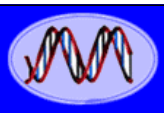
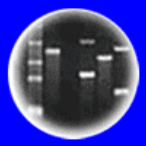

DNA
Genetic Code of Life


Entire Genetic Code of a Bacteria


DNA Fingerprinting


Cloning: Ethical Issues and Future Consequences


Plants of Tomorrow

HC70A & SAS70A Spring 2017
Genetic Engineering in Medicine, Agriculture, and Law

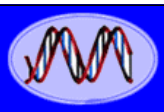
Professors Bob Goldberg & John Harada

Lecture 5

The Nuts & Bolts of Genetic Engineering: From Mutations to Drug – The Factor XIII Story

UCLA

UCDAVIS
UNIVERSITY OF CALIFORNIA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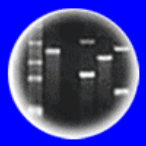
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Cloning: Ethical Issues and Future Consequences


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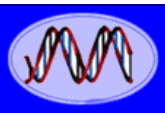
THEMES

1. What Causes Gene Mutations?
2. How Do Gene Mutations Lead to Genetic Variability?
3. How Can We Test For Gene Mutations at the DNA Level?
4. What is Hemophilia and How is it Inherited?
5. How Can a Disease Gene Be Found When It is Not Known Where the Gene is Expressed?
6. What Vectors Can Be Used For Cloning DNA?
7. What is the Advantage of Using a Virus Vector For Constructing Genome Libraries?
8. How To Make a Library of the Human Genome?
9. How Find a Gene With Only a Knowledge of the Protein Sequence?
10. How Use DNA Testing to Detect Factor VIII Disease Alleles?
11. How Isolate a Factor VIII cDNA Clone?
12. How Produce Factor VIII Protein For Use as a Drug?



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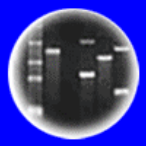

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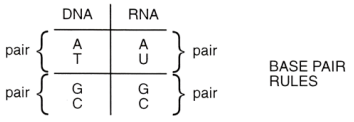
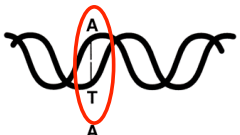
WHAT ARE THE PROPERTIES OF A GENE?

1. Replication
2. Stability (Mutations)
3. Universality
   a) All Cells
   b) All Organisms
4. Direct Cell Function/ Phenotype

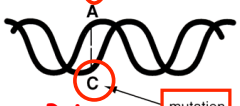
DNA Replication is Precise But Mistakes or Mutations Can Occur



Gene A



Replication①



Rare Base Mismatch

MUTATION DURING REPLICATION

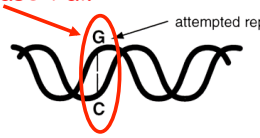
mutation

C mispairs with A

See Mutation As Change in Phenotype

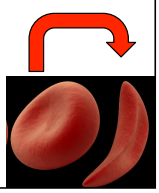
New Base Pair

Replication②
Gene A'
Allelic Variant



Change DNA Sequence From A = T to G ≡ C

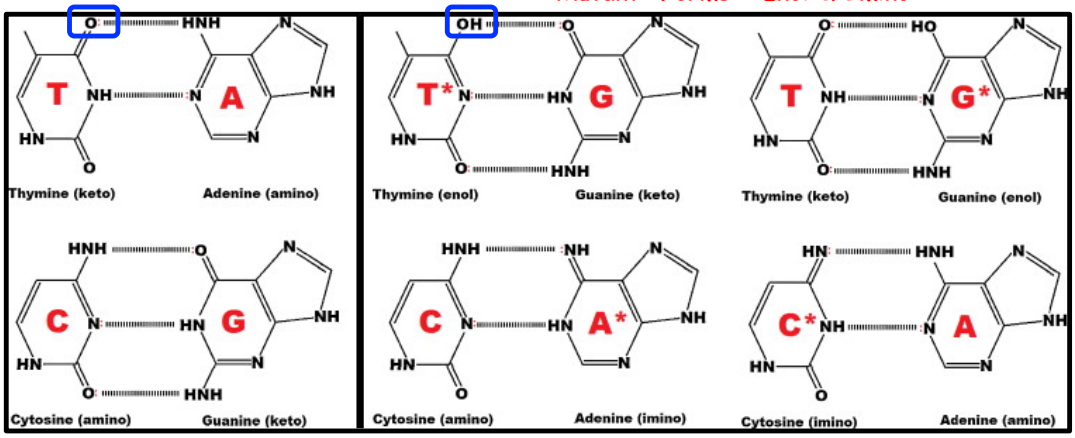
∴ Change Protein Amino Acid Sequence ⇨ Alter Function!



TAUTOMERS CHANGE BASE PAIRING RULES

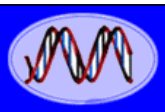
Normal Forms – Keto & Amino

"Mutant" Forms – Enol & Imino



And Lead To Mistakes in DNA Replication & Mutations ➤ Genetic Diversity

Chemistry Leads to Biology!!



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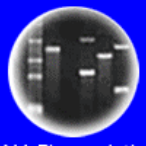

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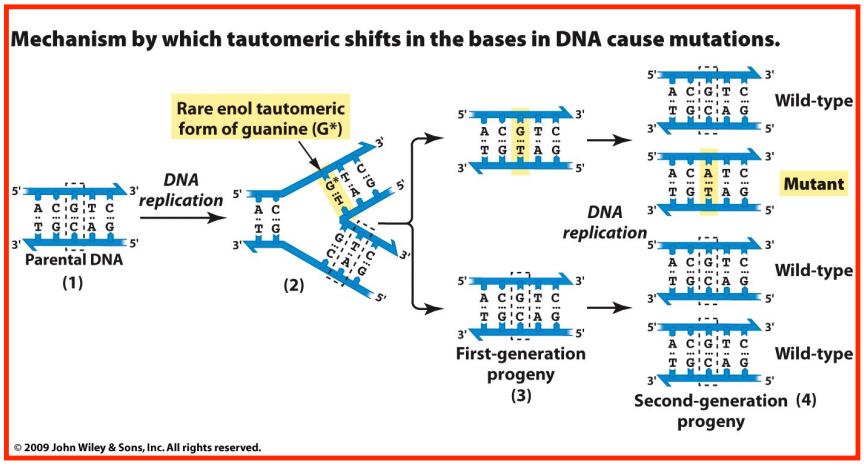
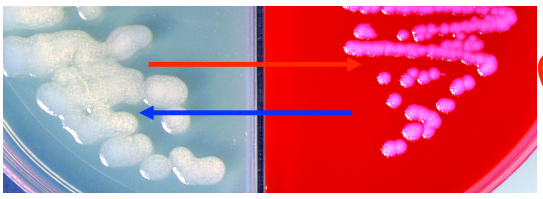
How Tautomeric Shifts Cause Mutations

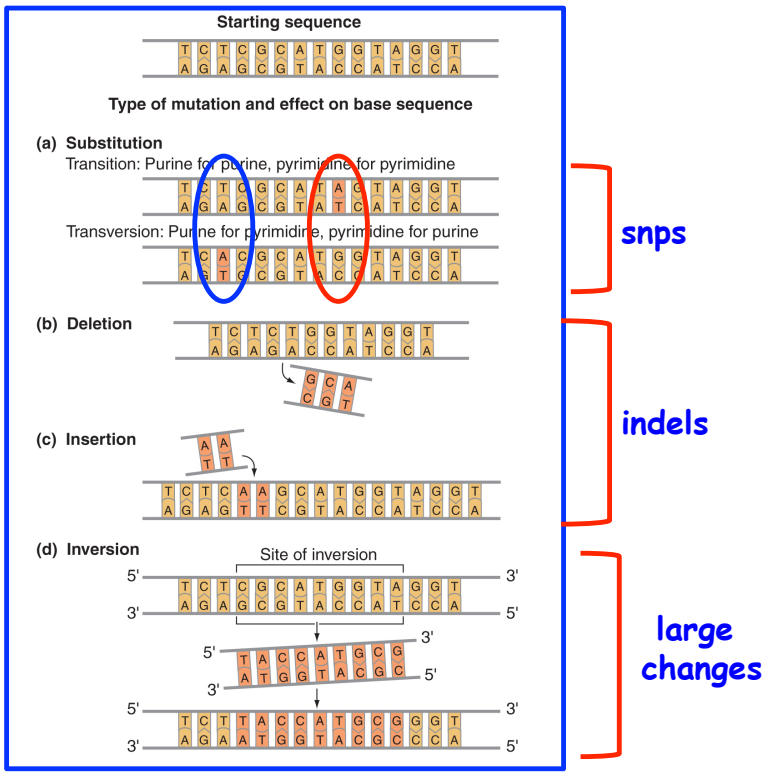


Smooth Virulent Form



Rough Avirulent Form

Different Events Cause Gene Mutations



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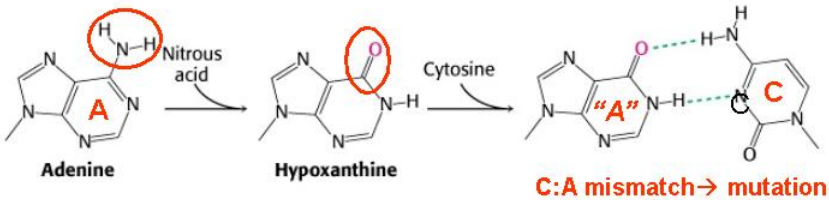
Chemicals Can Cause Mutations

