SOLVED PROBLEMS

1. A molecule of double-helical DNA was found to have a purine:pyrimidine ratio of 1:4 in one nucleotide chain. What must be the purine:pyrimidine ratio in the other strand?

Solution

What facts about DNA are relevant here? We know from the general structure of DNA that a purine in one strand will always pair with a pyrimidine in the other strand (purine A pairs with pyrimidine T, and purine G pairs with pyrimidine C). In the strand in question for every 4 pyrimidines there is 1 purine, which means that the purines occupy 1/(1 + 4), or 1/5, of the sites in one strand. If 1/5 of the sites in one strand are purines, which we know pair only with pyrimidines, then 1/5 of the sites in the other strand must be pyrimidines. Likewise 4/5 of the sites in the other strand must be purines. Therefore, the purine:pyrimidine ratio in the other strand will be 4/5:1/5, which is 4:1. (Note that this is the inverse of the ratio in the opposite strand.)

2. The human genome contains 3,000,000 kb and according to some estimates contains 100,000 genes. If we make the simple assumption that the average size of the coding region of a gene (the part that codes for protein) is 2 kb, from these data:

a. What can be concluded about the average spacing between genes on chromosomal DNA (measured from the central point of one gene to the central point of the next)?

b. What can be concluded about the proportion of the genome that codes for protein?

c. What occupies the noncoding regions?

Solution

a. The average spacing between the central points of adjacent genes must be 3,000,000 divided by 100,000, which equals 30 kb.

b. Since the protein-coding segment is only 2 kb, it is clear that only 1/15, or about 6 percent, of the genome actually codes for protein.

c. The remaining sequences must be composed of regulatory regions adjacent to genes, as well as repetitive DNA and nonrepetitive spacer DNA between adjacent protein-coding regions and introns within the protein-coding regions.

PROBLEMS

7. If thymine makes up 15 percent of the bases in a certain DNA sample, what percentage of bases must be cytosine?

8. Somebody tells you that the G content of the DNA in a certain species is 55 percent. Why should you be suspicious of this statement?

9. If someone tells you that a certain DNA sequence is GTTAACGCT, what further information would you need in order to assess its orientation within the DNA double helix?

11. In a certain 1-kb DNA molecule the G+C content is 60 percent. How many hydrogen bonds hold the two strands of this molecule together?

14. If the G+C content of a DNA sample is 48 percent, what will be the proportions of the four different nucleotides?

15. Draw a simple diagram of DNA that makes it clear what 5′ and 3′ ends are.

18. A certain segment of DNA has the following nucleotide sequence in one strand:

5′ ATTGGCTCT 3′

What must be the sequence in the other strand (label its 5′ and 3′ ends)?

19. In normal double-helical DNA is it true that

a. A plus C will always equal G plus T?

b. A plus G will always equal C plus T?

c. Purines always equal pyrimidines?

d. Phosphate always equals deoxyribose sugar?

21. What is a gene? What are some of the problems with your definition?

22. The genome of the bacterium *Hemophilus influenzae* is 1830 kb in size, and sequencing has shown it has 1703 genes.

a. What is the average spacing between the central points of the genes?

26. Progress in genome sequencing has led to the estimate that there is a 1.7 percent difference between the genomes of humans and chimpanzees. Assuming the two genomes are approximately the same size, how many nucleotide differences are there between these two species?

27. In sentence form describe the difference between

a. The purine and pyrimidine bases in DNA

b. Adenine and guanine

c. Cytosine and thymine

1. a. In how many cases in the genetic code would you fail to know the amino acid specified by a codon if you know only the first two nucleotides of the codon?

b. In how many cases would you fail to know the first two nucleotides of the codon if you know which amino acid is specified by it?

2. a. Use the codon dictionary (Figure 3-20) to complete the following table. Assume that reading is from left to right and that the columns represent transcriptional and translational alignments.

b. Label 5′ and 3′ ends of DNA and RNA, and amino and carboxyl ends of protein.

C											DNA double helix
					T	G	A				
	C	A			U						mRNA transcribed
								G	C	A	Appropriate tRNA anticodon
			TRP								Amino acids incorporated into protein

3. Consider the following segment of DNA:

5′ GCTTCCCAA 3′
3′ CGAAGGGTT 5′

If the top strand is the template strand used by RNA polymerase,

a. draw the RNA transcribed.

b. label its 5′ and 3′ ends.

c. draw the corresponding amino acid chain.

d. label its amino and carboxyl ends.

Repeat, assuming the bottom strand is the template strand.

8. The following table shows the ranges of enzymatic activity (in units we need not worry about) observed for enzymes involved in two recessive metabolic diseases in humans. Similar information is available for many metabolic genetic diseases.

