figure 18: Although a hot environment is the most common means by which sweating is initiated, the other two can be just as prominent. Of these, sizable sweating can occur with any kind of intense physical activity no matter what the environmental temperature may be – cold, hot or somewhere in between.

Sudomotor neurons elicit contraction of special muscle cells on sweat glands

physical activity → brain; emotional stress → brain

heat stress → body temperature → brain → sudomotor neurons → Sweat glands contract!

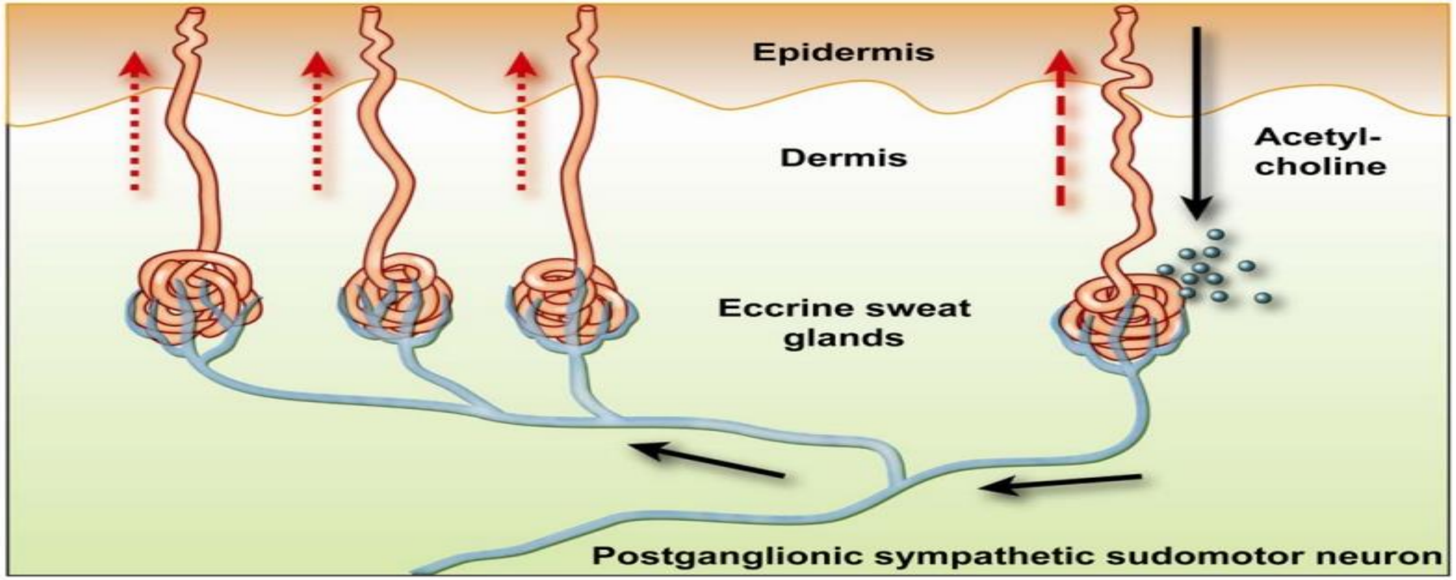


Figure 19: An often overlooked aspect of sweating is that it will only occur when sweat glands contract. If for some reason such contraction does not occur, neither will sweating no matter how hot your body may get. Failure of sweat glands to contract is usually one of the components of hyperthermia. Contraction of sweat glands is caused by activation of a group of nerve cells called sudomotor neurons. The term “sudo” means to sweat. Motor neurons are single nerve cells which initiate action of whatever cell or tissue they are innervating. The action of sudomotor neurons occurs by the release of the transmitter substance acetylcholine. Anything, such as a medication, which might interfere with acetylcholine will also interfere with sweating. Something to look out for in the side effects of medicines.

Sweating is maximal when physically active in hot weather!!!
(Combines effects of work and heat.)

In which environment is sweating most effective, dry (left), or humid (right)?

Figure 20: Pictured here are common activities in which intense sweating may occur due to the combination of physical activity and a warm environmental temperature. The answer to the question at the bottom of the figure is a dry environment, discussed further in the next figure.

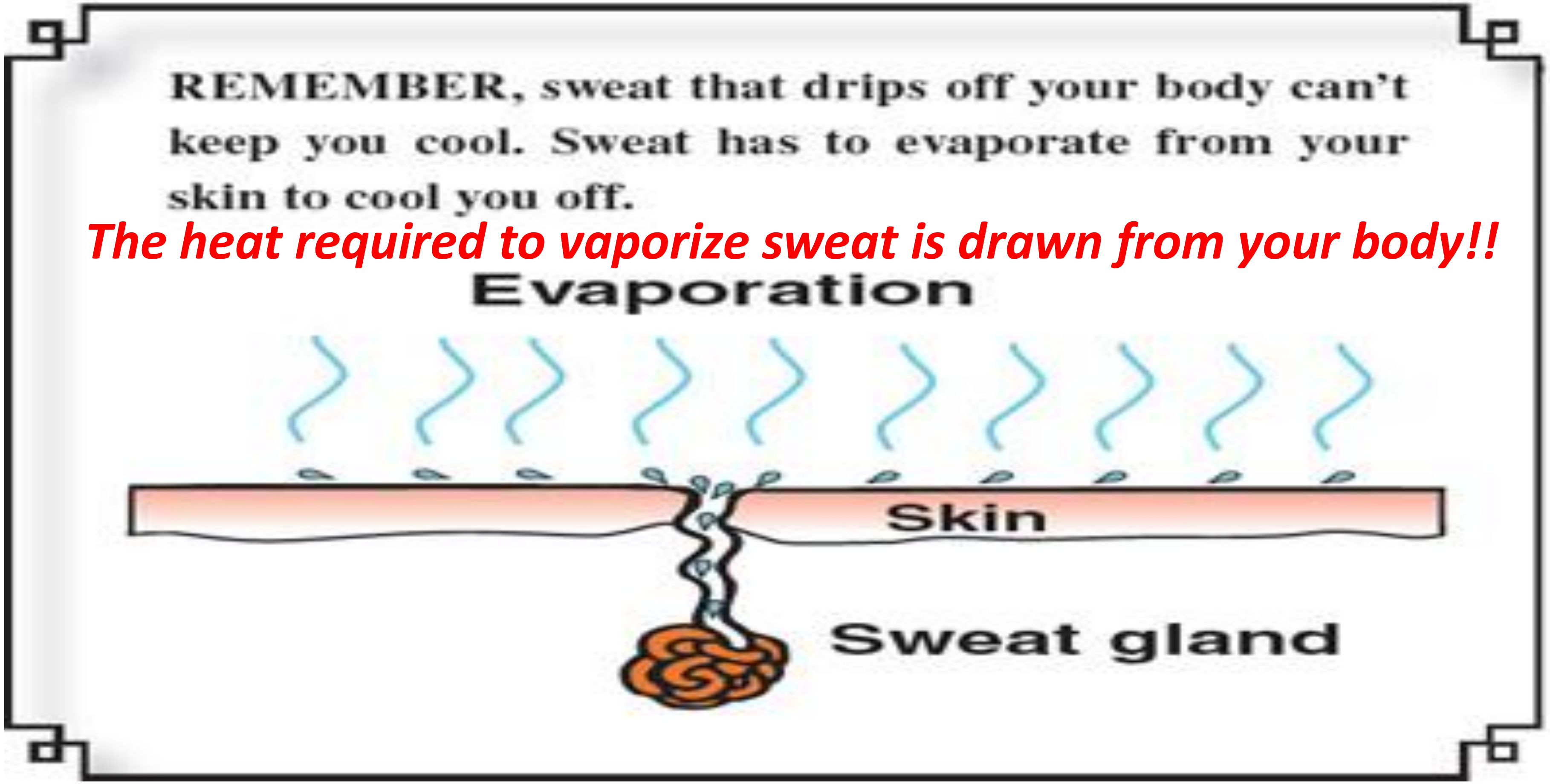


Figure 21: A common, and potentially lethal, misunderstanding about sweating is that it is working just fine if you can see or feel sweat dripping off of your skin, which always occurs in a humid environment. Actually, it's just the opposite! Sweating is called "evaporative cooling" because it is the vaporization of the water in sweat that carries heat away from your body. In a humid environment vaporization of sweat is inhibited because the air already has considerable vaporized water in it, and it can only hold so much. Accordingly, the higher the humidity, the less effective sweating becomes in keeping you cool.

Sweating is most effective in dry (low humidity) environment,

But it can also be dangerous because in such an environment:
Evaporative heat loss is imperceptible!
Such a situation can lead to:
Heat exhaustion, or more seriously
Heat stroke (aka hyperthermia)

Figure 22: Sweating is most effective in a low humidity dry environment because in this condition complete vaporization of the water in sweat occurs. However, this situation presents a different misunderstanding about sweating which can be lethal. Namely, that because in a dry environment sweating is imperceptible, you may not be aware that you're losing lots of water until it's too late.

Behaviors used to Beat the Heat

Stay hydrated
Dress for heat
Minimize midday sun exposure
Acclimate to warm weather

Figure 23: Listed here are some personal behaviors that can be used to help you stay cool in a hot environment. Each of these will be further described in subsequent figures.

Stay hydrated

Dehydration triggers the sensation of thirst

If you're thirsty, your dehydrated

Sensation of thirst diminishes with age

If us senior citizens are thirsty, we're really dehydrated.

Don't let yourself get thirsty!

Figure 24: Staying hydrated is probably the most important behavior to prevent heat stress. However, it's the one most often overlooked, particularly as you get older because the sensation of thirst diminishes with advancing age. Accordingly, the key to proper hydration is to not let yourself get thirsty. Admittedly this is easier said than done because of the tendency to not think about it when you're involved in outside activities.

During physical activity in a hot environment:

Drink before, every 15 to 20 min during and after activity such that you keep yourself from getting thirsty.

Monitor how you feel: alert, not dizzy, no cramping.

If possible observe the color of your urine.

Figure 25: Given that the sensation of thirst diminishes with aging, a good idea is to drink something on a regular basis whether you feel thirsty or not. In addition, pay attention to how you feel. If you're light-headed or having cramps of any kind, rest, out of the heat if possible, and drink something. Finally, if possible, when taking a break look at the color of your urine to see if it is in the hydrated range, as shown in the next figure.