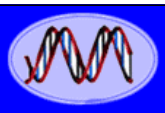
Chemical Mutagen : Nitrous acid (HNO_2)

Deamination causes A:T to G:C transitions



* HNO_2 also deaminates C to U: causes G:C to A:T transitions

By Altering Bases and Base Pairing Rules



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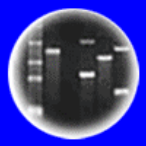

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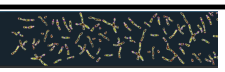
ARTICLE

1000 Genomes
A Deep Catalog of Human Genetic Variation



doi:10.1038/nature09534

A map of human genome variation from population-scale sequencing

The 1000 Genomes Project Consortium*

Nature, October 10, 2010

The 1000 Genomes Project aims to provide a deep characterization of human genome sequence variation as a foundation for investigating the relationship between genotype and phenotype. Here we present results of the pilot phase of the project, designed to develop and compare different strategies for genome-wide sequencing with high-throughput platforms. We undertook three projects: low-coverage whole-genome sequencing of 179 individuals from four populations; high-coverage sequencing of two mother–father–child trios; and exon-targeted sequencing of 697 individuals from seven populations. We describe the location, allele frequency and local haplotype structure of approximately 15 million single nucleotide polymorphisms, 1 million short insertions and deletions, and 20,000 structural variants, most of which were previously undescribed. We show that, because we have catalogued the vast majority of common variation, over 95% of the currently accessible variants found in any individual are present in this data set. On average, each person is found to carry approximately 250 to 300 loss-of-function variants in annotated genes and 50 to 100 variants previously implicated in inherited disorders. We demonstrate how these results can be used to inform association and functional studies. From the two trios, we directly estimate the rate of *de novo* germline base substitution mutations to be approximately 10^{-8} per base pair per generation. We explore the data with regard to signatures of natural selection, and identify a marked reduction of genetic variation in the neighbourhood of genes, due to selection at linked sites. These methods and public data will support the next phase of human genetic research.

- Sequenced Genomes of 2500 individuals & From 26 Different Global Populations
- Found 84 Million Variants (SNPs) & <0.5% Unique to a Population!
- Evidence For Common Ancestry of All Humans
- Found 250-300 Loss-Of-Function Mutations (KOs) Per Person
- Found 50-100 Mutations Implicated in Genetic Disorders Per Person
- 10^{-8} bp Mutations Per Generation (30 per Genome)

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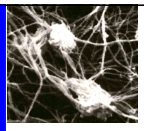
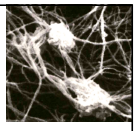


From Gene To Drug



Due to Mutations in a Different Class of Blood Proteins

The Molecular Genetics of Hemophilia

(Potentially Lethal Disease)

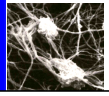
Hemophiliacs bleed because a defective gene deprives them of a key blood-clotting protein. The protein has now been made artificially by isolating the normal gene and then inserting it into cultured cells

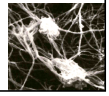
by Richard M. Lawn and Gordon A. Vehar

A Case Study of Cloning Genes and mRNAs

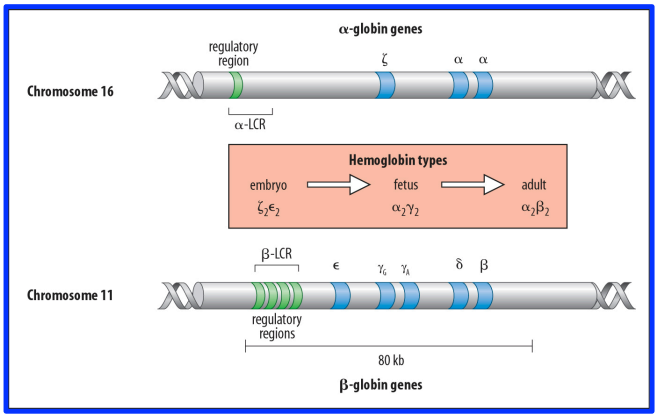
Reference: Scientific American, March 1, 1986

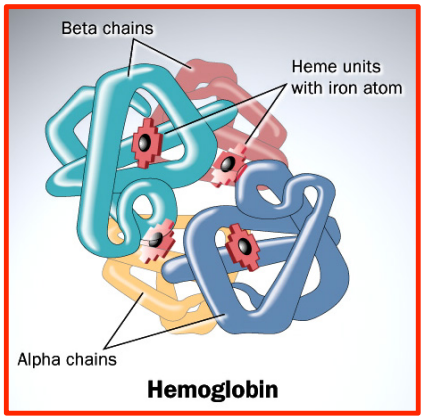
(Pick Up After Class)





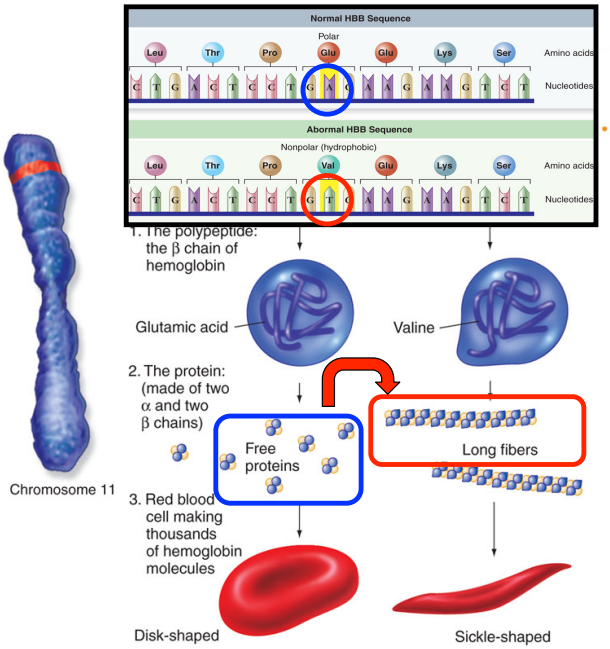
There Are Two Globin Gene Clusters in Human Chromosomes That Encode the Oxygen Carrier of Blood Cells - Hemoglobin



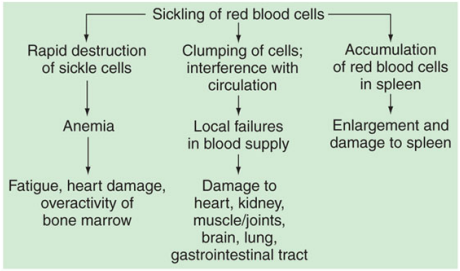


Max Perutz and John Kendrew – Nobel Prize in 1962 For Using X-Ray Diffraction to Determine the Structure of Hemoglobin

There Are Many Human Blood Disorders That Occur As A Result of Mutations: *Change Code-Alter Protein*



(b) Sickle-cell anemia is pleiotrophic



(c) β-chain substitutions/variants Thallasemias

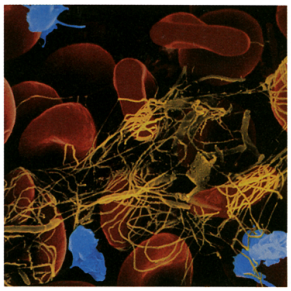
	Amino-acid position									
	1	2	3 ···	6	7 ···	26 ···	63 ···	67 ···	125 ···	146
Normal (HbA)	Val	His	Leu	Glu	Glu	Glu	His	Val	Glu	His
HbS	Val	His	Leu	Val	Glu	Glu	His	Val	Glu	His
HbC	Val	His	Leu	Lys	Glu	Glu	His	Val	Glu	His
HbG San Jose	Val	His	Leu	Glu	Gly	Glu	His	Val	Glu	His
HbE	Val	His	Leu	Glu	Glu	Lys	His	Val	Glu	His
HbM Saskatoon	Val	His	Leu	Glu	Glu	Glu	Tyr	Val	Glu	His
Hb Zurich	Val	His	Leu	Glu	Glu	Glu	Arg	Val	Glu	His
HbM Milwaukee 1	Val	His	Leu	Glu	Glu	Glu	His	Glu	Glu	His
HbDβ Punjab	Val	His	Leu	Glu	Glu	Glu	His	Val	Gln	His

Note Change in Protein Structure Leading to Sickle-Cell Anemia Phenotype!

Hemophilia Has Been Known As An Inherited Disease For >2500 Years!

