

1 **Human Skin Color**

An Introduction to Lab VI

2 **Skin**

- The body's largest organ
- Functions in many ways:
 - Thermoregulation
 - Protection from chemical and physical injury
 - Protection from invasion by organisms
 - Manufactures essential nutrients

3 **Skin Color and Human Variation Studies**

- One of the most conspicuous human polytypic variations, skin color has attracted more scholarly attention than any other aspect of human variability
- Skin color has served as a primary feature in most systems of racial classification

4 **Components of Skin Color**

- **Melanin:** a brown pigment secreted by cells called **melanocytes** in the bottom layer of skin and responsible for the majority of the variation present in skin color
- **Hemoglobin:** gives oxygenated blood cells their red color
- **Carotene:** a reddish-orange pigment found in the skin; results from an over-consumption of carotene rich foods like carrots

5 **Melanin, Melanocytes, and Skin Color**

- Melanocytes synthesize melanin which is combined with granules and injected into the surrounding keratinocytes
- People vary in the amount of melanin produced but not in the number of melanocytes

6 **Genetics of Skin Color**

- Comparisons of parents and offspring suggest that skin color is controlled by several genes
- From four to six genes have been proposed but probably many more

7 **Measuring Skin Color**

- Simple Color Divisions (earliest method of "measuring skin color")
 - Black
 - White
 - Yellow
 - Brown
 - Red

8 **Measuring Skin Color**

- Felix von Luschan skin color tiles: a chromatic scale with 36 different skin color tiles

9 **Measuring Skin Color**

- **Reflectance Spectrophotometer** – measures the percent of light reflected back from a given source at different wavelengths (Photovolt and EEL)
- Photovolt comes with a variety of filters (Blue – 240 mu, Tri-Blue – 450 mu, Green – 525 mu, Tri-green – 550 mu, Tri-amber – 600 mu, and Red – 670 mu)
- Measuring site: upper inner arm to minimize the effects of tanning

10 **Reflectometers and Skin Color**

11 **Facts About Skin Color**

- Skin color varies between sexes – males are typically darker than females
- Skin color is lighter in infants and children and slowly darkens with age
- Skin color shows a normal distribution within a population

12 **Skin Color Variation**

13 **Distribution of Skin Color**

14 **Correlation Between Skin Color, Latitude, and Solar Radiation**

15 **Skin Color and Latitude**

16 **Skin Color and Latitude**

- Hemispheric difference – skin color tends to be darker in the southern hemisphere than in the northern latitudes

17 **Latitude and Ultraviolet Radiation**

- High correlation between latitude and amount of ultraviolet radiation
- Ultraviolet radiation greatest at the equator and least farther away – also more uv radiation in the southern hemisphere and less in the northern hemisphere

18 **Selective Mechanisms Involved In Human Skin Color**

- Sunburn
- Cancer
- Temperature (Frostbite)
- Photochemical Effects (Vitamin D synthesis)

19 **Sunburn**

- Causes congestion of the subcutaneous capillaries
- Destruction of the cells at several layers
- Edema (collection of fluids under the skin's surface)
- Loss of skin can open the body to infection
- Reduction of ability to regulate body temperature (sweat gland function is reduced leading to heat exhaustion)

- Permanent damage to underlying tissues

20 **Skin Cancer**

- Skin cancer the result of overexposure to sunlight causing alteration of cellular DNA
- **Three types of skin cancer:**
 - **Basal cell cancer** (lowest level of the epidermis; one of the most common)
 - **Squamous cell cancer** (outer layer of the epidermis; one of the most common)
 - **Malignant melanoma** (cancer of the melanocytes; much more deadlier than the other two because it can grow and spread quickly)

21 **Skin Cancer Rates**

- Highest among fair-skinned people
 - Highest rates in white Australians (265 cases/100,000 males and 133 cases/100,000 females compared to British populations of 28 and 15, respectively per 100,000)
- Skin cancers occur rarely if ever in darker skinned populations

22 **Skin Color, Temperature, and Frostbite**

- Temperature is also highly correlated with latitude – higher average temperatures at the equator and lower temperatures with increasing latitude
- Cold injury is more prevalent in dark-skinned populations than light-skinned populations
 - First and Second World War and Korean War soldiers of dark skin were four times more likely to suffer from frostbite than light-skinned soldiers
 - Laboratory experiments with guinea pigs having both light and dark skin colors showed more frequent and more severe injury to dark skinned areas than light skinned areas

23 **Photochemical Effects of Sunlight**

- Decomposition of vitamins (folic acid, riboflavin, and vitamin E -- all essential for metabolism and can result in impaired growth and lowered reproductive capacity)
- Positive photochemical effect – Vitamin D synthesis essential for skeletal growth and absorption and transport of calcium