URINE COLOR CHAT (chart)

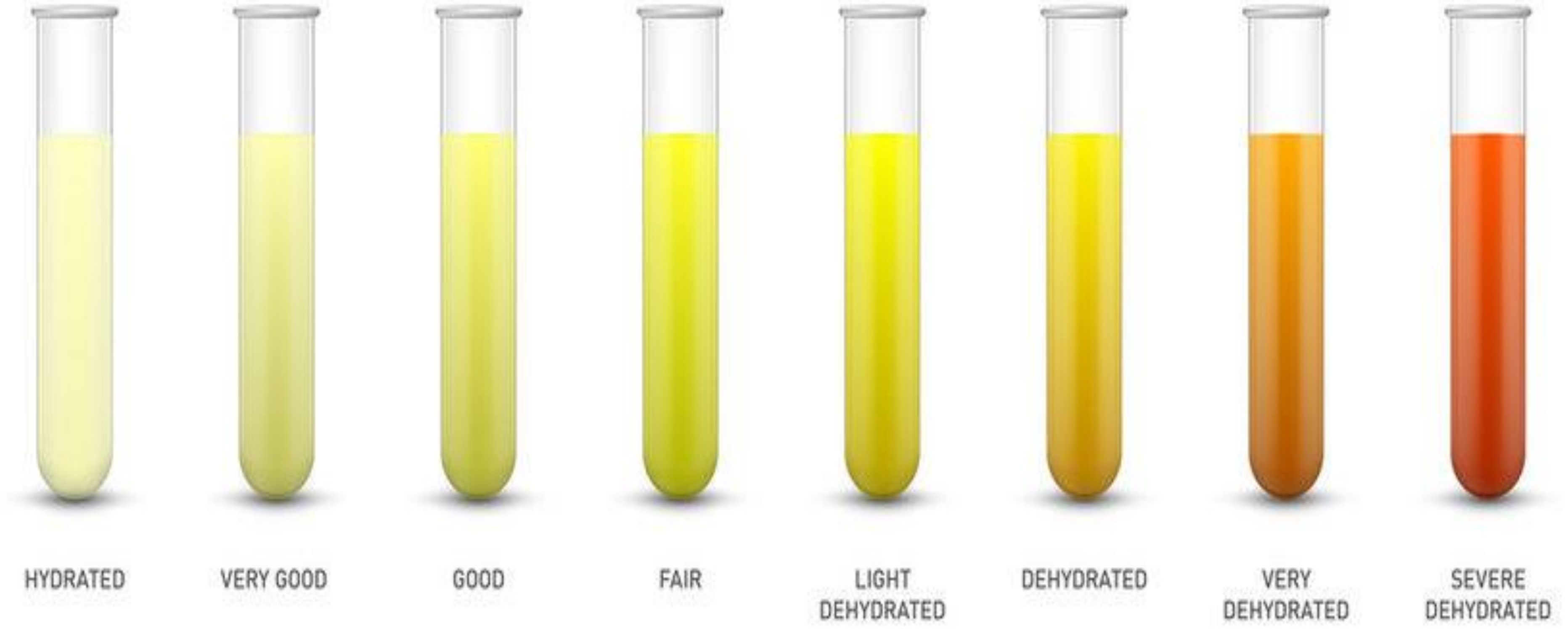


Figure 26: If the color of your urine is even in the light dehydrated range, drink more than you usually do and keep monitoring your urine when possible. Not that easy if you’re out on a public hiking trail. But it can be done.

What to drink

Water is OK, but when you sweat you're loosing more than water!

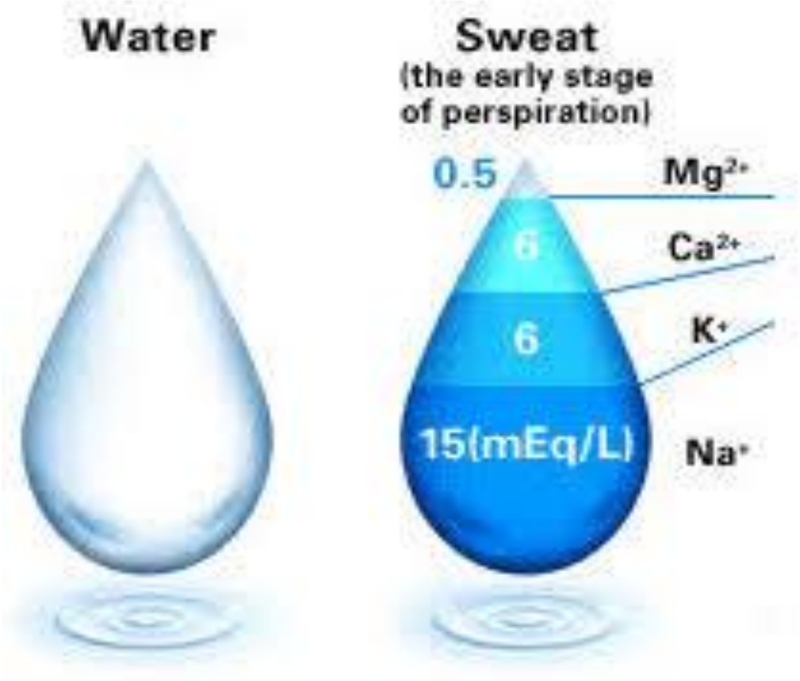


Figure 27: As shown here, sweat contains some key minerals (salts) essential for proper body functions. These should also be replaced along with water.

To replace salt and water, drink a sports drink

Figure 28: A variety of sports drinks contain the concentration of minerals found in human sweat. On this note, the first of these, Gatorade, was developed in the 1950s by analyzing the sweat excreted by players of the University of Florida (the Gators) football team, then dissolving the minerals found in their sweat in water along with sugar to make it palatable.

Warning! Regular sports drinks contain large amounts of sugar.

However: Some sports drinks (eg, Gatorade Zero) are sugar free.

Figure 29: To make sports drinks taste OK for marketing, they all contain large amounts of sugar. Not the best thing for elders, or anyone, prone to diabetes. Hence, some of the sports drinks, such as Gatorade, offer a sugar free variety.

Dressing for heat

Ventilated hat

Clothing that satisfies the three L's

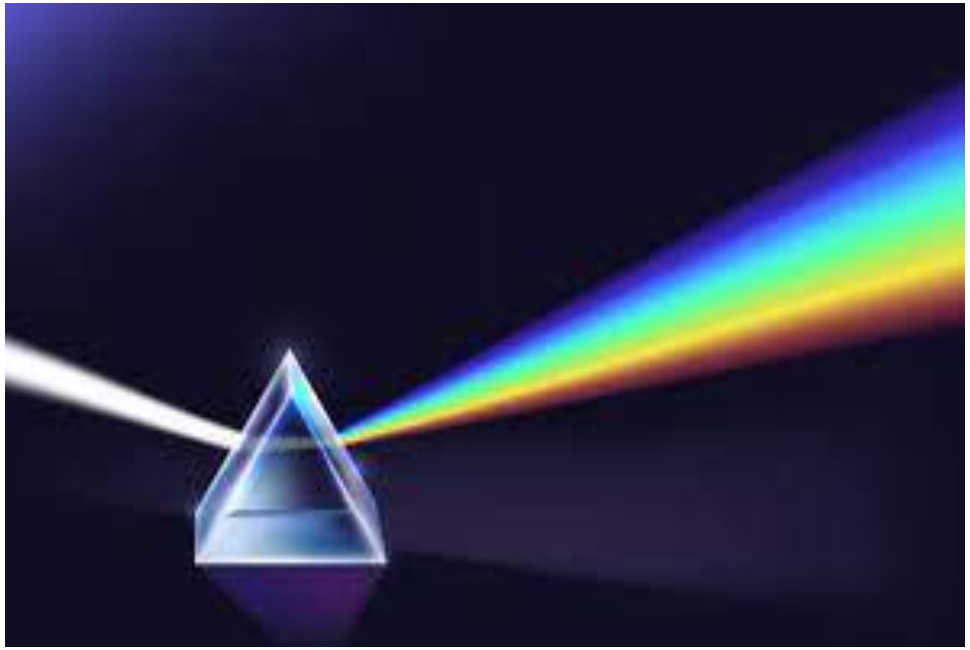
Light in weight.

Loose fitting.

Light in color.

Figure 30: Probably the easiest thing you can do to beat the heat is to dress properly beginning with a light weight broad rim ventilated hat. Proper attire for clothing to beat the heat should adhere to the "three L" rule. Light weight and loose fitting are best for vaporized sweat to escape and for air to adequately circulate between skin and cloth. The reason for light in color is described in the next figure.

Why light in color.



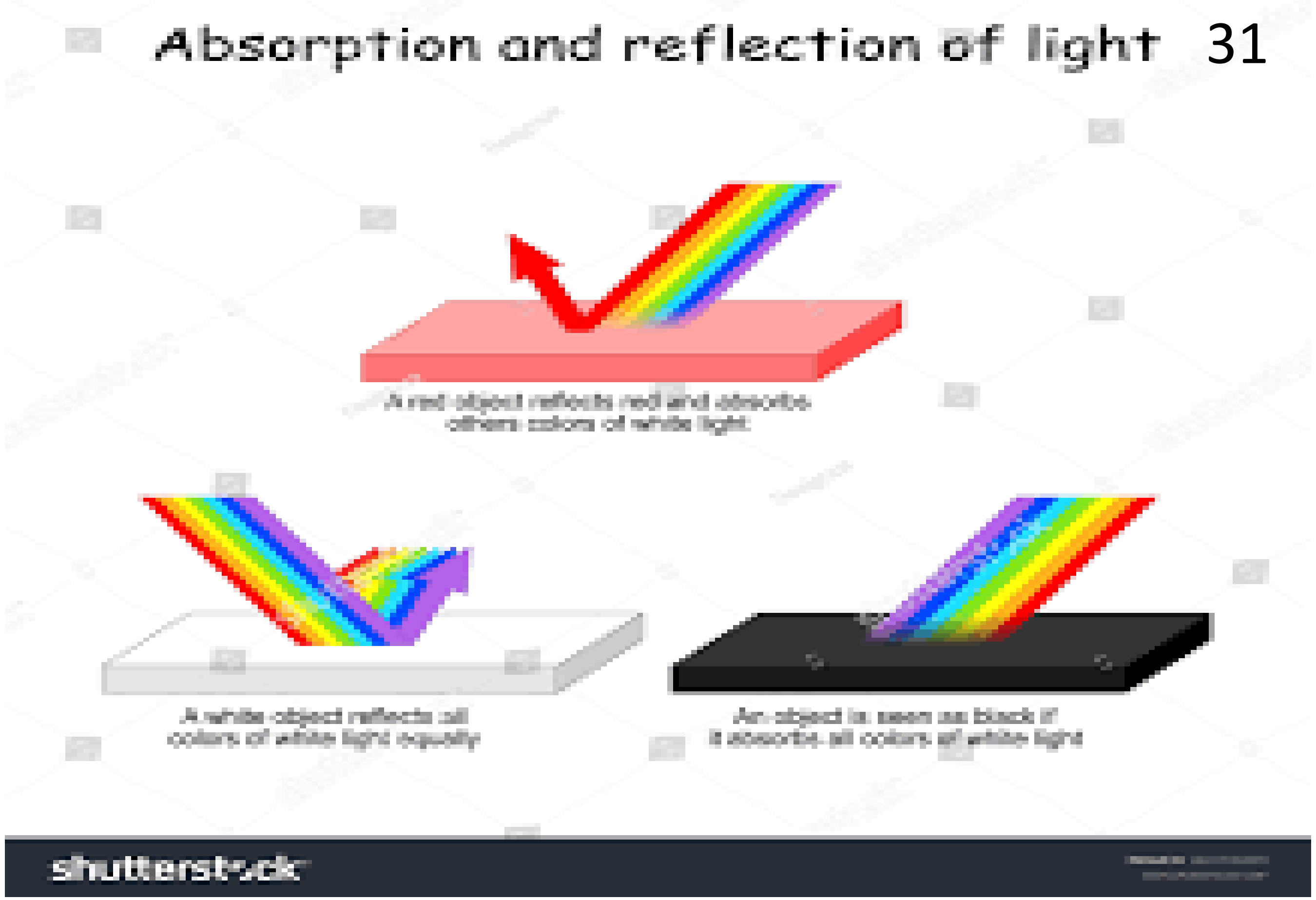


Figure 31: As Isaac Newton demonstrated by passing light through a prism, white light is a mixture of colors visible to the human eye. When we see a colored object, such as a red shirt, the object itself is not actually red, rather it is reflecting red light back to your eye while absorbing all of the other colors. As shown, we see objects as white because the material that makes up the object reflects all of the colors, whereas black objects absorb all of the colors thereby not reflecting any color back to your eye. The reason why this is important for staying cool is given in the next figure.