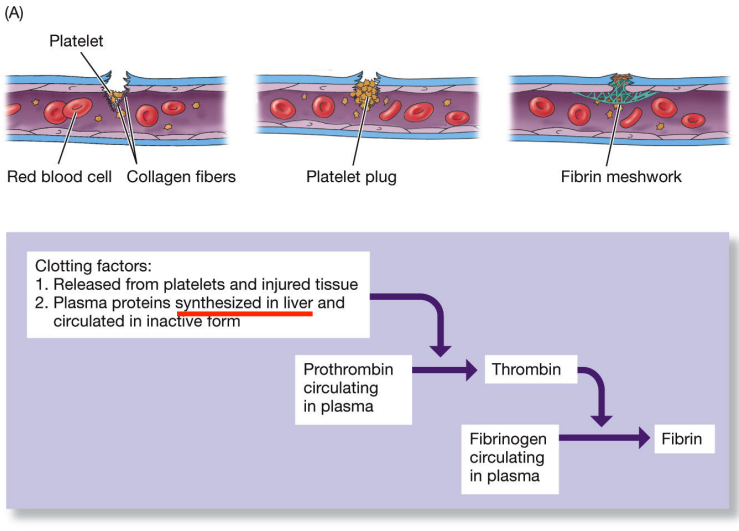
Old Testament-Circumcisions

Royal Family-Europe

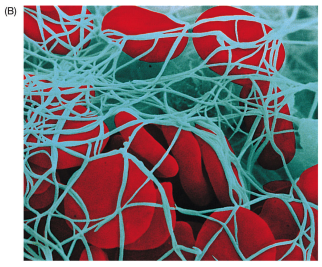


a = activated form

A Cascade Of Events After Wounding Leads to A Fibrin Clot



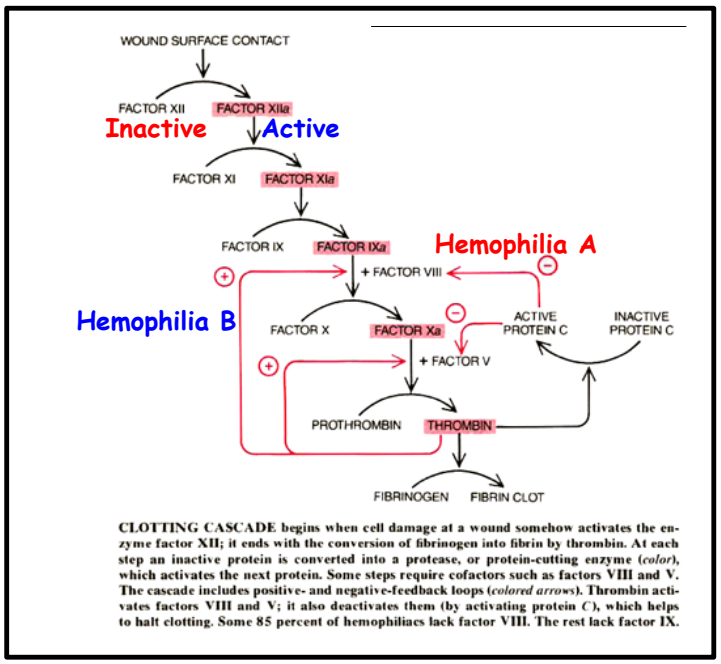
LIFE 8e, Figure 49.10 (Part 1)



LIFE 8e, Figure 49.10 (Part 2)

Clotting Factors Such As Factor VIII Play A Critical Role in This Process

How Does Blood Clot After Wounding?



CLOTTING CASCADE begins when cell damage at a wound somehow activates the enzyme factor XII; it ends with the conversion of fibrinogen into fibrin by thrombin. At each step an inactive protein is converted into a protease, or protein-cutting enzyme (*color*), which activates the next protein. Some steps require cofactors such as factors VIII and V. The cascade includes positive- and negative-feedback loops (*colored arrows*). Thrombin activates factors VIII and V; it also deactivates them (by activating protein C), which helps to halt clotting. Some 85 percent of hemophiliacs lack factor VIII. The rest lack factor IX.

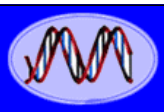
Eight Proteins/Genes Required:

1. Factor VII
2. Factor XI
3. Factor IX
4. Factor VIII
5. Factor X
6. Protein C
7. Prothrombin
8. Fibrinogen

What Happens If Any of These Proteins, or Genes, are Mutated?

↓

No Blood Clot!



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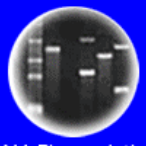

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Blood Clotting Factors

Disorder	Pathophysiology/ deficiency	Inheritance
Haemophilia A	VIII	X linked recessive
Haemophilia B	IX	X linked recessive
Haemophilia C	XI	Autosomal dominant or recessive
VW disease	VW factor	Autosomal dominant or recessive
Factor X deficiency	Factor X	Autosomal recessive
Factor V deficiency	V	Autosomal recessive
Factor VII deficiency	VII	Autosomal recessive
Prothombin deficiency	II	Autosomal recessive
Afibrinogenemia/ dysfibrinogenemia	I	Autosomal dominant

VW factor – Von Willebrand factor

Factor	Other name	Incidence	Bleeding severity
Factor I	Fibrinogen	1 in 1,000,000	Usually mild, except with complete absence of fibrinogen
Factor II	Prothrombin	1 in 1,000,000	Usually mild
Factor V	Parahemophilia	1 in 1,000,000	Usually mild
Combined factor V and factor VIII		1 in 1,000,000	Usually mild
Factor VII	Alexander's	1 in 1,000,000	Severe when factor VII levels are low
Factor X	Stuart Prower	1 in 500,000	Moderate to severe when factor X levels are below 10 %
Factor XI	Hemophilia C	1 in 100,000	Mild to moderate when factor XI levels are below 15%
Factor XIII		1 in 3,000,000	Severe

Hemophiliacs Have Mutations in Factor VIII, Factor IX, or Factor XI Genes

TABLE 13.2 Some Important Genetic Disorders

Disorder	Symptom	Defect	Dominant/ Recessive	Frequency Among Human Births
Cystic fibrosis	Mucus clogs lungs, liver, and pancreas	Failure of chloride ion transport mechanism	Recessive	1/2500 (Caucasians)
Sickle cell anemia	Blood circulation is poor	Abnormal hemoglobin molecules	Recessive	1/600 (African Americans)
Tay–Sachs disease	Central nervous system deteriorates in infancy	Defective enzyme (hexosaminidase A)	Recessive	1/3500 (Ashkenazi Jews)
Phenylketonuria	Brain fails to develop in infancy	Defective enzyme (phenylalanine hydroxylase)	Recessive	1/12,000
Hemophilia	Blood fails to clot	Defective blood-clotting factor VIII	X-linked recessive	1/10,000 (Caucasian males)
Huntington disease	Brain tissue gradually deteriorates in middle age	Production of an inhibitor of brain cell metabolism	Dominant	1/24,000
Muscular dystrophy (Duchenne)	Muscles waste away	Degradation of myelin coating of nerves stimulating muscles	X-linked recessive	1/3700 (males)
Hypercholesterolemia	Excessive cholesterol levels in blood lead to heart disease	Abnormal form of cholesterol cell surface receptor	Dominant	1/500

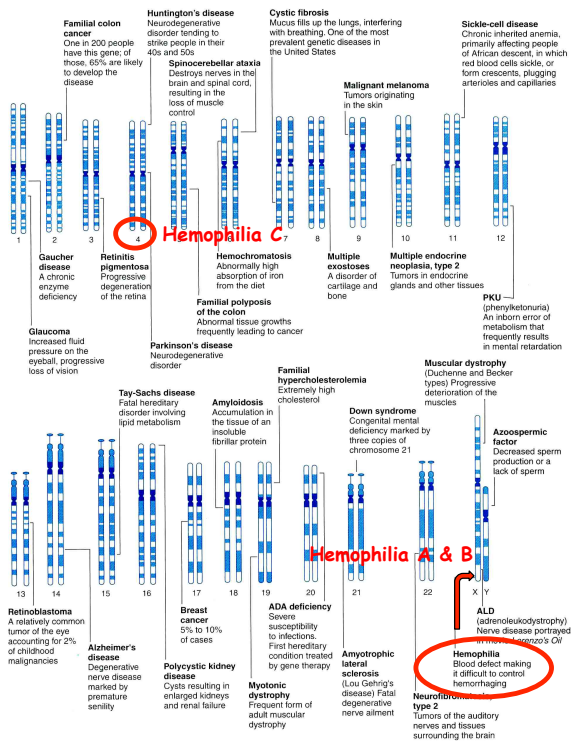
18,000 People in US Have Hemophilia & 400 Babies/Year Are Born With Disorder
Prior to 1960s – Average Life Span Was 11 Years

Hemophilia A	Defective Factor VIII Gene	1/10,000 males	80%
Hemophilia B	Defective Factor IX Gene	1/30,000 males	20%
Hemophilia C	Defective Factor XI Gene	Autosomal	<1%

