12E: Regulation of Gene Expression (Exercises)

These are homework exercises to accompany Nickle and Barrette-Ng’s "Online Open Genetics" TextMap. Genetics is the scientific study of heredity and the variation of inherited characteristics. It includes the study of genes, themselves, how they function, interact, and produce the visible and measurable characteristics we see in individuals and populations of species as they change from one generation to the next, over time, and in different environments.

Study Questions:

12.1 List all the mechanisms that can be used to regulate gene expression in eukaryotes.

12.2 With respect to the expression of β-galactosidase, what would be the phenotype of each of the following strains of *E. coli*?

a) $\alpha^+\beta^+\gamma^+$ (no glucose, no lactose)

b) $\alpha^+\beta^+\gamma^+$ (no glucose, high lactose)

c) $\alpha^+\beta^+\gamma^+$ (high glucose, no lactose)

d) $\alpha^+\beta^+\gamma^+$ (high glucose, high lactose)

e) $\alpha^+\beta^-\gamma^+$ (no glucose, no lactose)

f) $\alpha^+\beta^-\gamma^+$ (high glucose, high lactose)

g) $\alpha^+\beta^-\gamma^+$ (high glucose, high lactose)
h) $I^+,$ Oc, $Z^+,$ $Y^+$ (no glucose, no lactose)

i) $I^+,$ Oc,$ Z^+,$ $Y^+$ (no glucose, high lactose)

j) $I^+,$ Oc, $Z^+,$ $Y^+$ (high glucose, no lactose)

k) $I^+,$ Oc, $Z^+,$ $Y^+$ (high glucose, high lactose)

l) $I^+,$ Oc, $Z^+,$ $Y^+$ (no glucose, no lactose)

m) $I^+,$ Oc, $Z^+,$ $Y^+$ (no glucose, high lactose)

n) $I^+,$ Oc, $Z^+,$ $Y^+$ (high glucose, no lactose)

o) $I^+,$ Oc, $Z^+,$ $Y^+$ (high glucose, high lactose)

p) $I^+,$ Oc, $Z^+,$ $Y^+$ (no glucose, no lactose)

q) $I^+,$ Oc, $Z^+,$ $Y^+$ (no glucose, high lactose)

r) $I^+,$ Oc, $Z^+,$ $Y^+$ (high glucose, no lactose)

s) $I^+,$ Oc, $Z^+,$ $Y^+$ (high glucose, high lactose)

12.3 In the *E. coli* strains listed below, some genes are present on both the chromosome, and the extrachromosomal F' factor episome. The genotypes of the chromosome and episome are separated by a slash. What will be the β-galactosidase phenotype of these strains? All of the strains are grown in media that lacks glucose.

a) $I^+,$ Oc, $Z^+,$ $Y^+ / O^+,$ $Z^-,$ $Y^-$ (high lactose)

b) $I^+,$ Oc, $Z^+,$ $Y^+ / O^-,$ $Z^-,$ $Y^-$ (no lactose)

c) $I^+,$ Oc, $Z^-,$ $Y^+ / O^-,$ $Z^+,$ $Y^+$ (high lactose)

d) $I^+,$ Oc, $Z^-,$ $Y^+ / O^-,$ $Z^+,$ $Y^+$ (no lactose)

e) $I^+,$ Oc, $Z^-,$ $Y^+ / I^-,$ $O^+,$ $Z^-,$ $Y^+$ (high lactose)

f) $I^+,$ Oc, $Z^-,$ $Y^+ / I^-,$ $O^+,$ $Z^-,$ $Y^+$ (no lactose)

g) $I^+,$ Oc, $Z^-,$ $Y^+ / I^-,$ $O^+,$ $Z^-,$ $Y^+$ (high lactose)

h) $I^+,$ Oc, $Z^-,$ $Y^+ / I^-,$ $O^+,$ $Z^-,$ $Y^+$ (no lactose)

i) $I^+,$ Oc, $Z^-,$ $Y^+ / I^-,$ $O^+,$ $Z^-,$ $Y^+$ (high lactose)

j) $I^+,$ Oc, $Z^-,$ $Y^+ / I^-,$ $O^+,$ $Z^-,$ $Y^+$ (no lactose)
k) $I^+, O^+, Z^-, Y^+/I^+, Oc, Z^+, Y^+$ (high lactose)