Electromagnetic spectrum

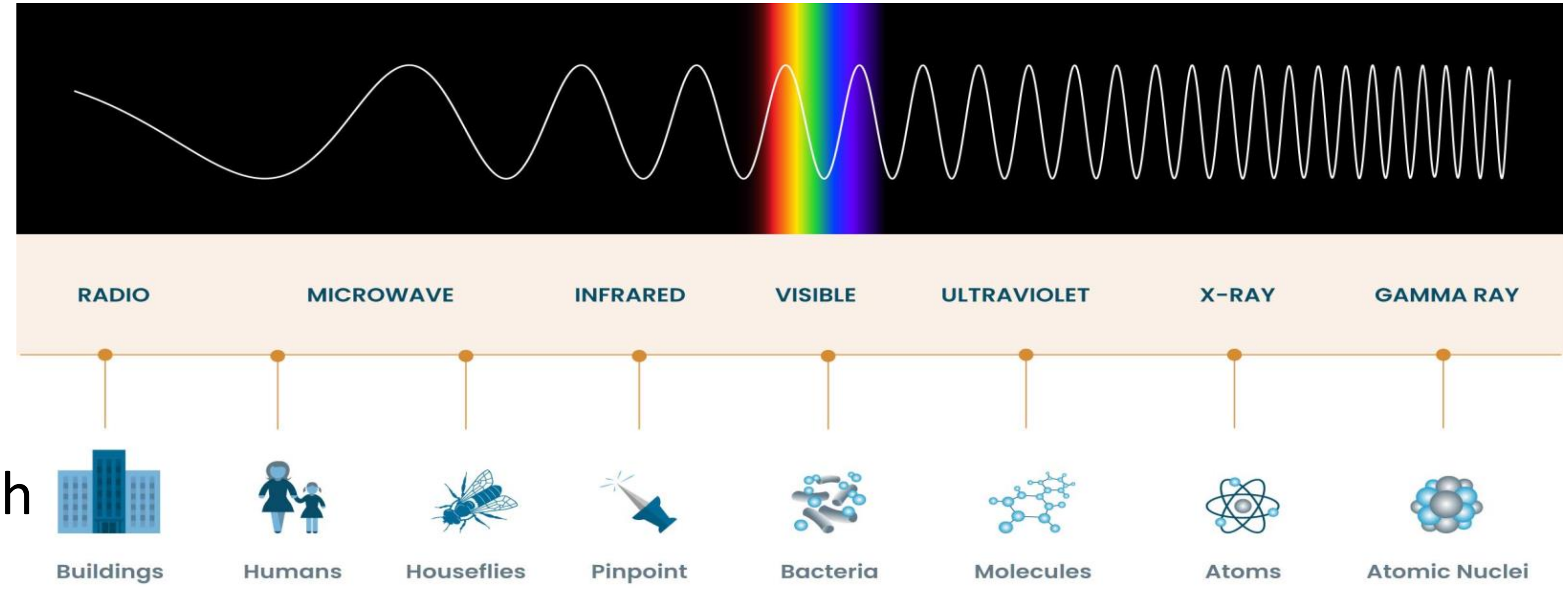
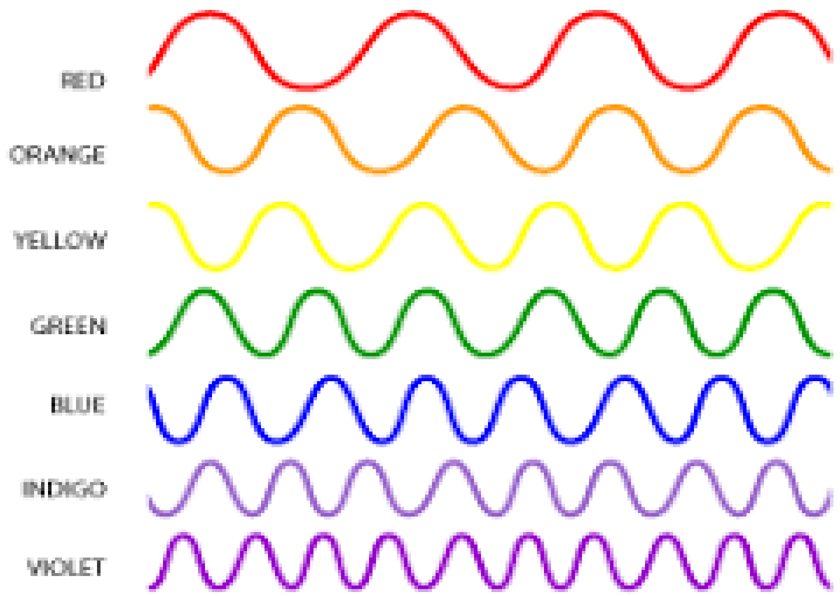


Figure 32: As shown, visible light exists within the spectrum of electromagnetic waves having wave lengths from about the length of a large building for radio waves to lengths smaller than the nucleus of an atom for gamma rays. Each of these waves carry energy proportional to their frequency, which is the inverse of the wave length (the shorter the wave length, the higher the frequency). Hence, radio waves have the lowest energy while gamma rays have the highest. Accordingly, visible light which sits in the middle of the electromagnetic spectrum contains energy with red having the lowest frequency, hence the lowest energy, while blue to violet with higher frequency have the highest energy. On this note, light colors, such as light blue, either contain varying amounts of white material that reflects all light, or have had some of the color intensity bleached out of them. In either case, the lighter the color the more that heat containing light energy is reflected away.

Electromagnetic waves travel in discrete units of a given frequency each of which travels at the speed of light, 300,000 km/sec.



Single waves within a given unit are energy carrying components, called photons.

Figure 33: The usual manner of presenting the electromagnetic spectrum as a continuous progression of waves from long to short wave lengths is a bit misleading. As shown in the left hand portion of this figure, waves of a given wave length, such as red or blue colors, travel independent of other waves in the electromagnetic spectrum. The right-hand segment of the figure shows that waves can also exist as single energy carrying entities termed photons.

Most of the electromagnetic radiation from the sun is in the visible light range.

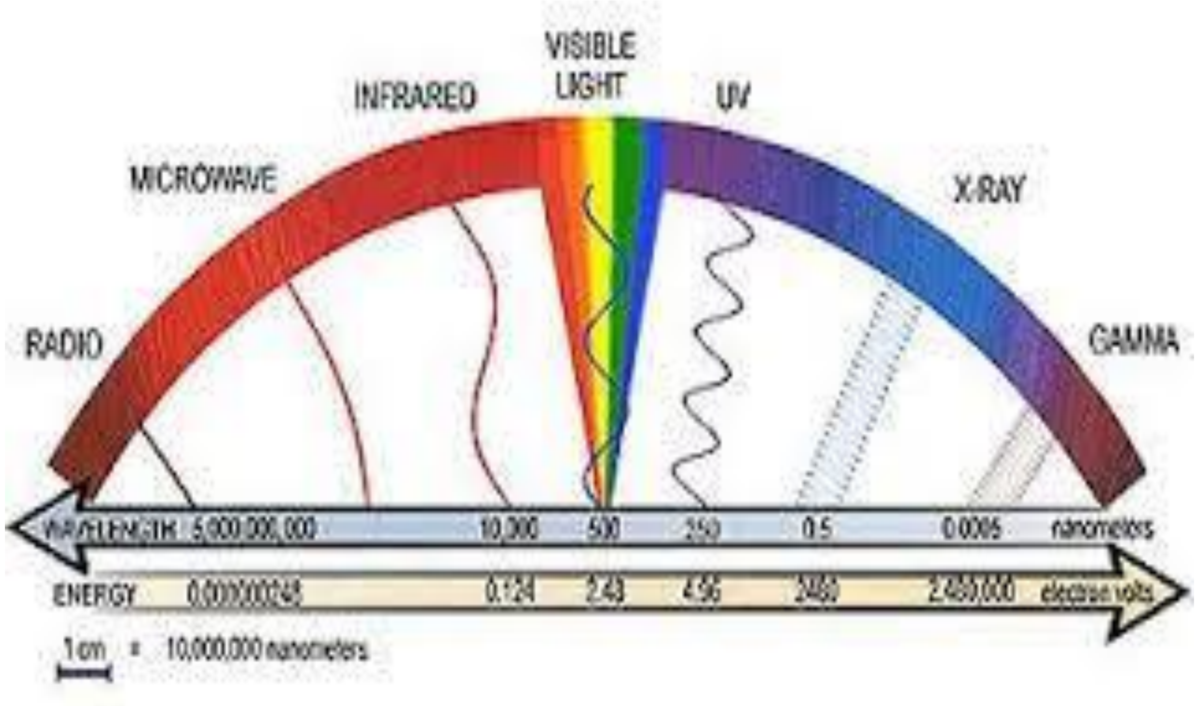


Figure 34: The height of the arch from the grey horizontal line indicates the relative magnitude of different components of the electromagnetic spectrum in the sun's rays that reach the surface of the earth. As indicated, most of the energy of the sun that reaches us is in the visible light range of the spectrum. No doubt why our eyes have evolved receptors sensitive to the red through violet rays.

While white clothing reflects all visible light thereby keeping you cool, dark blue, and other dark colors, will absorb UV rays keeping them from reaching your skin.

Thought to give good protection against UV rays.
(Cancer Council of Australia, 2020)

Figure 35: Australia has a high rate of skin cancer. On this note, their science teams did much of the pioneering research showing that dark colors, in particular dark blue, absorb cancer causing ultraviolet (UV) rays thus preventing them from reaching your skin. The tradeoff here is that dark colored clothing provides little protection from the heat of the sun. The best option for blocking both heat and UV rays is given in the next figure.

Best option:
White shirts with special weaving that blocks UV rays.
Columbia brand with a UPF* rating of 30 is about $45 at REI.

*UPF (ultraviolet protection factor)
1/UPF = fraction of UV rays that will pass through a fabric.
1/30 = 0.033 = 3.3% of UV rays will pass = 96.7% UV rays blocked.

Figure 36: Several clothing manufactures, (e.g., Columbia) market clothing made with a weave pattern that blocks UV rays, and such clothing comes in a variety of colors, including white. The degree of UV blockage is given as an index called the Ultraviolet Protection Factor (UPF). As shown in the math example, given beside the figure, the higher the UPF the higher the percentage of UV light that is blocked. Most outdoor equipment stores, such as Recreational Equipment Inc. (REI), carry UPF clothing.

Sunscreen: Protects skin from UV rays

"Slather" face and other exposed skin
with SPF of 30 or higher about 30 min before going out.
SPF (Sun Protection Factor) essentially same as UPF
except that SPB refers to cancer causing UVB rays

Figure 37: Dressing for heat includes the application of sunscreen to protect exposed areas of skin from UV rays. In this context "slather" means to put on a thick coat. The Sun Protection Factor (SPF) is similar to the UPF for clothing except that SPF refers to UVB rays which have a shorter wave length than UVA rays. Hence, UVBs carry more energy than UVAs and are more cancer causing. However, like the UPF for clothing, the higher the SPF for sunscreen the higher the percentage of UV rays that are prevented from reaching the skin. For example, a SPF of 30 will block 97% of UVB rays.

Minimize midday sun exposure: Usually 10:00 AM to 3:00 or 4:00 PM

When sun is most direct and UV rays are high. Produces highest temp and most high energy UV exposure.