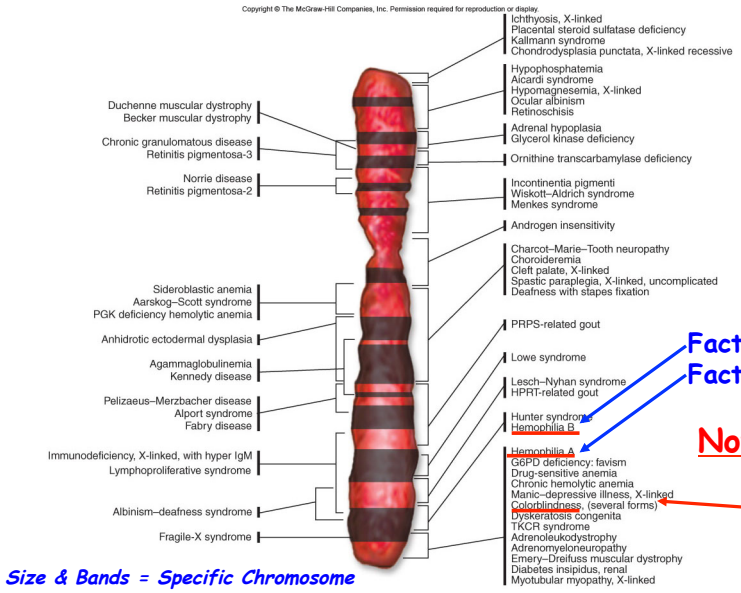
Hypothesis For High Frequency in Males?

Both Factor VIII & IX Genes on X-Chromosome (♀➔♂'s)

Human Disease Genes Have Been Mapped To Specific Chromosomal Locations



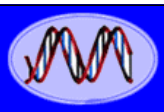
Factor VIII and Factor IX Genes are Closely Linked on the X Chromosome



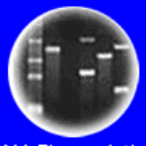
Nature, March, 2005

Note: Factor VIII gene is closely *linked* to Colorblindness Gene

The X chromosome has ~1098 Genes and 150,000,000 bp (150 Mb). *168 Mendelian Diseases Explained by 113 X-Linked Genes*


DNA
Genetic Code of Life


Entire Genetic Code of a Bacteria


DNA Fingerprinting


Cloning: Ethical Issues and Future Consequences

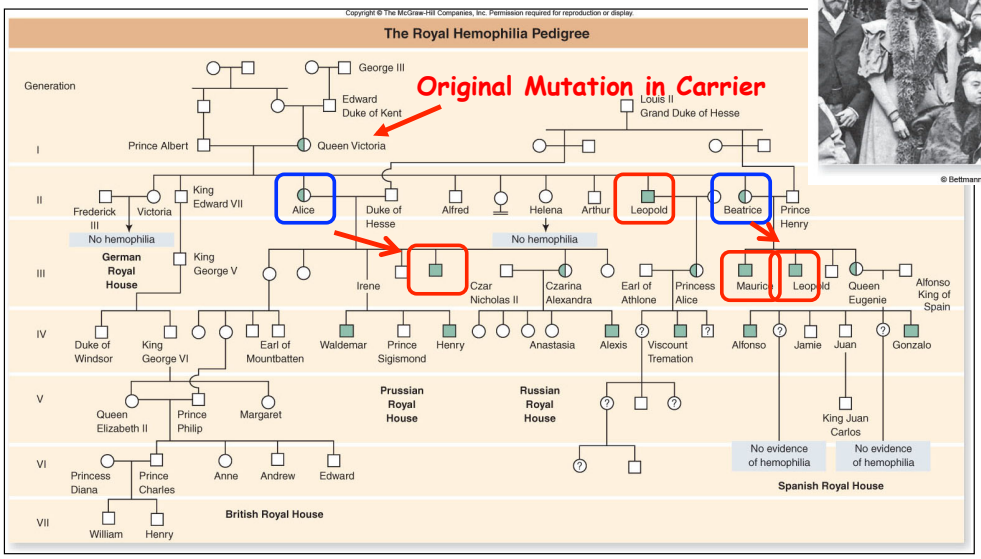

Plants of Tomorrow

Pedigrees Can Be Used To Determine If a Trait is Dominant or Recessive

Each Type of Inheritance Predicts Specific Results in Each Generation

Hemophilia A and B Genes Are Sex Linked & Recessive Traits When Mutated

© Bettmann/Corbis



Note: 1. Males Obtain Detective Gene From Mothers

2. 50% of Sons Of A Maternal Carrier Have The Defective Gene

Hemophilia A and B Sex-Linked Inheritance

Carrier Female

Healthy Male: Egg / Sperm	X	X
X	XX ♀ *Carrier*	XX ♀ *Healthy*
Y	XY ♂ Hemophiliac	XY ♂ *Healthy*

Sex-Linked Inheritance

♀ Carriers → 1/2 Sons Afflicted + No Daughters!

Only One X-Chromosome is in ♂

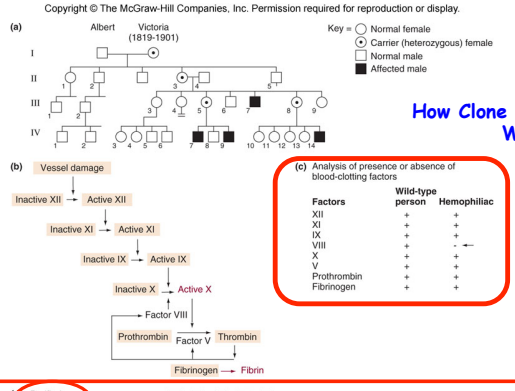
What Was Known About Factor VIII *Before Gene Cloned?*

1. Blood Protein (But Perhaps Synthesized Elsewhere!)
2. Could be purified in small amounts from >20 Liters of human blood + cow blood + pig blood
3. Short Stretch of Protein Sequenced = Known Protein Sequence!
4. Hemophilia A could be treated by *blood transfusions* from normal individuals, ∴ clotting factor in blood
5. 1980s AIDS Epidemic Caused Many Hemophiliacs to Get HIV/AIDS (~50% of hemophiliacs got AIDS in 1985)

The Problem

For Factor VIII- *Not Known Where Gene is Expressed* ∴ Must Use Genome Library

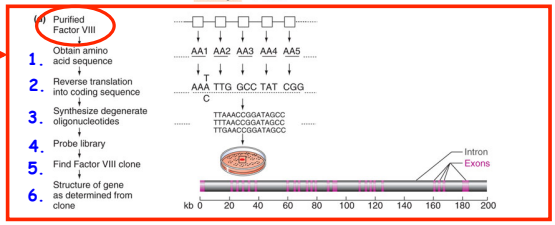
Early 1980's



Key Concept

How Clone A Gene When You Don't Know Where it is Expressed !

Key: Protein Sequence Known



How Find Gene & cDNA?

Protein → Gene → mRNA → Drug !

Knowledge of the Protein Sequence and the Genetic Code Makes it Possible to Identify a Gene

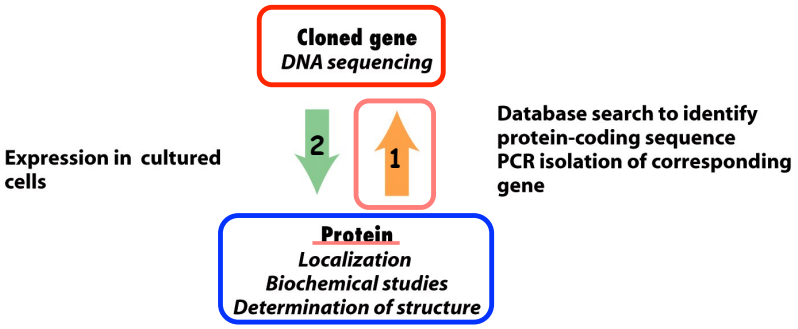


Figure 5-1
Molecular Cell Biology, Sixth Edition
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∴ 1. Protein → Gene → Drug

Factor VIII Strategy (1985)

or

2. Gene → Protein Using Sequencing and Genetic Code

Genomics

GenBank

2016

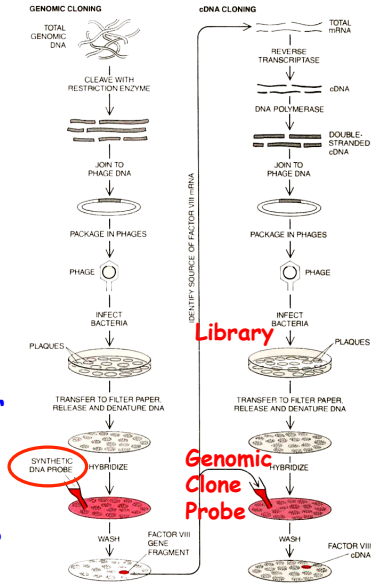
3. Just Sequence Everything + Identify Protein-GenBank Huge

Steps Required to Clone Factor VIII Gene and cDNA

Gene

1. Make Genome Library Because Factor VIII Gene in Genome!
2. Purify Protein from Blood- that's where it works (wasn't known where made)
3. Reverse Translate using the genetic code a portion of the protein sequence
4. Synthesize a DNA probe complementary to Factor VIII gene corresponding to protein sequence
5. Screen Genome Library

Entire Gene on The Clone?



cDNA

1. Use Gene probe to screen cDNA library for Factor VIII cDNA clone
2. How know what mRNA to use to make cDNA library?
3. Use gene probe to probe RNA blots containing mRNA from all major organs (liver, kidney, blood, etc.)
4. Find Factor VIII mRNA in liver- male, liver- secrete into blood

Why Need cDNA?