24 **Vitamin D Synthesis**

- Most vitamin D is synthesized in the body through the action of sunlight on compounds in the skin
- Exposure of a small amount of skin for a short period of time is sufficient to synthesize the Vitamin D necessary for body metabolism
- Darker skin requires six times as long to make the same amount of vitamin D as light skin; variation also by latitude – longer to synthesize vitamin D in more northern and southern latitudes

25 **Rickets, Osteomalacia, and Low Vitamin D**

- A condition known as rickets results from chronic low vitamin D in children and a similar condition is known in adults (osteomalacia)
- Results in poor mineralization of weight-bearing parts of the skeleton, bones of the leg and pelvis in particular which become distorted and misshapen
- Can cause death in severe cases
- Can also reduce fertility and increase mortality in women with abnormally shaped pelvis

26 **Evidence for an Association Between Reduced Sunlight Exposure and Reduced Vitamin D Levels and Rickets**

- Industrialization and rickets
- Seclusion and veiling in women and rickets
- East Indies and Pakistanis in Europe and African Americans

- Lighter skin color in females compared to males may relate to increased need for vitamin D in females during pregnancy

27 Vitamin D and Folate Deficiencies

28 Hypervitaminosis D and Skin Color

- Overexposure to sun can lead to **hypervitaminosis D** – an overabundance of vitamin D in the body
- Can result in calcification of many soft tissues throughout the body but also can impair kidney function
- Dark skinned people are at an advantage in the tropic region

29 Selective Mechanisms Overview

- Selection of Dark Skin
 - Sunburn and Infection
 - Solar Radiation and Cancer
 - Hypervitaminosis D
 - Folate, Riboflavin, and Vitamin E Destruction
- Selection of Light Skin
 - Low Vitamin D, Rickets, and Osteomalacia
 - Low Temperatures and Frostbite

30 Hemoglobin Variants and Malarial Environments

31 Hemoglobin

- Red blood cells contain a variety of proteins – the largest percentage being a protein called hemoglobin (85-90%)
- Hemoglobin functions to transport oxygen to body tissues

32 Hemoglobin Structure

- Hemoglobin is a large, complex molecule composed of four groups of **heme**, each containing an atom of ferrous iron (combines with O₂) and a long chain of amino acids (a polypeptide chain)
- Four chains are arranged into two identical pairs labeled **alpha** and **beta**

33 Hemoglobin Genetics

- Each chain is coded for by a gene (alpha-globin gene and the beta-globin gene)
- The alpha chain contains 141 amino acids coded for by a gene on Chromosome 16
- The beta chain contains 146 amino acids coded for by a gene on Chromosome 11

34 Sickle Cell Trait

- The **sickle cell trait** is a common hemoglobin variant (different from the “normal” hemoglobin) that occurs in polymorphic frequencies in certain populations
- The sickle cell trait is caused by a single amino acid substitution at the beginning of the beta-globin gene (Valine replaces Glutamic Acid at position 6 on the beta chain)

35 **Sickle Cell Trait**

- This seemingly small change causes the generally smooth and rounded red blood cells to develop sharp irregular edges when packed with sickle hemoglobin and clog the capillaries – the body responds by attacking and lysing (breaking apart the cells)

36 **Genetics of the Sickle Cell Trait**

Simple Inheritance, Two codominant alleles – HbA (normal allele) and HbS (sickle cell allele)

Genotype	Phenotype	
Hb ^A Hb ^A	Normal Hemoglobin	
Hb ^A Hb ^S oxygen	Sickle Cell Trait – normal deprivation	hemoglobin except under
Hb ^S Hb ^S in death	Sickle Cell Disease – severe (100,000 deaths yearly)	anemia – frequently results

37 **Sickle Cell Disease**

38 **Polymorphic Frequency
of the Sickle Cell Trait**

- HbS allele frequency can reach 25% occurrence in some populations
- Why isn't the trait eliminated? Clues come from:
 - Distribution of the trait
 - Studies of mortality of normal and abnormal individuals

39 **Distribution of the HbS Allele**

40 **Distribution of the HbS Allele**

- Found in high frequency in tropical regions
- Found in highest frequency in people from west Africa where the frequency may reach over 25%
- A few comparable areas are known in the Mediterranean and in India and Arabia
- In northern Europe and east of India the gene is rare
- The gene is absent in New World prior to introduction by African slaves

41 **Distribution of Sickle Cell Trait and Malaria**

42 **Sickle Cell Trait, Malaria and Mortality**

- Studies of mortality in normal and sickle cell carrier individuals indicates an increased fitness of heterozygotes and reduced fitness of normal hemoglobin individuals in areas where malaria is present

43 **Malaria**

- Malaria is an infectious disease found mainly in tropical areas but also in subtropical areas

where seasonal fluctuations in climate allow it to spread

- Caused by four protozoan species of the genus *Plasmodium*.
 - *P. vivax*
 - *P. ovale*
 - *P. malariae*
 - *P. falciparum* – most deadly

44 **Transmission of Malaria**

- The protozoan are transmitted to humans by mosquitos, particularly of the genus *Anopheles* (females) and so the distribution of malaria is closely linked to the distribution of suitable habitat for this mosquito species.