Figure 38: Limiting outdoor activity to the early morning and late afternoon hours is a good way to minimize both heat and UV exposure. To know more exactly when during the day that it would be best for you to be outside, the internet address shown below will give you an hour-by-hour prediction of the intensity of that day's UV rays in your zip code area.

Web site to look up hourly UV index in your zip code (*https://chromedomecaps.com/uv-index-today/*)

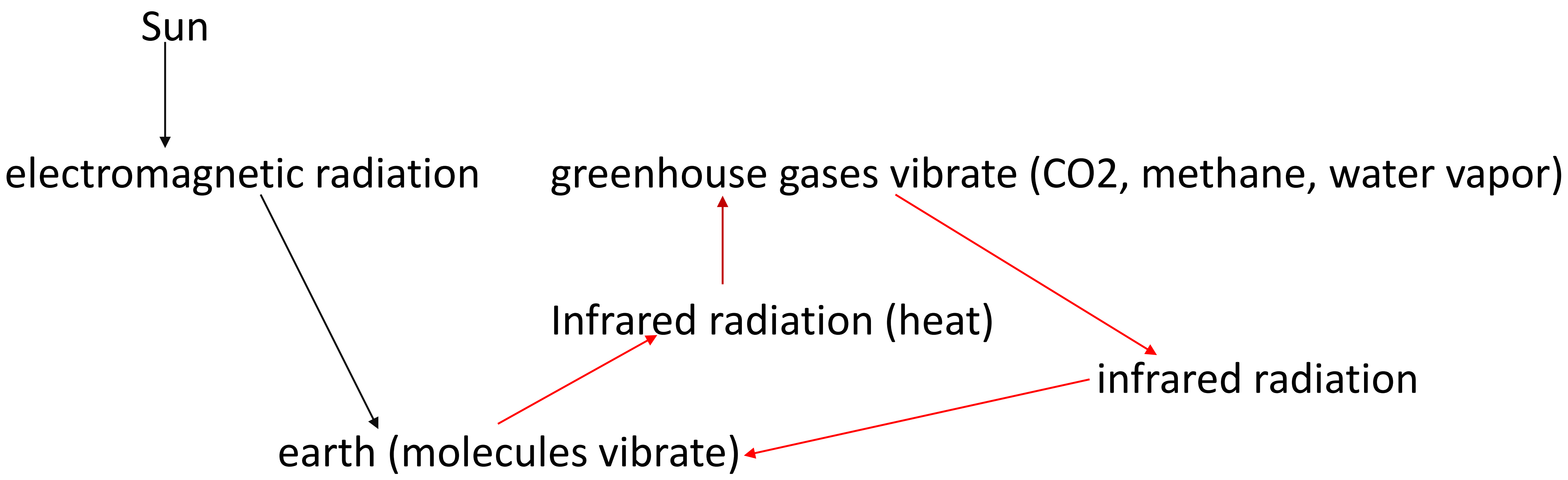
Caution: Heat and UV (ultraviolet) rays are not the same.

On October 31, 2023, 11:30 AM

Tempe, AZ, elevation 1,180 ft	Tonto Village, AZ, elevation 5,700 ft
Air Temp – 76 F	Air Temp – 62 F
UV index – 3.8	UV index - 4.0

Figure 39: Although, at a given location, environmental temperature and UV rays track each other during the day, they are separate entities. The entire surface of the earth from lowest to highest point exists within the troposphere component of our atmosphere where all life forms, including us, live. Within this realm ***environmental temperature decreases by about 3.5 degrees F for every 1,000 feet of ascent.*** On the other hand, the intensity of UV rays coming from the sun is only slightly modified by how much of the troposphere it passes through. The example given to illustrate this point was obtained on a given day at two different locations in Arizona that I am familiar with.

What we feel as heat on a hot day is infrared radiation generated largely by the greenhouse effect.



Figures 40 and 41: These two figures present respectively a diagram and a written description of the greenhouse effect by which the surface of the earth obtains its warmth. As the authors of the text from where this information came pointed out, without a mild greenhouse effect the average annual temperature on earth would be below freezing.

The Greenhouse Effect*

Energy from the sun's rays cause molecules within all matter on earth to vibrate.

This vibration causes these molecules to emit infrared radiation (what is felt as heat) which is projected in all directions including back up into the atmosphere.

Some of the projected radiation is absorbed by certain molecules in the atmosphere, such as carbon dioxide, methane and water vapor.

A portion of the absorbed infrared radiation is reemitted back toward earth where it is reabsorbed by earthly matter and reemitted.

This back-and-forth is known as the greenhouse effect, and the participating atmospheric molecules are known as greenhouse gases.

The greenhouse effect continues throughout the day as the sun rises producing our steadily increasing temperature, then reverses as the sun goes down.

*From: Neil DeGrass Tyson & Lindsey Nyx Walker, "*To Infinity and Beyond*", 2023 pp 22-23.

In northern hemisphere UV rays are higher and temperature is warmer in summer because the sun is more direct.

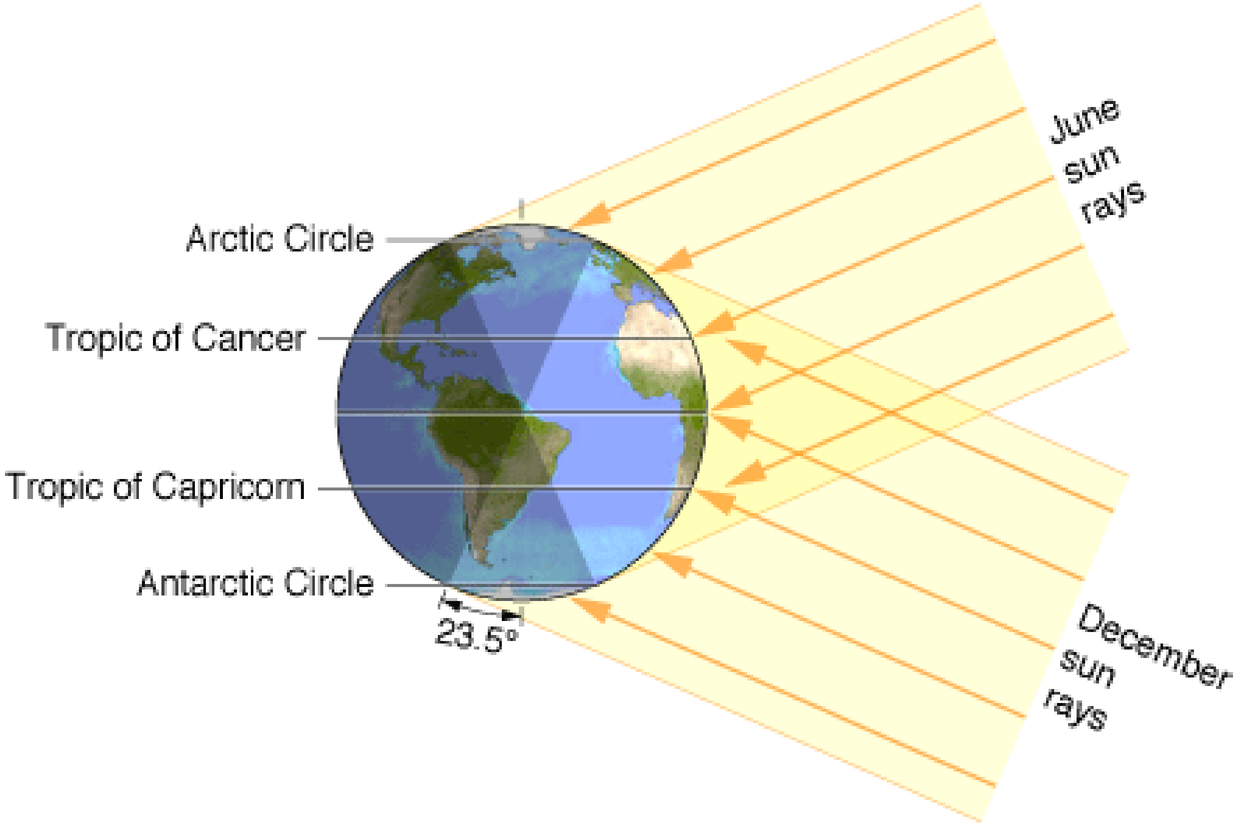


Figure 42: As pointed out here, the amount of both heat and UV rays that we experience are to a large part determined by the angle with which the sun strikes the earth, being more direct in summer months for the northern hemisphere.

Acclimating to a Warmer Environment

Acclimation: The Key Process in Evolution.

How flying Squirrels evolved:
"This may sound crazy, but I think I figured out a way to get up there!"

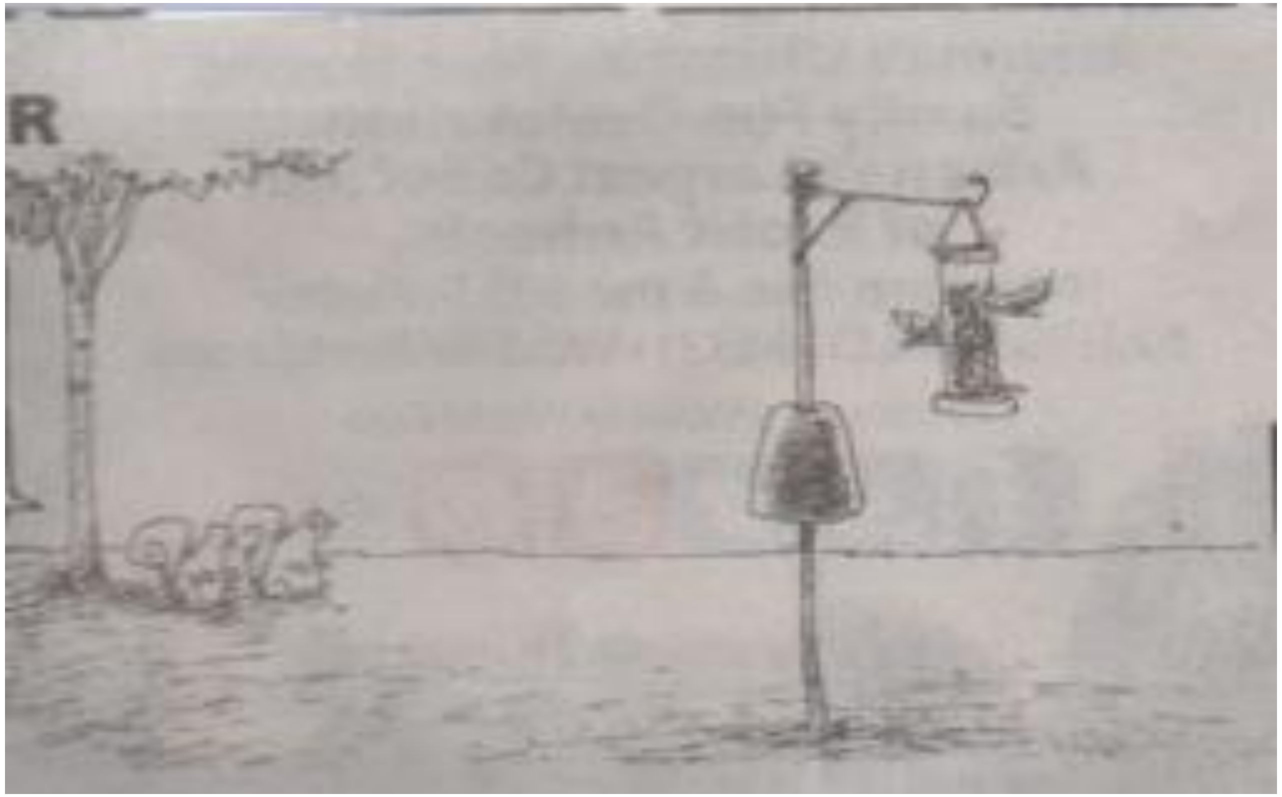


Figure 43: This cartoon, which anyone who lives where birds and squirrels coexist can appreciate, introduces the concept of acclimation which is an important long-term aspect of adapting to a warmer world.