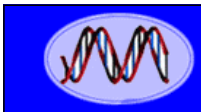
Story continued

Want cDNA to Manufacture Factor VIII as a Drug to Treat Hemophilia A!

Step One

How to Construct a Human Genome Library to Find the Factor VIII Gene?

If It is Not Known Where Gene is Active Can "Look" to Genome Instead of mRNA to Find + Clone Gene!



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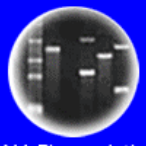
Entire Genetic Code of a Bacteria



DNA Fingerprinting

Cloning: Ethical Issues and Future Consequences

Plants of Tomorrow

Vectors Used in Genetic Engineering Have Similar Conceptual Properties But are Used in Different Situations

Table 3.2 A COMPARISON OF DNA VECTORS AND THEIR APPLICATIONS

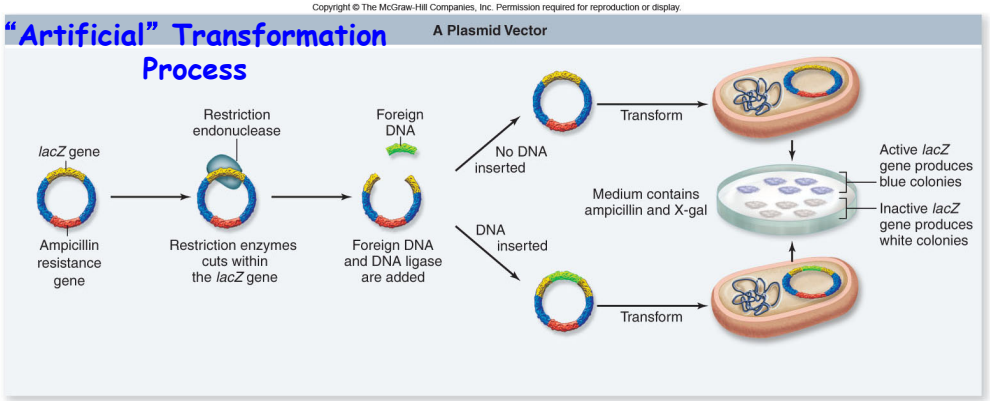
Vector Type	Maximum Insert Size (kb)	Applications	Limitations
Bacterial plasmid vectors (circular)	~6–12	DNA cloning, protein expression, subcloning, direct sequencing of insert	Restricted insert size; limited expression of proteins; copy number problems; replication restricted to bacteria
	DNA	DNA	
Bacteriophage vectors (linear)	~25	cDNA, genomic and expression libraries	Packaging limits DNA insert size; host replication problems
Cosmid (circular)	~35	cDNA and genomic libraries, cloning large DNA fragments	Phage packaging restrictions; not ideal for protein expression; cannot be replicated in mammalian cells
Bacterial artificial chromosome (BAC, circular)	~300	Genomic libraries, cloning large DNA fragments	Replication restricted to bacteria; cannot be used for protein expression
Yeast artificial chromosome (YAC, circular)	200–2,000	Genomic libraries, cloning large DNA fragments	Must be grown in yeast; cannot be used in bacteria
Ti vector (circular)	Varies depending on type of Ti vector used	Gene transfer in plants	Limited to use in plant cells only; number of restriction sites randomly distributed; large size of vector not easily manipulated

Plasmids vs. Bacteriophage Vectors

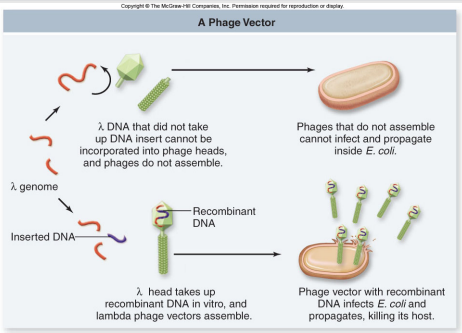
1. Replicate
2. Selectable
3. Can be used to insert foreign genes/restriction sites
4. Easily isolated + transferred back to cells

Plasmid vs. Bacteriophage Vectors for Cloning DNA Fragments

"Artificial" Transformation Process



a.

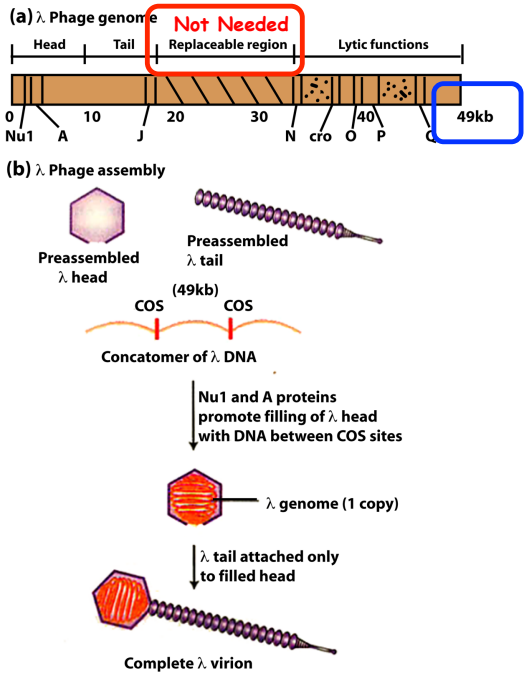


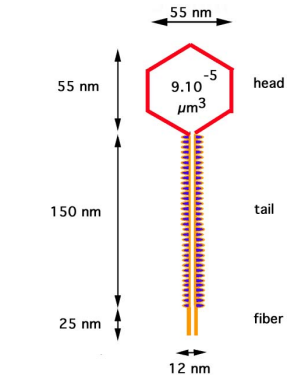
b.

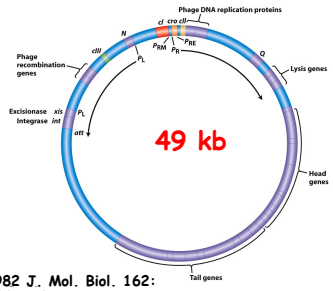
"Natural" Infection Process

- Much More Efficient
- Can Use Less DNA
- Get Lots More Clones

Structure of the λ Phage and Its Genome



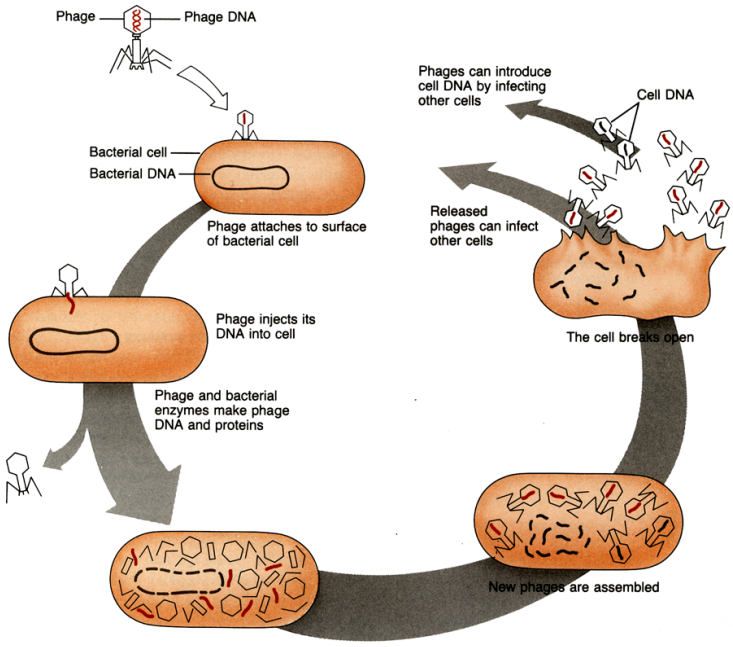




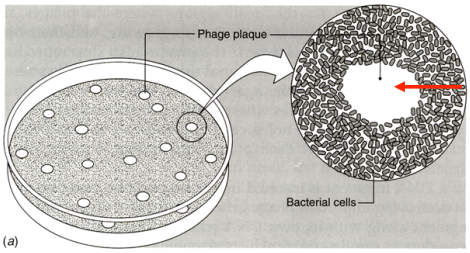
One of First Genome Sequences

Sanger et al. 1982 J. Mol. Biol. 162: 729-773.