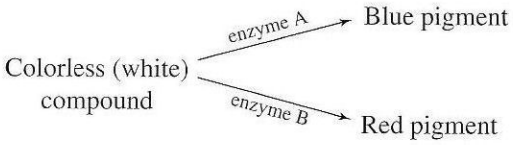
		RANGE OF ENZYME ACTIVITY		
Disease	Enzyme involved	Patients	Hetero-zygotes	Normal individuals
Acatalasia	Catalase	0	1.2–2.7	4.3–6.2
Galactosemia	Gal-1-P uridyl transferase	0–6	9–30	25–40

a. Of what use is such information to a doctor who is counseling prospective parents who know that these diseases have occurred in their families?

b. Indicate any possible sources of uncertainty in trying to advise prospective parents.

c. Discuss the concept of dominance in the light of such data.

9. In a certain plant, the flower petals are normally purple. Two recessive mutations arise in separate plants and are found to be in different genes. Mutation 1 (*m1*) gives blue petals when homozygous (*m1 / m1*). Mutation 2 (*m2*) gives red petals when homozygous (*m2 / m2*). Biochemists working on the synthesis of flower pigments in this species have already described the following pathway:

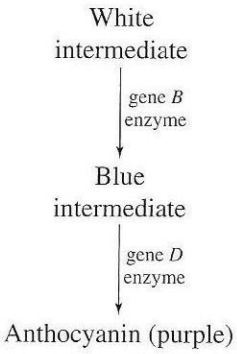


a. Which mutant would you expect to be deficient in enzyme A activity?

b. A plant has the genotype $m1^+ / m1 \ . \ m2^+ / m2$ (it is heterozygous for both genes). What would you expect its phenotype to be?

c. Why are these mutants recessive?

10. In sweet peas, the synthesis of purple anthocyanin pigment in the petals is controlled by two genes, *B* and *D*. The pathway is



a. What petal color would you expect in a plant homozygous for a recessive mutation that renders it unable to catalyze the first reaction?

b. What petal color would you expect in a plant homozygous for a recessive mutation that renders it unable to catalyze the second reaction?

12. Normally the thyroid growth hormone thyroxine is made in the body by an enzyme as follows:

$$\text{Tyrosine} \xrightarrow{\text{enzyme}} \text{thyroxine}$$

If the enzyme is deficient, the symptoms are called *genetic goiterous cretinism* (GGC), a rare syndrome consisting of slow growth, enlarged thyroid (called a *goiter*), and mental retardation.

a. If the normal allele is haplo-sufficient, would you expect GGC to be inherited as a dominant or a recessive phenotype? Explain.

b. Speculate on the nature of the GGC-causing allele, comparing its DNA sequence with the normal allele. Under your model show why it results in an inactive enzyme.

c. How might the symptoms of GGC be alleviated?

d. At birth infants with GGC are perfectly normal and develop symptoms only later. Why do you think this is so?

18. Several yeast mutants are isolated, all of which require compound G for growth. The compounds (A to E) in the biosynthetic pathway to G are known, but not their order in the pathway. Each compound is tested for its ability to support the growth of each mutant (1 to 5). In the following table, "+" indicates growth and "−" indicates no growth:

	COMPOUND TESTED					
	A	B	C	D	E	G
Mutant 1	−	−	−	+	−	+
2	−	+	−	+	−	+
3	−	−	−	−	−	+
4	−	+	+	+	−	+
5	+	+	+	+	−	+

a. What is the order of compounds A to E in the pathway?

b. At which point in the pathway is each mutant blocked?

21. Explain fully the following observations on two genes in *Drosophila.* In all cases invent allele symbols.

a. Twenty units of enzyme E are normally found in homozygous wild-type cells. A homozygous mutant shows zero units. A heterozygote is mutant in appearance and has 10 units of E per cell.

b. Thirty units of enzyme F are normally found in homozygous wild-type cells. A homozygous mutant shows zero units. A heterozygote is wild-type in appearance and has 15 units of F per cell.

23. In babies with PKU, a special diet low in phenylalanine allows development to continue without retardation. Indeed it has been found that after the child's nervous system has developed, the patient can be taken off the special diet. However, tragically, many women who had been born with PKU developed normally under the special diet but stopped the diet in adulthood and then gave birth to babies who were born mentally retarded. Giving the special diet to these babies had no effect on them.

a. Why do you think the babies of these mothers were born retarded?

b. Why did the special diet have no effect on these babies?

c. Explain the reason for the different response to the low-phenylalanine diet by the babies born with PKU and babies of mothers born with PKU.

d. Propose a treatment that might allow mothers with PKU to have unaffected children.

e. Write a short essay on PKU, integrating concepts at the genetic, diagnostic, enzymatic, and physiological levels.

24. A single nucleotide addition and a single nucleotide deletion approximately 15 sites apart in the DNA cause a protein change in sequence from

Lys—Ser—Pro—Ser—Leu—Asn—Ala—Ala—Lys

to

Lys—Val—His—His—Leu—Met—Ala—Ala—Lys

a. What are the old and the new mRNA nucleotide sequences? (Use the codon dictionary in Figure 3-20.)

b. Which nucleotide has been added and which has been deleted?

(Problem 24 is from W. D. Stansfield, *Theory and Problems of Genetics.* McGraw-Hill, 1969.)