Mechanism of Acclimation:
Involves environmental induced modification of genes.

Short term (seasonal):
genetically modified physiological adjustments.

Long term (several generations):
genetically modified anatomical and physiological adjustments.

Figure 44: The salient aspect pointed out here is that the mechanisms of both short-term and long-term adaptation are genetic in nature.

Examples of evolutionary modification of body structure

Fennec (Desert) Fox

McFly and Noelle on display at Phoenix Zoo

Polar (Artic) Fox

Figure 45: Evolution is the process of long term (generational) adaptation, such as with changes in body structure. Comparison of desert and artic foxes is frequently given as an illustration of adaptation that takes many generations to achieve.

Grand Canyon Squirrels

North Rim 8,000 ft ← 10 miles → South Rim 7,000 ft

Figure 46: The physical adaptations of desert and artic foxes occurred over many generations and in markedly different environments thousands of miles apart. The figure shown here comparing squirrels of the north and south rims of Arizona's Grand Canyon points out that different adaptive physical changes can occur between similar animals living in slightly different environments separated by as little as 10 miles. The Albert squirrel of the more desert like environment of the south rim has longer ears and more white fir in comparison to the Kaibab squirrel of the higher and colder environment of the north rim. Furthermore, before they became separated about 10,000 years ago, a short time in both geologic and evolutionary history, the Albert and Kaibab squirrels were the same species. This points out that physical adaptations to a changing environment can occur in a relatively short geologic time span. Accordingly, might humans physically adapt somewhat to a warmer would? A question that only time will answer.

Sensing the environment:

The initial step in genetic mediated adaptation and evolution.

Darwin had it half right. Evolution occurs by genetic mutations, but they aren't random. Instead, living organisms sense the environment through signals coming from the environment that can directly affect a cell's genes. This often leads to mutations that enhance adaptation to a change in the environment.

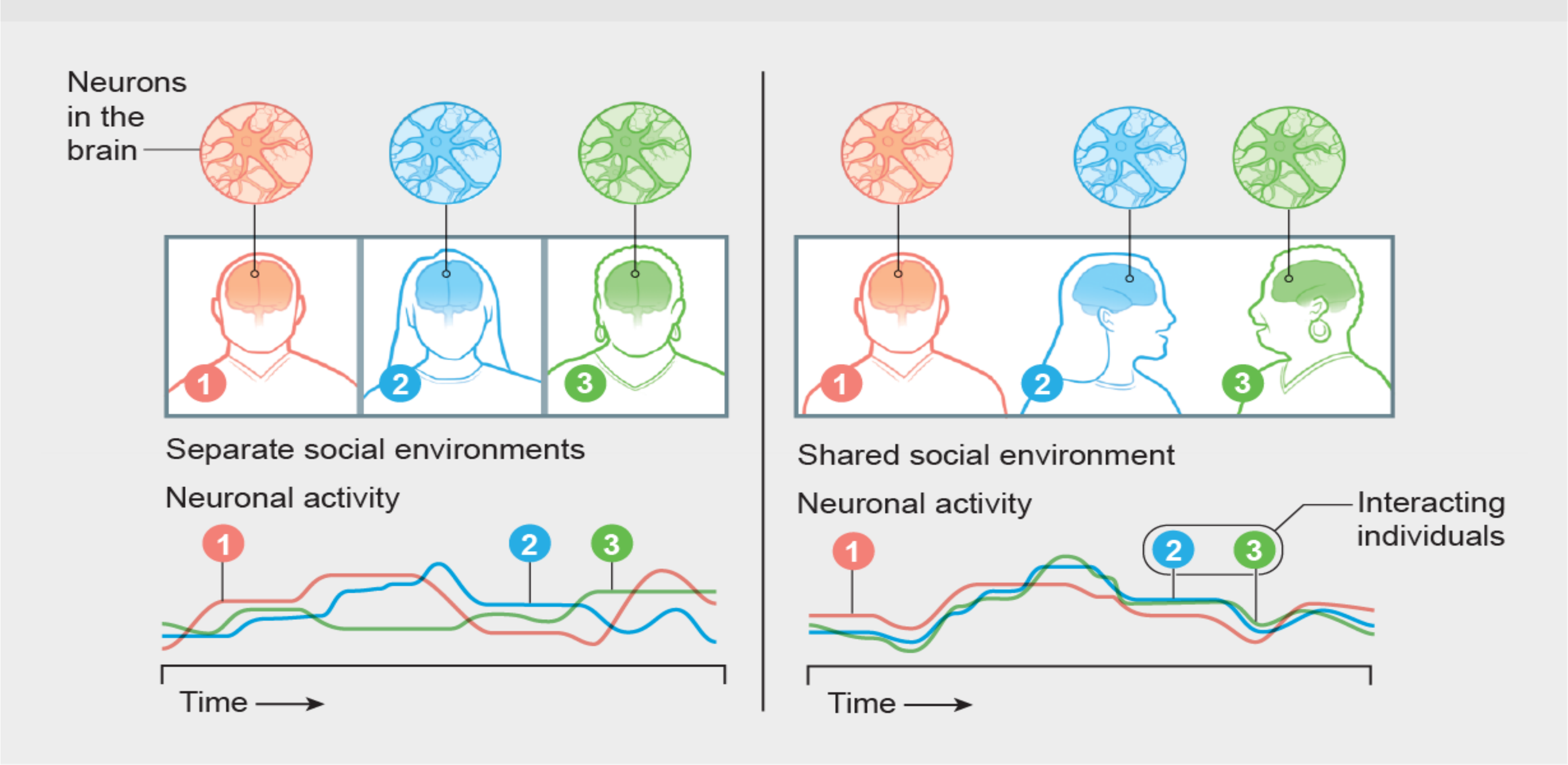
Figure 47: Darwin thought that evolution occurred by random mutations of genes with the gene that produces the most survivable characteristics of an organism then being passed on to subsequent generations. We now know that while evolution occurs through mutations of genes, they are not random but rather are triggered by changes in an organism's environment. Accordingly, any environmentally induced genetic modification must start with a means by which genes can detect the environment. Currently the most likely proposed mechanism for this is given in the next figure.

Current Hypothesis

Living organisms communicate with the environment by an exchange of *photons*.

External environment ⇄ Photons ⇄ Organisms people, animals, birds etc

Figure 48: In the 1970s Fritz-Albert Popp, a German physicist, discovered that living organisms, including humans, emitted and received photons, single energy carrying waves of the electromagnetic spectrum (see Figure 33). The hypothesis here is that our genes are sensitive to photons received from our surrounding environment, including those representing environmental temperature. This then could possibly be the initial signal that triggers genetic modification in response to a warming environment.



From: Denworth, Lydia
"Synchronized Minds"
In: Scientific American
July/August 2023

Figure 49: Presented here is some recent evidence of extrasensory communication. When two or more individuals (the ones in blue and green) interact their brain waves become synchronized. This is further evidence that humans are sensitive to external signals, in this case those that are exchanged between individuals.

Next step – activating specific genes.

What are genes: Sections of DNA (deoxyribonucleic acid) on chromosomes which are located in the nucleus of all cells.

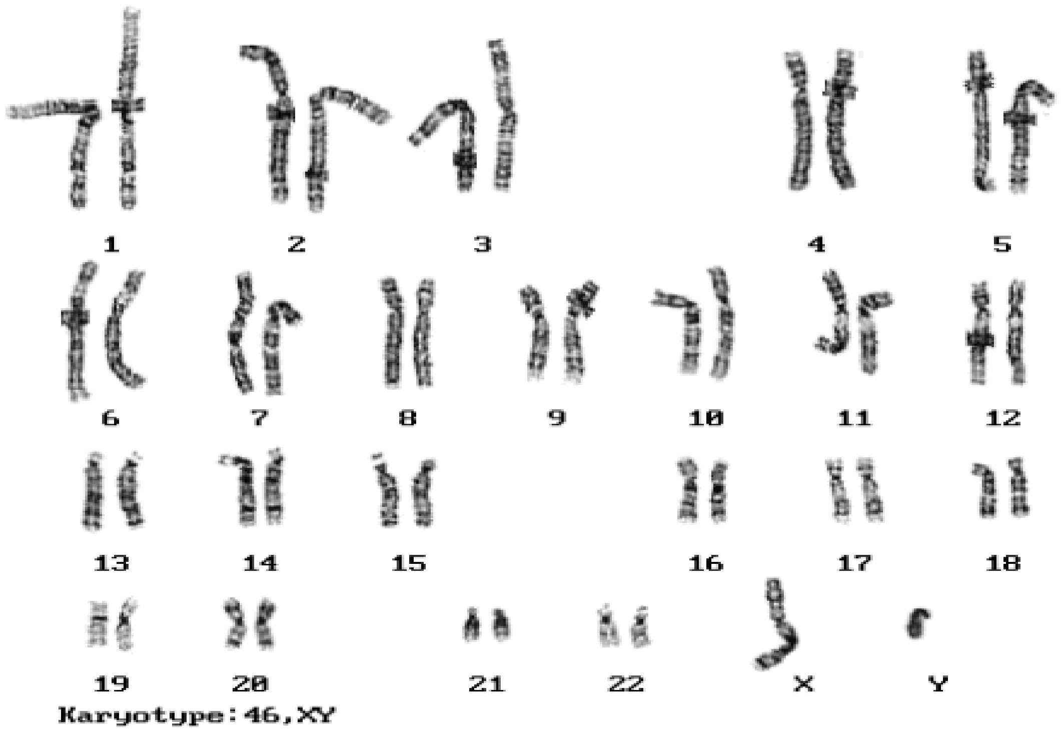
What do genes do: Code for the manufacture of proteins in a process termed genetic expression.

How do genes interact with the environment: By way of epigenetic molecules on the surface of DNA which receive signals from the environment.

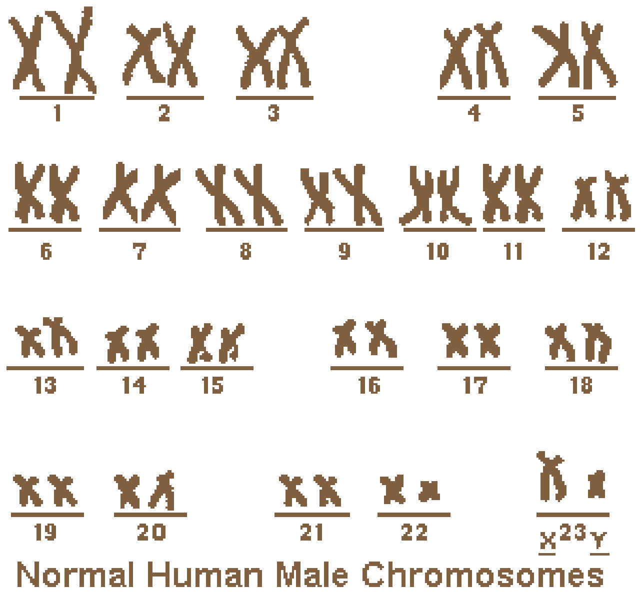
Figure 50: In the case of environmental adaptation, signals from the environment attach to *epigenetic* molecules on the surface of DNA, a step which activates genes, which then go on to orchestrate the manufacturing of specific proteins which carry out the adaptation.

epigenetic (epi = above, genetic = genes)

human male chromosomes



chromosomes duplicate during cell division.