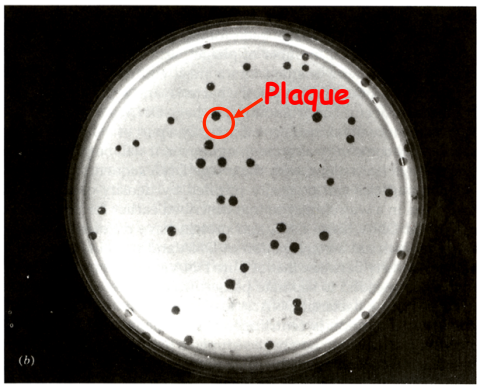
λ Phage Infects E.coli & Destroys (Lyses) cells



Lysed Cells Can Be Seen as Clear Plaques on Agar Plates



Plaque



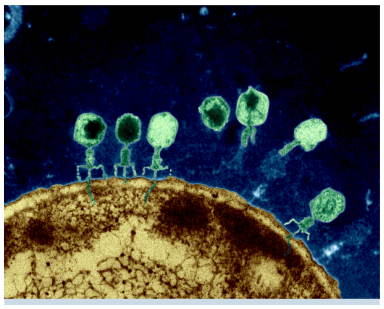
1. Each Plaque is a Virus Clone Representing One Viral Infection!

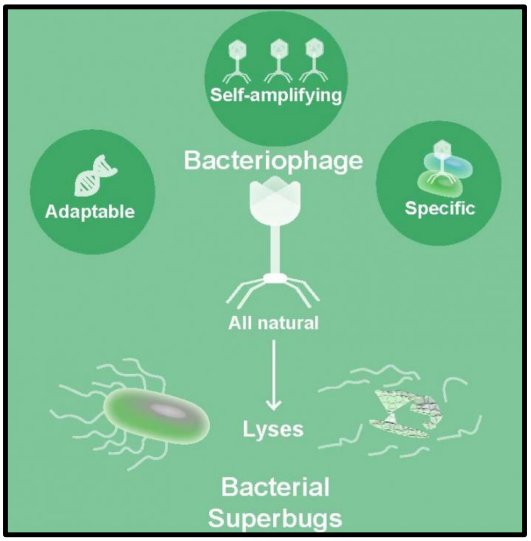
2. Selectable Marker is Bacterial Cell Destruction & Plaque Formation

Using Phage as "Drugs" to Treat Antibiotic Resistant Bacteria That Cause Sepsis

Resistant Superbugs Meet Natural Foe in Phage Therapy Genetic Engineering News, January 2017

Jeffrey S. Buguliskis, Ph.D.





Each year in the United States, at least 2 million people become infected with bacteria that are resistant to antibiotics and at least 23,000 people die each year as a direct result of these infections. Many more people die from other conditions that were complicated by an antibiotic-resistant infection.

Advantages of λ Virus as a Vector for Cloning DNA

1. Long DNA Segments can be Cloned (~20kb) Need fewer clones for whole Genome!

2. Can clone DNA Segments in Viral Genome & Self-Assemble with viral proteins into virus in a test tube!

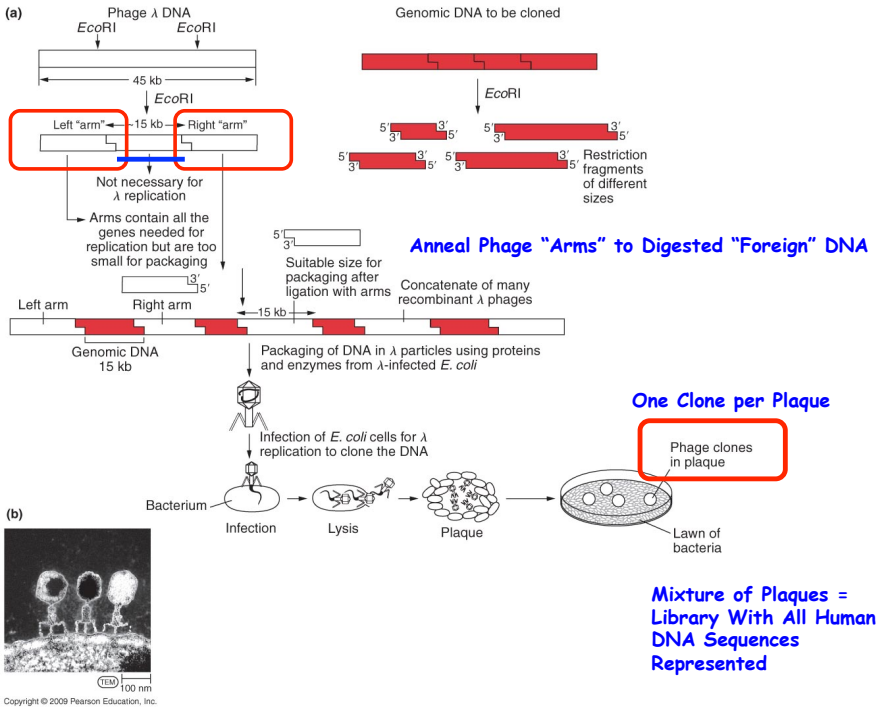
   ∴ Make Recombinant Viruses in the Lab!

3. Use "Natural" Infection process to Generate Large Number of Clones for a Eukaryotic Genome Library.

   Much higher efficiency for getting recombinant DNA →bacterial cells compared with DNA transformation.

   ∴ set more clones per amount of recombinant DNA!

Using a Bacterial Virus To Clone the Human Genome

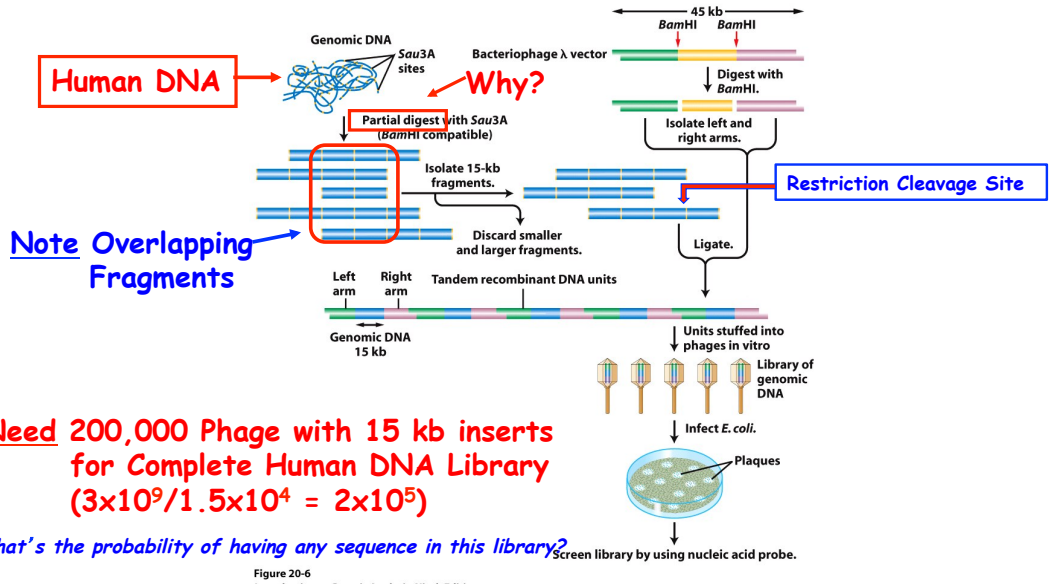


Anneal Phage "Arms" to Digested "Foreign" DNA

One Clone per Plaque

Mixture of Plaques = Library With All Human DNA Sequences Represented

Cloning the Human Genome and Screening for the Factor VIII Gene



Need 200,000 Phage with 15 kb inserts for Complete Human DNA Library ($3 \times 10^9 / 1.5 \times 10^4 = 2 \times 10^5$)

What's the probability of having any sequence in this library?

Figure 20-6
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Why Partial Digestion? An Important Concept!

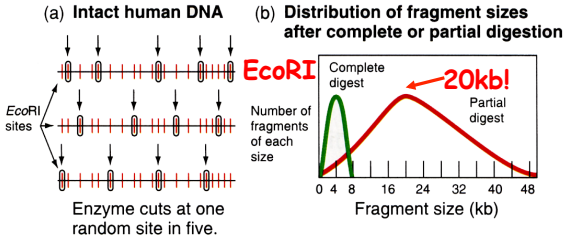
What is Complete & Partial Digestion?

What is the Purpose of Partial Digestion of Human DNA?

Sau 3A= 4bp= $^{5'}GATC^{3'}$ ∴ 1 site every 280bp if digest to completion = $1x10^7$ DNA fragments

Eco RI= 6bp= $^{5'}GAATTC^{3'}$ ∴ 1 site every 3100 bp if digest to completion (cleaves every site) = 972,000 DNA fragments

1. Complete Digestion Produces fragments that are too small to clone in λ virus (need 20Kb)
2. Complete Digestion would create huge genome libraries with large # clones to screen
3. Complete Digestion would break up genes of different DNA fragments- particularly if human genes big- ∴ would have one gene on many different clones- parts separated !
4. Complete Digestion provides no way to find neighbors of clones in genome- what's next to gene in chromosome!