l) $I^+, O^+, Z^-, Y^+/I^+, Oc, Z^+, Y^+$ (no lactose)

m) $I^+, O^+, Z^-, Y^+/I^p, O^+, Z^+, Y^+$ (high lactose)

n) $I^+, O^+, Z^-, Y^+/I^p, O^+, Z^+, Y^+$ (no lactose)

o) $I^p, O^+, Z^-, Y^+/I^+, O^+, Z^+, Y^+$ (high lactose)

p) $I^p, O^+, Z^-, Y^+/I^+, O^+, Z^+, Y^+$ (no lactose)

12.4 What genotypes of E. coli would be most useful in demonstrating that the lacO operator is a cis-acting regulatory factor?

12.5 What genotypes of E. coli would be useful in demonstrating that the lacI repressor is a trans-acting regulatory factor?

12.6 What would be the effect of the following loss-of-function mutations on the expression of the lac operon?

a) loss-of-function of adenylate cyclase

b) loss of DNA binding ability of CAP

c) loss of cAMP binding ability of CAP

d) mutation of CAP binding site (CBS) cis-element so that CAP could not bind

12.7 How are eukaryotic and prokaryotic gene regulation systems similar? How are they different?

12.8 Deep-water sticklebacks that are heterozygous for a loss-of-function mutation in the coding region of Pitx look just like homozygous wild-type fish from the same population. What phenotype or phenotypes would be observed if a wild-type fish from a deep-water population mated with a wild-type fish from a shallow-water population?

12.9 Some varieties of Arabidopsis, including those adopted for lab use, do not require vernalization before flowering. How might these varieties have evolved?

12.10 Histone deacetylase (HDAC) is an enzyme involved in gene regulation. What might be the phenotype of a winter annual plant that lacked HDAC function?

Chapter 12 - Answers

12.1 Transcriptional: initiation, processing & splicing, degradation

Translational: initiation, processing, degradation

Post-translational: modifications (e.g. phosphorylation), localization

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Others: histone modification, other chromatin remodeling, DNA methylation

12.2 Legend:

+++ Lots of β-galactosidase activity

+ Moderate β-galactosidase activity

-- No β-galactosidase activity

-- a) $I^+$, $O^+$, $Z^+$, $Y^+$ (no glucose, no lactose)

+++ b) $I^+$, $O^+$, $Z^+$, $Y^+$ (no glucose, high lactose)

-- c) $I^+$, $O^+$, $Z^+$, $Y^+$ (high glucose, no lactose)

+ d) $I^+$, $O^+$, $Z^+$, $Y^+$ (high glucose, high lactose)

-- e) $I^+$, $O^+$, $Z^+$, $Y^+$ (no glucose, no lactose)

-- f) $I^+$, $O^+$, $Z^+$, $Y^+$ (high glucose, high lactose)

+ g) $I^+$, $O^+$, $Z^+$, $Y^+$ (high glucose, high lactose)

+++ h) $I^+$, $Oc$, $Z^+$, $Y^+$ (no glucose, no lactose)

+++ i) $I^+$, $Oc$, $Z^+$, $Y^+$ (no glucose, high lactose)

+ j) $I^+$, $Oc$, $Z^+$, $Y^+$ (high glucose, no lactose)

+ k) $I^+$, $Oc$, $Z^+$, $Y^+$ (high glucose, high lactose)

+++ l) $I^+$, $O^+$, $Z^+$, $Y^+$ (no glucose, no lactose)

+++ m) $I^+$, $O^+$, $Z^+$, $Y^+$ (no glucose, high lactose)

+ n) $I^+$, $O^+$, $Z^+$, $Y^+$ (high glucose, no lactose)

+ o) $I^+$, $O^+$, $Z^+$, $Y^+$ (high glucose, high lactose)

-- p) $I^+$, $O^+$, $Z^+$, $Y^+$ (no glucose, no lactose)

-- q) $I^+$, $O^+$, $Z^+$, $Y^+$ (no glucose, high lactose)

-- r) $I^+$, $O^+$, $Z^+$, $Y^+$ (high glucose, no lactose)
-- s) $I^f$, $O^+$, $Z^+$, $Y^+$ (high glucose, high lactose)