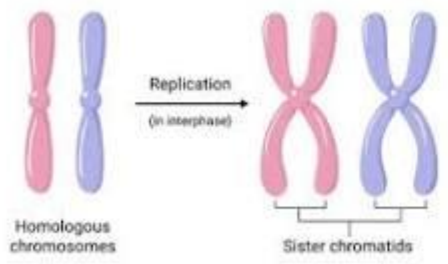
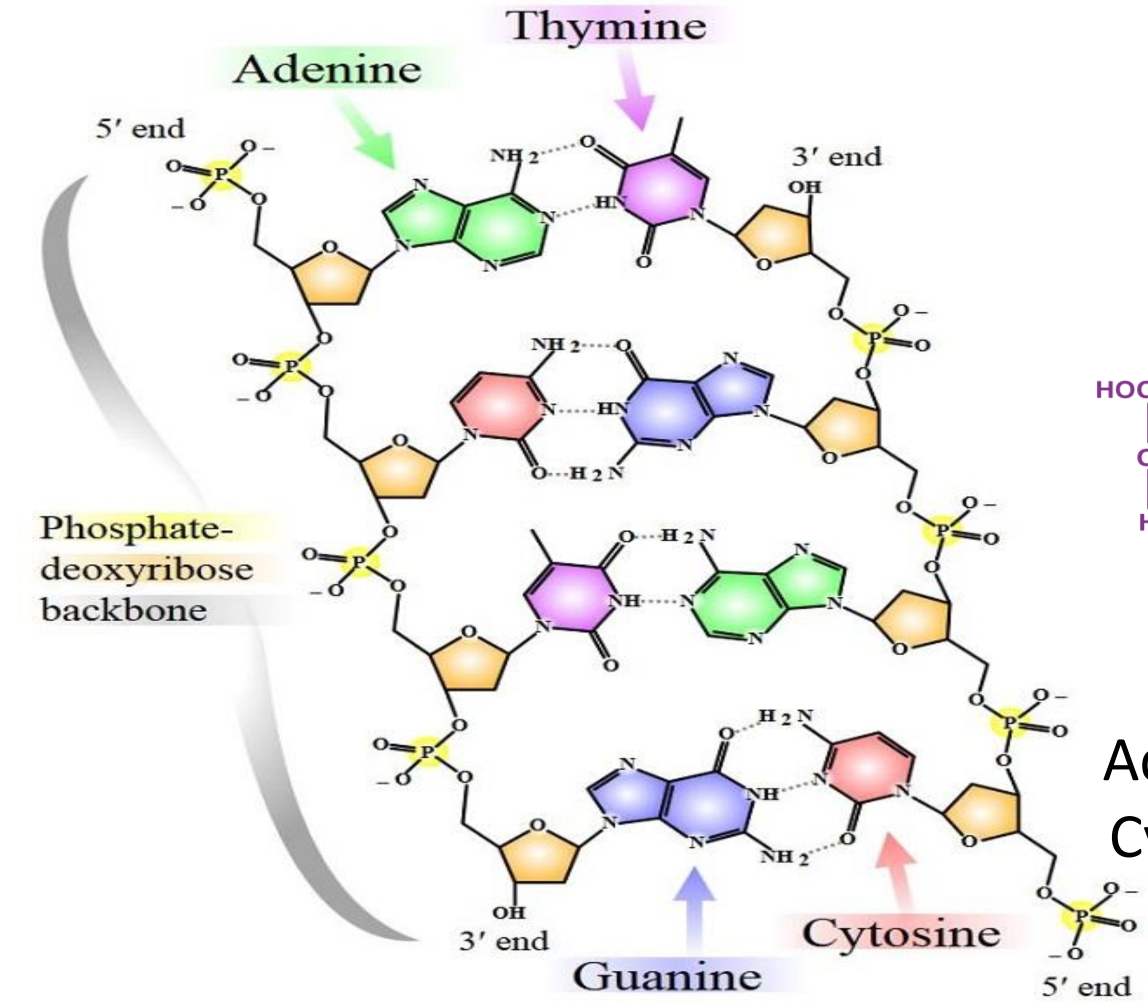
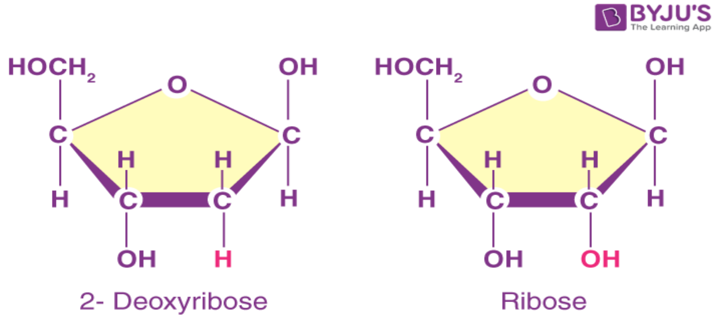
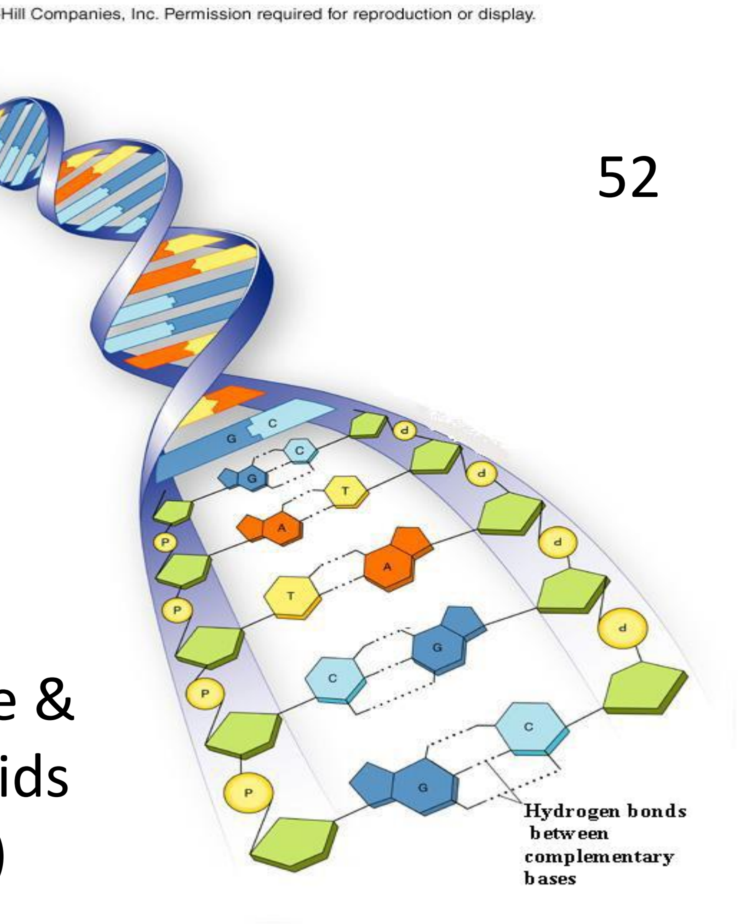


Figure 51: Genes are components of long strands of deoxyribonucleic acid (DNA) which make up our chromosomes. Humans have 22 pairs of somatic (meaning of the body) chromosomes numbered from 1 to 22, in roughly descending order according to length, and one pair of sex chromosomes. One member of each pair comes from the mother and one comes from the father. Regarding the sex chromosomes, the female has two X chromosomes and the male one X and one Y chromosome. At one time the only way to view chromosomes was during cell division when each chromosome was making a duplicate of its self, as shown in the right-hand portion of the figure. Today chromosomes can be viewed as single strands before they duplicate, as shown on the left side of the figure.







Adenine, Thymine, Guanine & Cytosine are the nucleic acids In DNA (aka nucleotides)

Figure 52: Shown here are details of the double-helix structure of DNA. The nucleotides that occupy the center of the structure provide the code for the proteins that each gene makes.

Elucidation of Deoxyribonucleic acid (DNA), Cambridge circa 1953
(A necessary step in understanding how genes work.)

Rosalind Franklin, British Chemist.
Demonstrated double-helix structure of DNA in her famous X-ray crystallograph photo 51.

James Watson, American Biologist &
Francis Crick, British physicist.
Worked out the details of the double-helix shown in Franklin's photo 51.

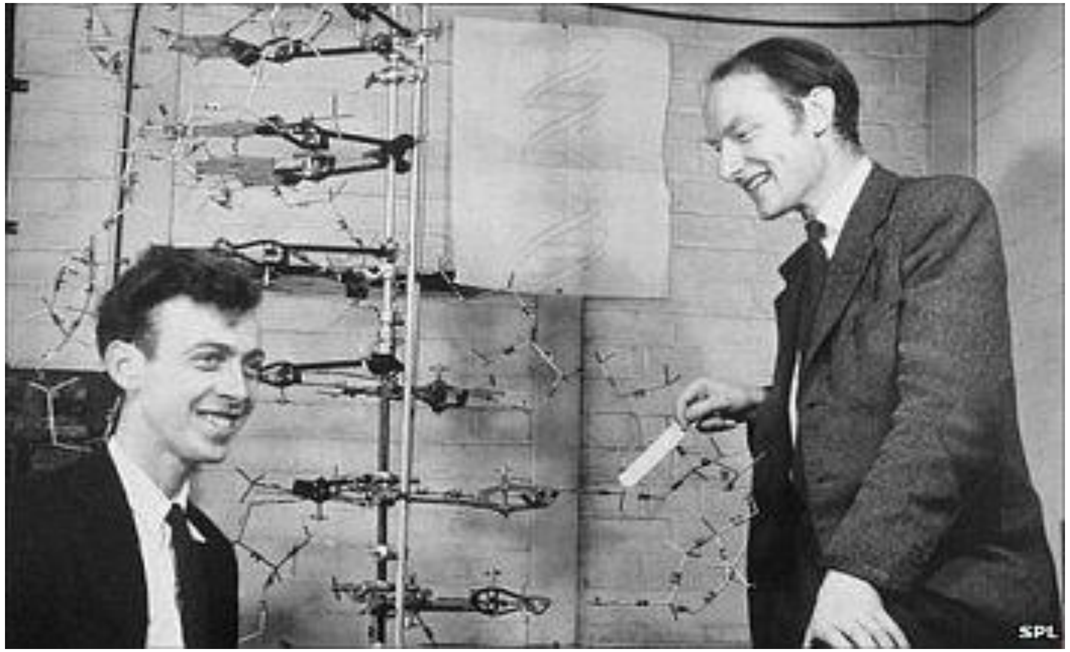


Figure 53: During the 20th century Women began entering the fields of science and math in substantial numbers. But, particularly in the early days, they were often overlooked in giving credit for important discoveries, as was the case with Rosalind Franklin. It was she who in reality was the first scientist to discover DNA's double-helix structure, although Watson and Crick are the ones most often sighted for this achievement.