45 **Malaria and Mortality**

- The malarial parasite is the most deadly organism to humans on the planet
- Causes more than 2 million direct deaths annually – mostly infants
- Thought to have been responsible for over half of all human deaths since the Stone Age, particularly after the advent of agriculture which served to increase suitable habitat for the *Anopheles* species

46 **Relationship of Malaria and Agriculture**

47 **Selective Advantage of the Sickle Cell Trait**

- Individuals with sickle cell anemia and carriers of the trait have red blood cells that provide a less conducive environment for the parasite to reproduce itself
- Selective advantage of the heterozygote in a malarial environment allows the balancing of the two allele forms (A and S) – a balanced polymorphism:
 - Hb^AHb^A – get malaria
 - Hb^AHb^S – less frequently infected by malaria and when infected exhibit less of the parasite in the blood
 - Hb^SHb^S – sickle cell anemia

48 **Test of the Relationship Between the Sickle Cell Trait and Malaria**

- African-American descendants of West African slave populations have shown dramatic declines in the frequency of the S allele (5-10% versus 20% in source populations)

49 **Other Genetic Adaptations to Malarial Environments**

- Other Hemoglobin Variants
- Thalassemias
- G-6-PD (Glucose – 6 – phosphate dehydrogenase) Variants

50 **Other Hemoglobin Variants**

- Hemoglobin variants have been noted in both alpha and beta chains
 - 150 variants in the beta chain
 - 70 variants in the alpha chain

- Most are rare but some reach polymorphic proportions
- All show anemia to some degree in the heterozygote and exhibit little or no pathological abnormality in the heterozygote

51 Other Hemoglobin Variants

52 Polymorphic Hemoglobin Variants

- **C** beta chain (Position 6 – lysine) substituted for glutamic acid)
- **E** beta chain (Position 26 – acid) lysine substituted for glutamic acid)
- **D Punjab** beta chain (Position 121 – glutamine) glutamic acid substituted for glutamine)
- **J Tongariki** alpha chain (Position 115 – aspartic acid substituted for alanine)

53 Hemoglobin Type E

- Third most common hemoglobin variant
- Limited distribution – begins where HbS ends
- Occurs in high frequency (>15%) among populations extending from India through SE Asia and to New Guinea
- The homozygote (EE) does not suffer as severely from acute anemia as does the (SS) nor is their cell distortion, but there appears to be differences between the fitness of the genotypes that favors the heterozygote (AE)

54 Hemoglobin Type C

- Limited area of west Africa
- Overlap with distribution of the S allele but where C is high, S is low

55 Hemoglobin Type D Punjab

- Found in various parts of the world but in highest frequency among Indian populations (1-5% in Sikhs and Gujeratis)

56 Hemoglobin Type J Tongariki

- Islands of the south Pacific and New Guinea

57 Thalassemias

- Thalassemias result from the interruption of the synthesis of the Beta or Alpha Globin chain
- Not caused by point mutations as in Hemoglobin variants but caused by a shift or deletion in the sequences of DNA that code for the alpha and beta chains
- Result is that the Alpha and Beta chains are shortened or sometimes eliminated altogether (Alpha and Beta Thalassemias)

58 Beta Thalassemias

- 37 genes that can affect the rate of synthesis of the Beta chains
- **Thalassemia major (Cooley's Anemia):** inherited as an autosomal dominant on the beta globin gene cluster on Chromosome 11
- Reduces or halts the production of beta chains
- Common in the Mediterranean (35% of Italians are carriers of some form of BT)

- Ranges from lethal to mild depending on the site of the mutation

59 **Alpha Thalassemias**

- Even more variable than Beta Thalassemias
- Deficiencies of Alpha chain production
- Mild to severe to lethal
- More complicated mode of inheritance: two loci on Chromosome 16

60 **G-6-PD (Glucose – 6 – Phosphate Dehydrogenase)**

- Enzyme present in all body cells; catalyst for a variety of functions (aids in the reduction of glucose-6-phosphate, a sugar) but also vital for red blood cell maintenance
- Under control by a gene on the sex chromosome (X; no locus on the Y chromosome)
- A number of different alleles (A+, A-, B-) on this gene, some of which code for abnormal forms of the G6PD enzyme
- Under conditions of infection or parasitism the red blood cells lyse (burst) and individual becomes anemic slowing or halting the reproduction of the malarial parasite

61 **G6PD Variants**

- 326 variants known

62 **G6PD Distribution**

- Because the trait is sex linked it is found more common in males than in females
- Highest frequencies occur in and around the Mediterranean especially in Egyptians and Sardinians

63 **Distribution of Thalassemias and G6PD**

64 **Thalassemia, G6PD, and Elevation in Sardinia**

65 **Thalassemia, G6PD, and Elevation in Sardinia**