12.3 Legend:

+++ Lots of β-galactosidase activity

+ Moderate β-galactosidase activity

-- No β-galactosidase activity

+++ a) $I^+$, $O^+$, $Z^+$, $Y^+$ / $O^-$, $Z^-$, $Y^-$ (high lactose)

-- b) $I^+$, $O^+$, $Z^+$, $Y^+$ / $O^-$, $Z^-$, $Y^-$ (no lactose)

+++ c) $I^+$, $O^+$, $Z^+$, $Y^+$ / $O^-$, $Z^+$, $Y^+$ (high lactose)

+ d) $I^+$, $O^+$, $Z^+$, $Y^+$ / $O^-$, $Z^+$, $Y^+$ (no lactose)

+++ e) $I^+$, $O^+$, $Z^+$, $Y^+$ / $I^+$, $O^+$, $Z^+$, $Y^+$ (high lactose)

-- f) $I^+$, $O^+$, $Z^+$, $Y^+$ / $I^+$, $O^+$, $Z^+$, $Y^+$ (no lactose)

+++ g) $I^+$, $O^+$, $Z^+$, $Y^+$ / $I^+$, $O^+$, $Z^+$, $Y^+$ (high lactose)

-- h) $I^+$, $O^+$, $Z^+$, $Y^+$ / $I^+$, $O^+$, $Z^+$, $Y^+$ (no lactose)

+++ i) $I^+$, Oc, $Z^+$, $Y^+$ / $I^+$, Oc, $Z^+$, $Y^+$ (high lactose)

+++ j) $I^+$, Oc, $Z^+$, $Y^+$ / $I^+$, Oc, $Z^+$, $Y^+$ (no lactose)

+++ k) $I^+$, $O^+$, $Z^+$, $Y^+$ / $I^+$, Oc, $Z^+$, $Y^+$ (high lactose)

+++ l) $I^+$, $O^+$, $Z^+$, $Y^+$ / $I^+$, Oc, $Z^+$, $Y^+$ (no lactose)

-- m) $I^+$, $O^+$, $Z^+$, $Y^+$ / $I^+$, $O^+$, $Z^+$, $Y^+$ (high lactose)

-- n) $I^+$, $O^+$, $Z^+$, $Y^+$ / $I^+$, $O^+$, $Z^+$, $Y^+$ (no lactose)

-- o) $I^+$, $O^+$, $Z^+$, $Y^+$ / $I^+$, $O^+$, $Z^+$, $Y^+$ (high lactose)

-- p) $I^+$, $O^+$, $Z^+$, $Y^+$ / $I^+$, $O^+$, $Z^+$, $Y^+$ (no lactose)

12.4 You could demonstrate this with just $I^+O^cZ^+/I^+O^+Z^+$. The fact that this does not have constitutive lactose expression shows that the operator only acts on the same piece of DNA on which it is located. There are also other possible answers.
12.5 You could also demonstrate this with just $I^+O^+Z^-/I^+O^+Z^+$. The fact that this has the same lactose-inducible phenotype as wild-type shows that a functional lacI gene can act on operators on both the same piece of DNA from which it is transcribed, or on a different piece of DNA. There are also other possible answers.

12.6 For all of these, the answer is the same: The lac operon would be inducible by lactose, but only moderate expression of the lac operon would be possible, even in the absence of glucose

a) loss-of-function of adenylate cyclase

b) loss of DNA binding ability of CAP

c) loss of cAMP binding ability of CAP

d) mutation of CAP binding site (CBS) cis-element so that CAP could not bind

12.7 Both involve trans-factors binding to corresponding cis-elements to regulate the initiation of transcription by recruiting or stabilizing the binding of RNApol and related transcriptional proteins at the promoter. In prokaryotes, genes may be regulated as a single operon. In eukaryotes, enhancers may be located much further from the promoter than in prokaryotes.

12.8 These fish would all have spiny tales like the deep-water population.

12.9 These could have arisen from loss-of-function mutation in FLC, or in the cis-element to which FLC normally binds.

12.10 If there was no deacetylation of FLC by HDAC, transcription of FLC might continue constantly, leading to constant suppression of flowering, even after winter.

Contributors

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