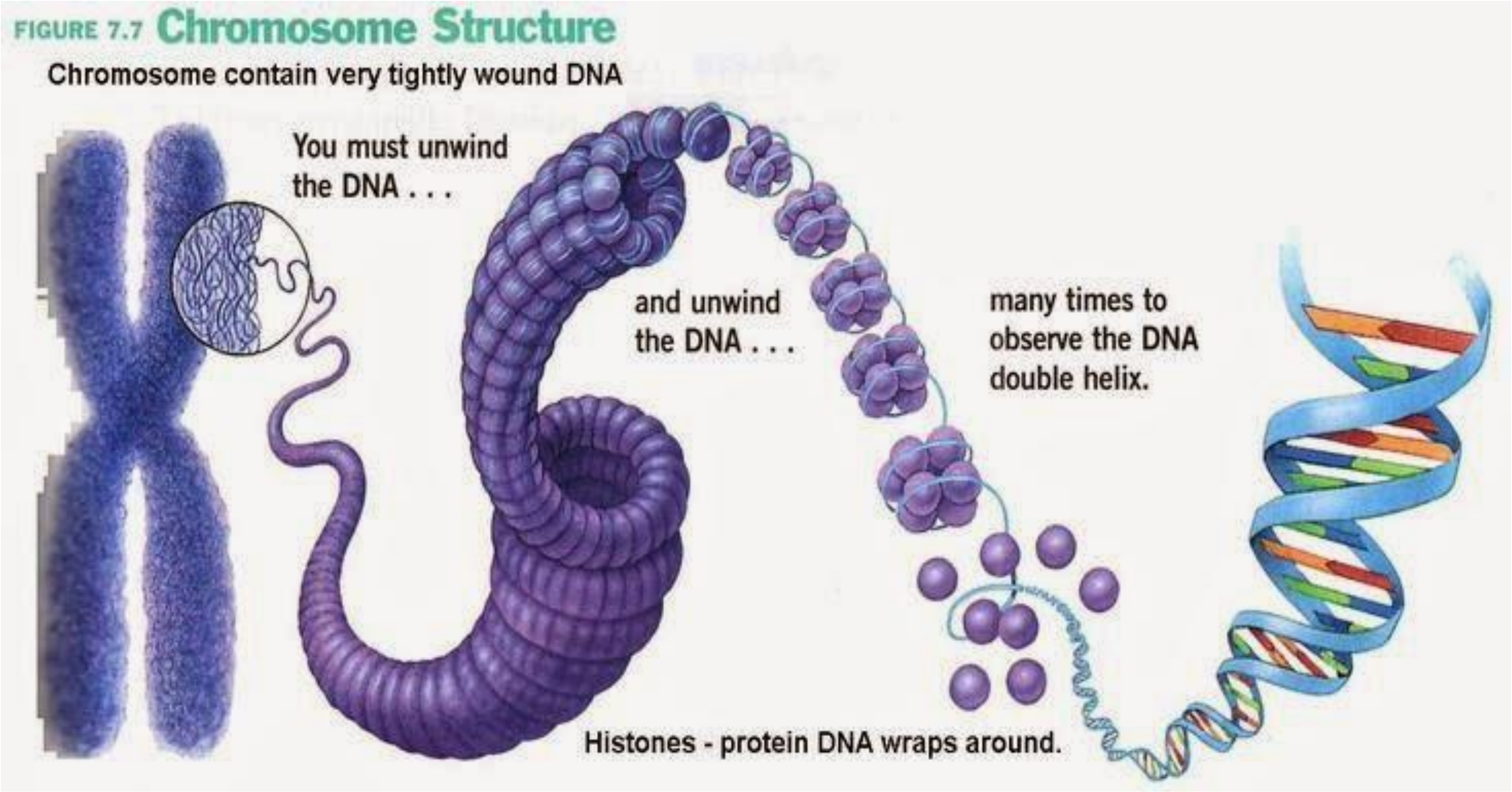


Figure 54: Given here is a more complete picture of the structure of a chromosome depicted during cell division in which the chromosome has duplicated. As indicated the chromosome's DNA exists in an exceedingly long strand wound around proteins called histones then packaged in a coiled manner. A given chromosome contains many genes existing in separate sections along the strand of DNA.

Genetic Expression and the Genetic Code

The genetic code is the combination of nucleotides that determines the sequence of amino acids in a protein

Genetic expression is the set of events between the activation of a gene and the completion of a manufactured protein.

Figure 55: Essentially, proteins are a combination of amino acids organized in structures unique for each protein. The sequence of nucleotides (aka nucleic acids) in a gene is the code that determines the sequence of amino acids in a protein. The latter sequence is the primary structure of the protein which is folded and shaped in unique ways for each individual protein. Genetic Expression is the name given to the entire process from activation of a gene to completion of a functional protein.

There are two basic processes in genetic expression

Transcription: Transcribing the genetic Code in DNA onto RNA

Translation: Translating the nucleotide language of DNA/RNA into the amino acid language of a protein.

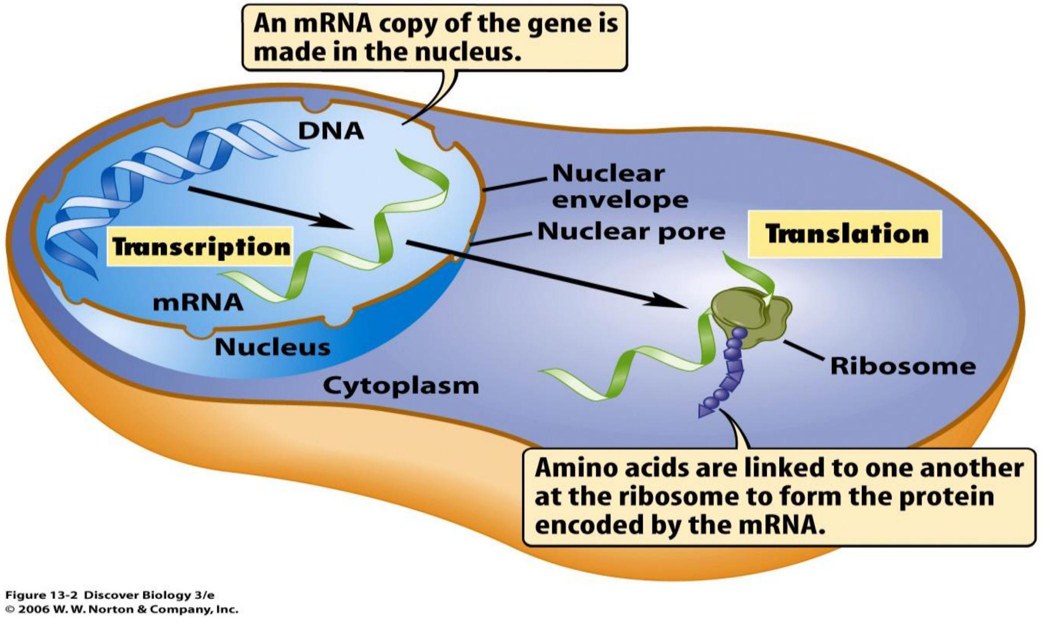


Figure 56: Genetic expression is divided into two sequential steps, ***transcription*** and ***translation***. The first of these, transcription, occurs in the nucleus of a cell and consists of splitting the two halves of the double-helix of DNA with the exposed nucleotides on one of the halves serving as a template for the manufacture of a similar molecule called messenger RiboNucleic Acid (mRNA). The only difference between DNA and RNA is that DNA is missing an oxygen atom present in RNA. As its name implies, mRNA carries the unique sequence of nucleotides (the message) necessary to make the primary structure of the coded protein. After transcription is complete, mRNA carries the coded message of DNA into the cytoplasm of a cell where it translates the sequence of nucleotides into the sequence of amino acids that comprises the primary structure of the protein.

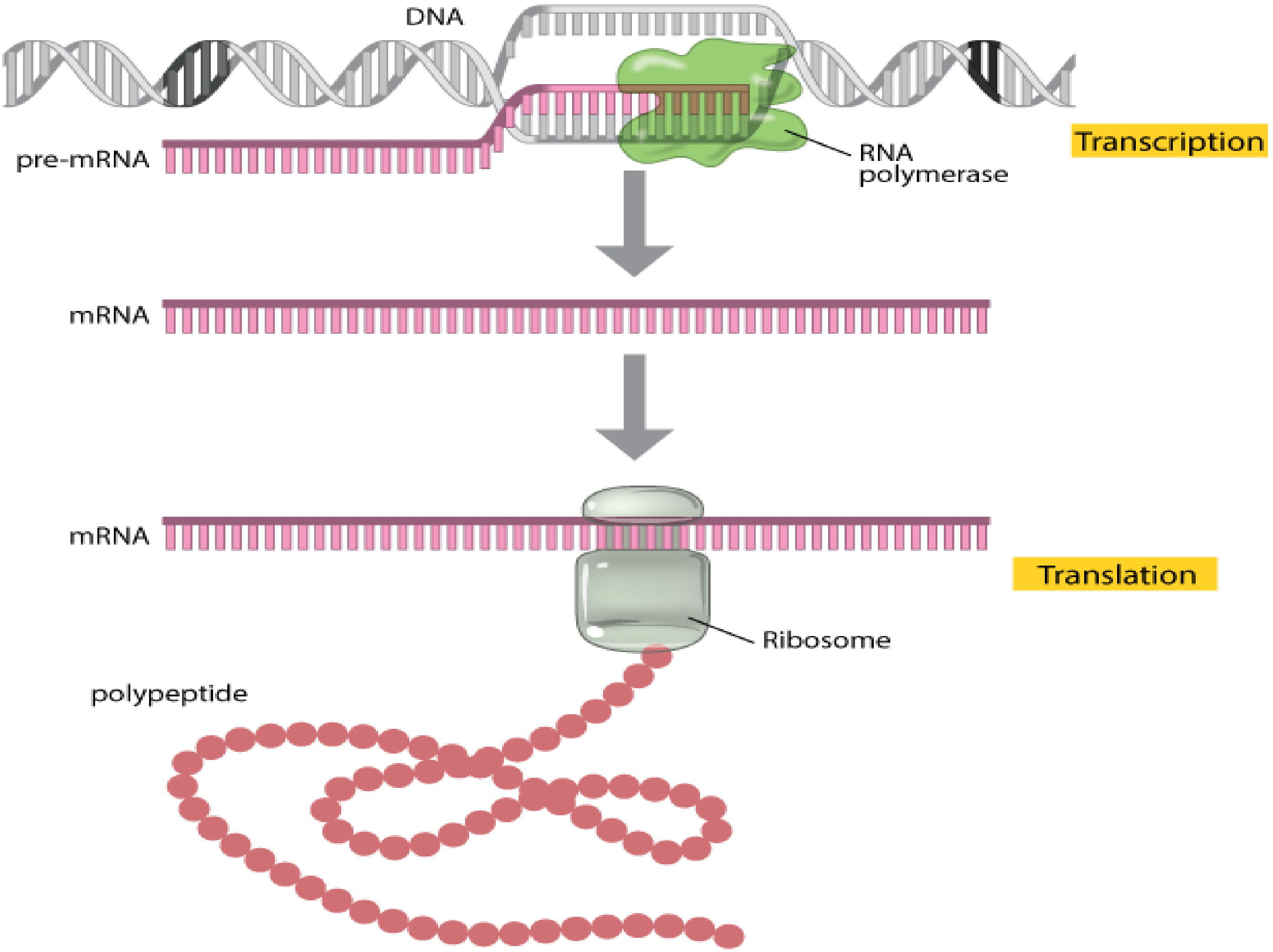


Figure 57: This figure gives another illustration of the transcription and translation steps described in the previous figure.