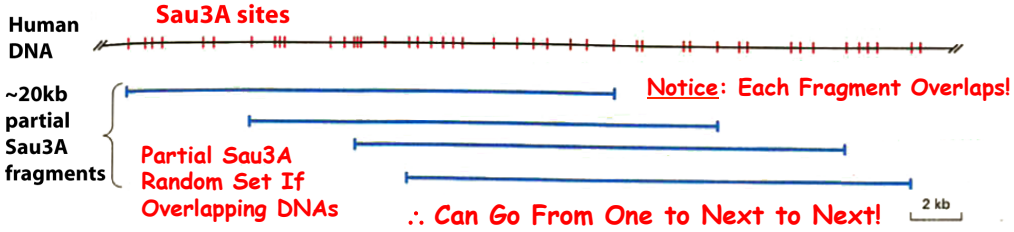


Principle of Genome Sequencing Too!!

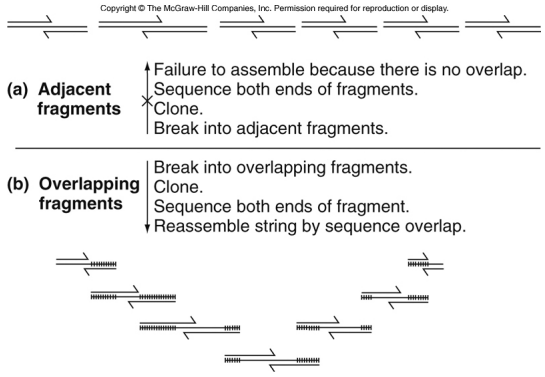
Partial Digestion Produces A series of Large, Overlapping DNA Fragments/ Clones

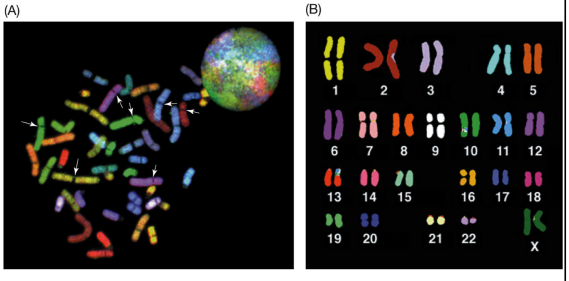
Can connect one clone with another!! Build up clones of each chromosome!!

Constructing a Human Genome Library by Partial Digestion Creates a Set of Overlapping DNA Fragments/ Clones



∴ An overlapping set for each of the 24 chromosomes would allow clones to be ordered from beginning to end by restriction mapping because each chromosome contains one DNA molecule !





Step Two

How Find the Factor VIII Gene in a Human Genome Library?

The Genetic Code

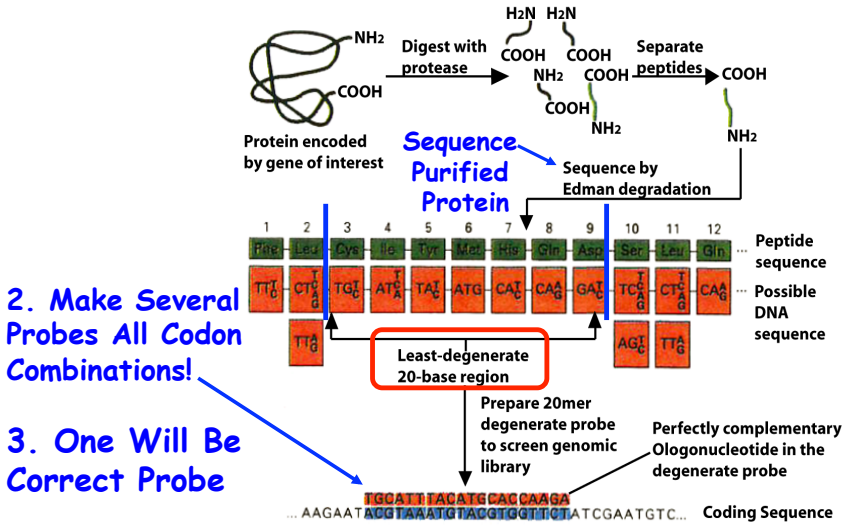
1st letter	Second Letter: U	Second Letter: C	Second Letter: A	Second Letter: G	3rd letter
U	UUU Phe UUC UUA Leu UUG	UCU UCC UCA Ser UCG	UAU Tyr UAC UAA Stop UAG Stop	UGU Cys UGC UGA Stop UGG Trp	U C A G
C	CUU CUC CUA Leu CUG	CCU CCC CCA Pro CCG	CAU His CAC CAA Gln CAG	CGU CGC CGA Arg CGG	U C A G
A	AUU AUC AUA Ile AUG Start Met	ACU ACC ACA Thr ACG	AAU Asn AAC AAA Lys AAG	AGU Ser AGC AGA Arg AGG	U C A G
G	GUU GUC GUA Val GUG	GCU GCC GCA Ala GCG	GAU Asp GAC GAA Glu GAG	GGU GGC GGA Gly GGG	U C A G

Properties

- Universal
- Three Nucleotides
- Punctuation
- Degenerate

Factor VIII Protein → Gene

Using the Factor VIII Protein Sequence and Genetic Code as a Guide to Synthesize a Factor VIII Probe



2. Make Several Probes All Codon Combinations!

3. One Will Be Correct Probe

1. Use Genetic Code

How many Combinations of Synthetic Probes?

2x3x2x1x2x2x2=96

Using the Genetic Code to go From Protein Sequence to Gene Sequence

(b) Synthesizing DNA probes based on reverse translation

Protein sequence	N	Glu	Asp	Met	Trp	Tyr C
Degenerate coding sequences	5'	GAA GAG	GAT GAC	ATG	TGG	TAT 3' TAC
Sequences that must be present in the probe		②	②	①	①	②

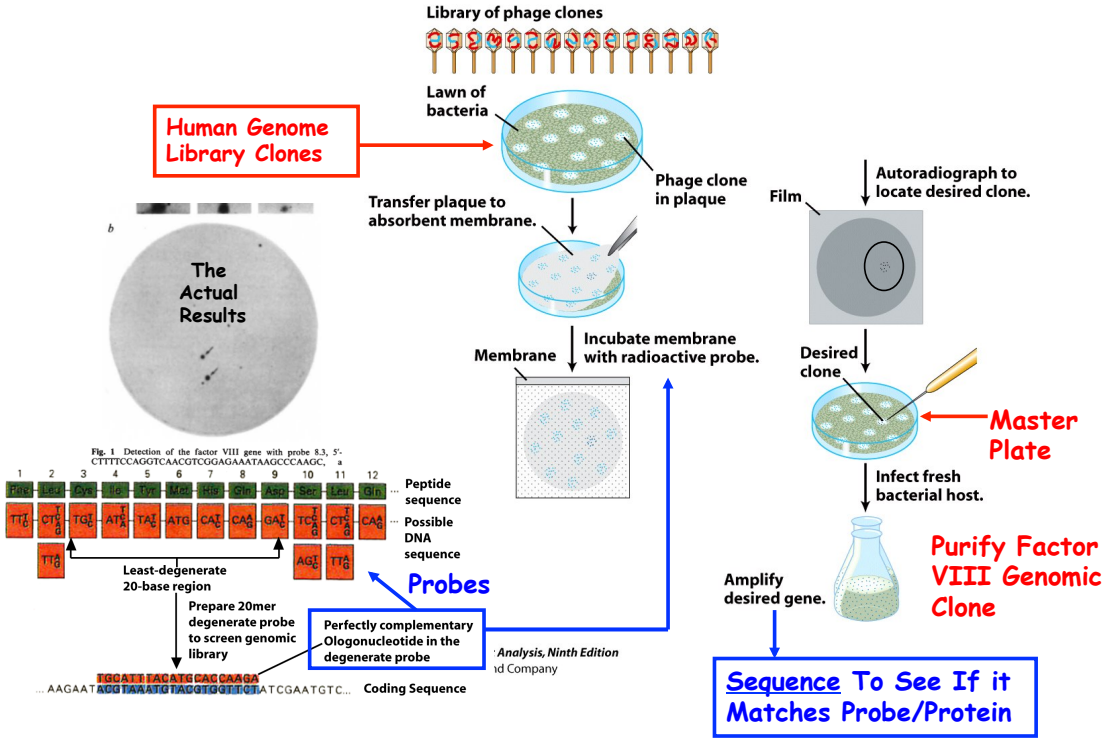
= 8 Codon Combinations

Mixed Probes (Contains All 8 Sequence Combinations)