Protein Structure

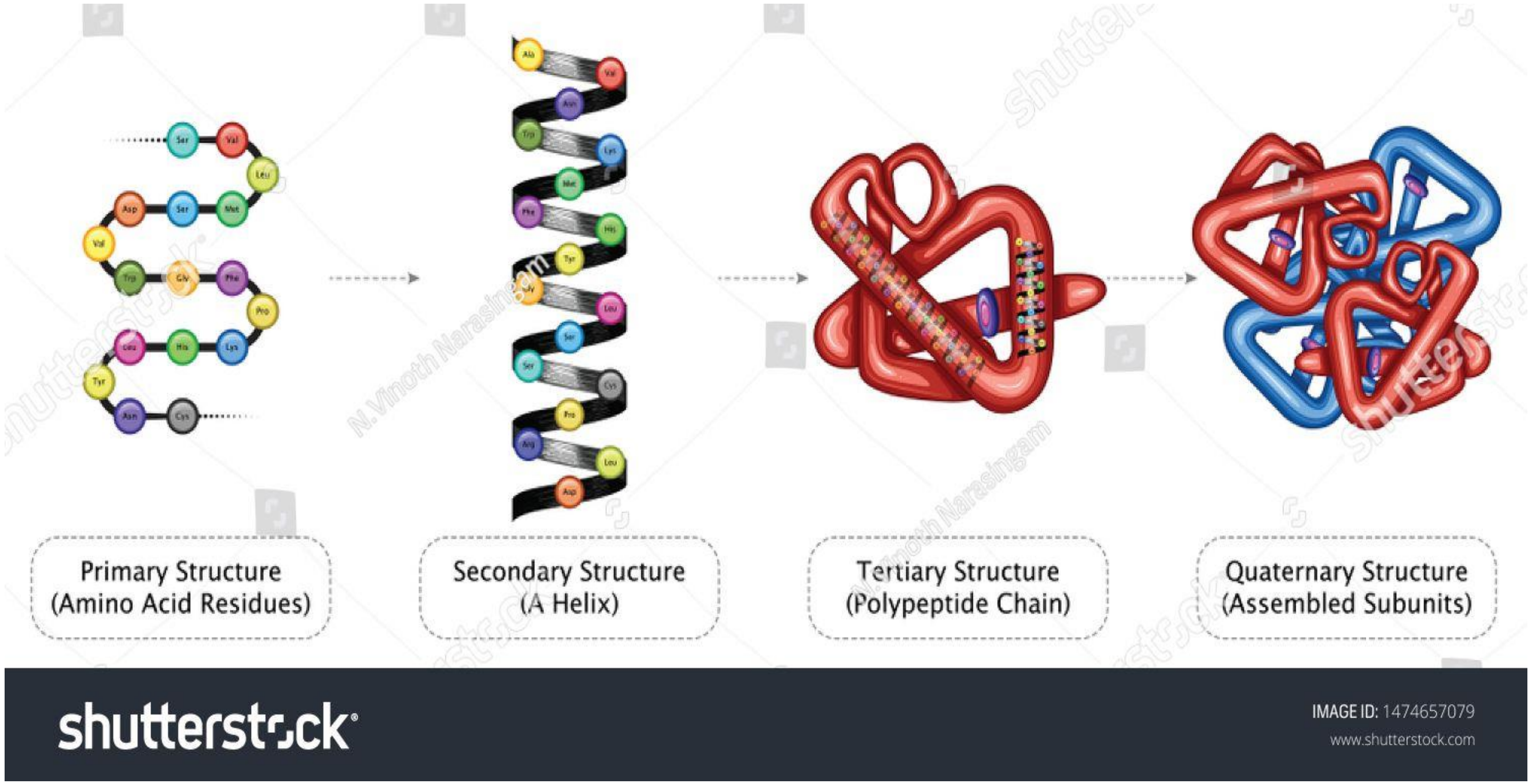
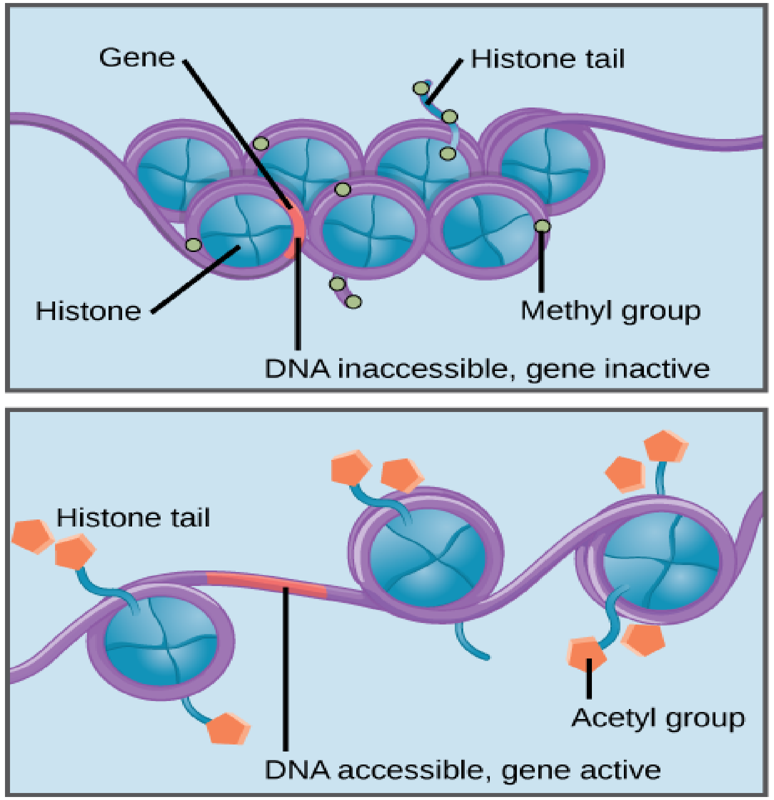
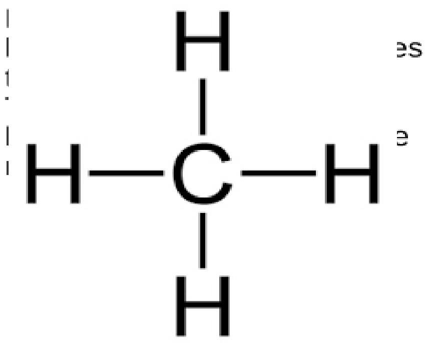


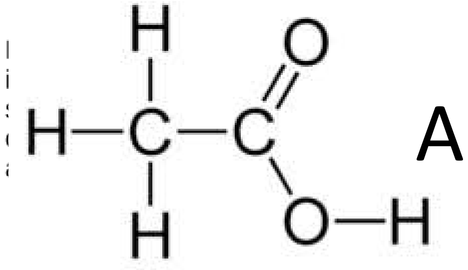
Figure 58: As illustrated here, the primary protein structure, shown on the left (the amino acid sequence) is simply the initial step in the construction of a functional protein the complete structure of which consists of secondary, tertiary, etc structures.

Control of genetic expression involves molecules on the surface of DNA and histones termed epigenomes. Methyl groups and Acetyl groups are examples.





Methane



Acetate

Figure 59: What controls the start of genetic expression are molecules, called epigenomes (epi = surroundings; genomes = genes), which are attached to the surface of both DNA and the histones that the DNA wraps around. It is the epigenomes that the receive signals, including those from our environment, that initiate the expression of a gene.

Role of Epigenomes in Acclimating to the Environment:

Epigenomes receive signals from the environment, and are the link by which environmental change induces adaptive responses of an organism.

Form a *"memory"* of an environmental change, which provides a more rapid adaptive response to subsequent exposures.

Figure 60: The strange thing about epigenomes, which is not completely understood, is that once they have attached to a signal that starts the expression of a gene, they form what is figuratively described as a memory of the process. Subsequent attachment of similar signals are then more effective.

Epigenomes Initiate a Heat Shock (stress) Response

Environmental Stress → environmental signal → Epigenome → *Transcription* of "heat shock" proteins (aka stress proteins)

- heat
- cold
- physical activity
- injury
- infection
- emotional stress
- etc

"heat shock" proteins (aka stress proteins) → heat shock response → damage repair / acclimation

Figure 61: In 1962 it was discovered that epigenomes activated in response to environmental heat initiate what was has been termed a *"heat-shock response".* Subsequent studies showed that this response was not limited to heat, but is a general response to a variety of stresses, some of which are listed in the left-hand portion of the figure. Regardless of which particular stress is involved, the response is similar. Basically, the epigenomes activated by a stress related signal initiate the transcription of a set of proteins called heat-shock proteins, a term that remains in the literature even though these proteins are now known to respond to stress in general. Fundamentally, heat-shock proteins do two things: 1) repair cellular damage caused by the stress, and 2) orchestrate changes in body functions geared toward acclimation to the particular stress involved.

Effects of Heat-Shock Proteins

Repair of damaged proteins and more

- Restore damaged protein structure
- Uncouple aggregated proteins
- Stabilize and protect protein interactions
- Repair damaged cell membranes
- Etc

Figure 62: One of the major jobs of heat-shock proteins is to repair a cell's proteins and membranes damaged by the stress. This particular action of these proteins has been termed a "chaperone function". My best guess for this term is because, in addition to repair, an other job of heat-shock proteins is to keep a cell's proteins from experiencing further damage.

Effects of Heat-Shock Proteins: continued

Adaptive (acclimation) effects:

- Increase in sweating efficiency.
  - earlier onset of sweating
  - increased sweat production
  - reduced loss of electrolytes in sweat
- Increased blood flow to the skin.
  - more effective evaporative and convective cooling.
- lower body temperature at a given environmental temp.

Figures 63 and 64: These two figures list the various roles of heat-shock proteins in acclimation of an individual to frequent encounters of environmental heat.

Adaptive (acclimation) effects of heat shock proteins: Continued

Reduced activation threshold for thermoreceptors.
More rapid response to heat exposure.

Improved coupling between body water and thirst.
Reduces risk of dehydration.

Facilitates transcription of new-heat shock proteins
More effective acclimation.

Steps in Acclimating to a Warm Environment

Do outdoor summer activity before 10:00 AM or after 4:00 PM when UV rays are low (it will still be plenty hot enough in the valley). But dress properly and use sun screen.

As for how to heat acclimate, there are no specific guidelines for elders. General guidelines can be found in the following Time magazine article: *How to Build Up Your Heat Tolerance to Prepare for a Hotter World* https://time.com/6207087/improve-heat-tolerance/ The key steps mentioned in this article are listed in the next figure.

Disclaimer: If you are accustomed to doing outside activities year round on a regular basis, you will naturally acclimate to whatever the weather may be. Nonetheless, to be on the side of safety, it would be best to follow the precautions mentioned in this presentation for dealing with heat, such as dressing properly and staying hydrated.

Guidelines for heat acclimation in the Time article recommend 15 min of mild* outside activity daily for 9 to 14 days. But use your best judgment as to both time* and frequency* depending on your experience with heat and exactly how hot it is.

* These instructions are subjective, leaving room for you to use your own judgment.

You might want to go for every other day rather than every day.

If you're not use to the heat, start at a temp below 100^{o} F and for less than 15 min.

Once you have done this 14 or so times, then maintain your acclimation by repeating two or three times a week.

As our world gets warmer, you can still safely get out and enjoy!
Whatever your pleasure may be, do, but don't overdo!