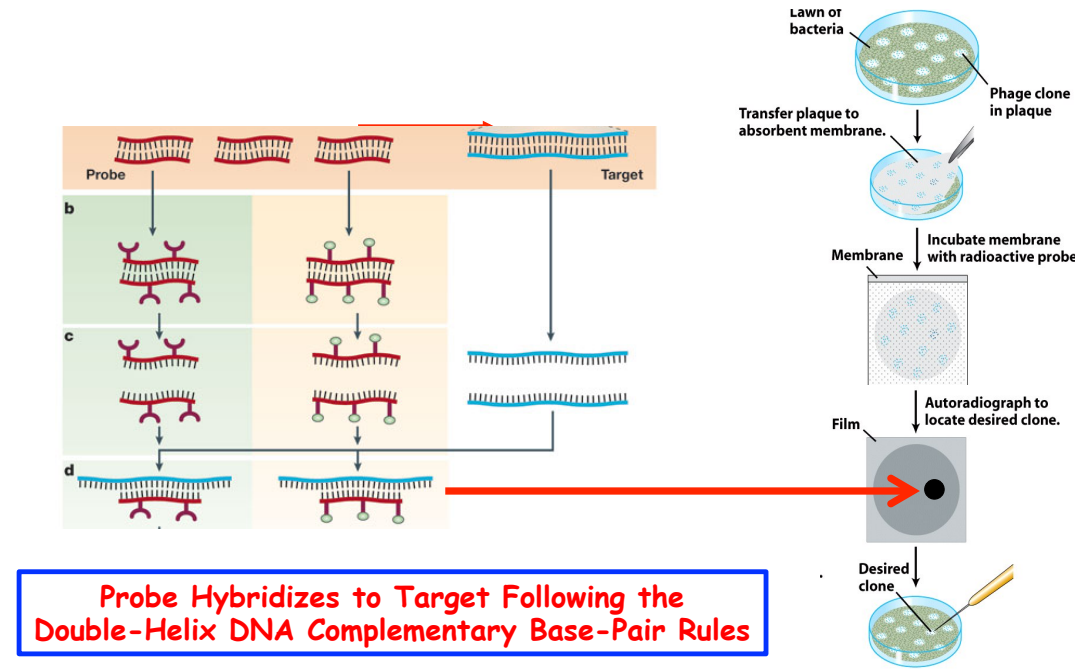
GAAGATATGTGGTAT
GAGGATATGTGGTAT
GAAGACATGTGGTAT
GAGGACATGTGGTAT
GAAGATATGTGGTAC
GAGGATATGTGGTAC
GAAGACATGTGGTAC
GAGGACATGTGGTAC

1. Need Amino Acid Sequence of Part of the Protein
2. Need DNA Sequences Representing all Codon Combinations
3. Synthesize DNA Sequence Probes!

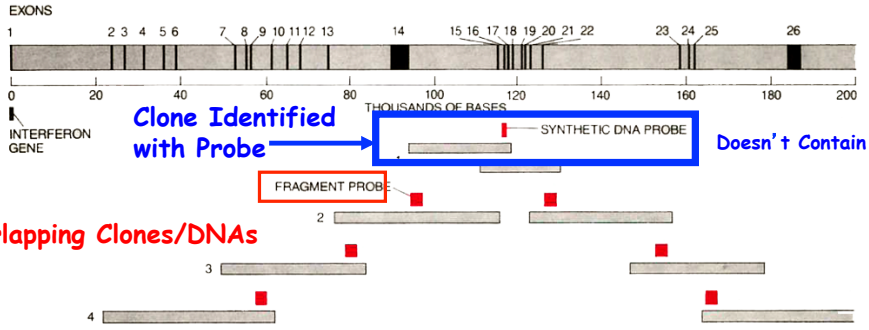
Finding The Factor VIII Gene Or Part of Gene!!



Using Synthetic Probes To Find The Factor VIII Gene Or Part of Gene!!



The Result-The Factor VIII Gene is Huge- 186,000 bp- The Probe Identified a Clone Containing Only One Part of Gene !!! Why?



Doesn't Contain Entire Gene!

Overlapping Clones/DNAs

How Find Clones with Rest of Gene? Key Question !

Remember - the library contains overlapping DNA clones ∴ can use one part of first clone to re-screen library & "walk" to other gene regions- using restriction maps & sequencing (compare with protein sequence) as guides!

Sequence ----------> GenBank

Step Three — Finding the Entire Factor VIII Gene? Walking & Sequencing

Walking Up and Down Genes and Chromosomes

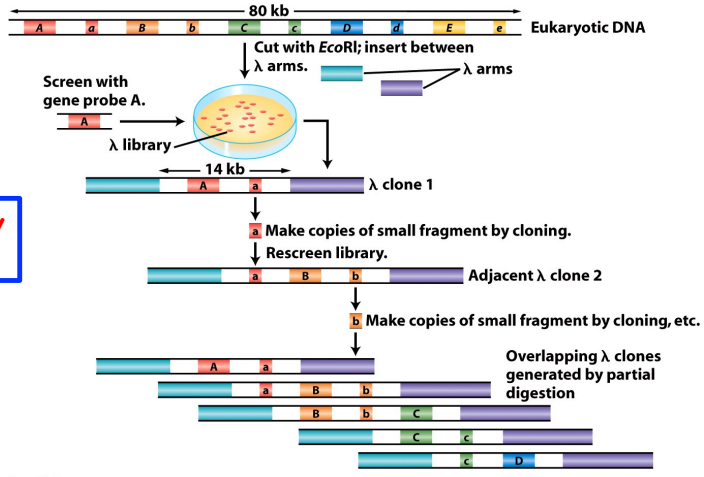


Figure 20-13
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Reiterative Library Screening Process

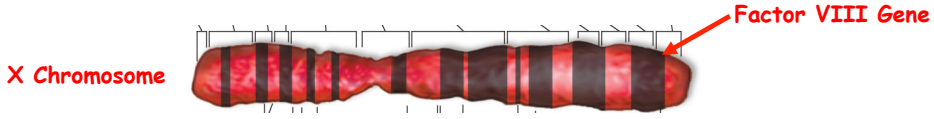
Basis of Genome Projects & Whole Genome Sequencing

Key Concepts → How know Find Complete Factor VIII Gene?

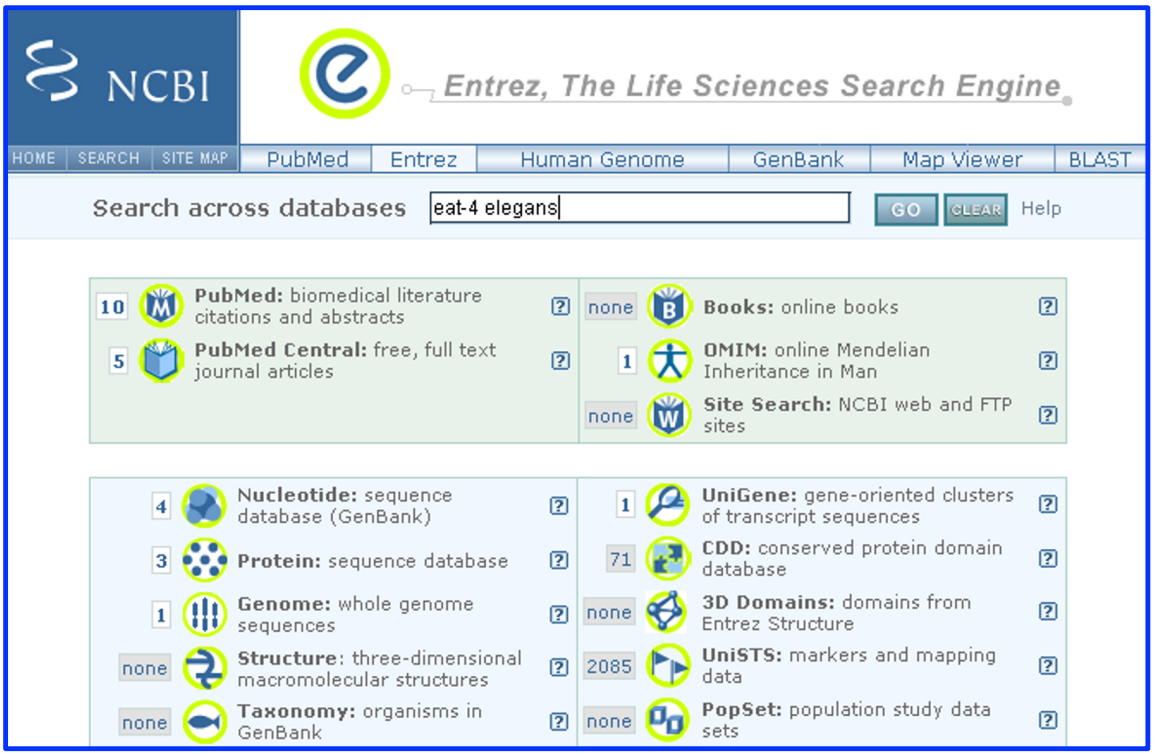
→ Compare Protein & DNA Sequences

The Factor VIII Gene Was Found To Be Very Large

- 186,000 Nucleotides in Length (Won't Fit in One Phage Clone)
- 25 Introns
- 9,000 Nucleotide Coding Sequence (cDNA)
- 2,351 Amino Acids in Protein



Using NCBI to Search For Gene Information



Factor VIII Mutations Occur Throughout the Gene

[*Haemophilia* 11, 481-491 (2005)]

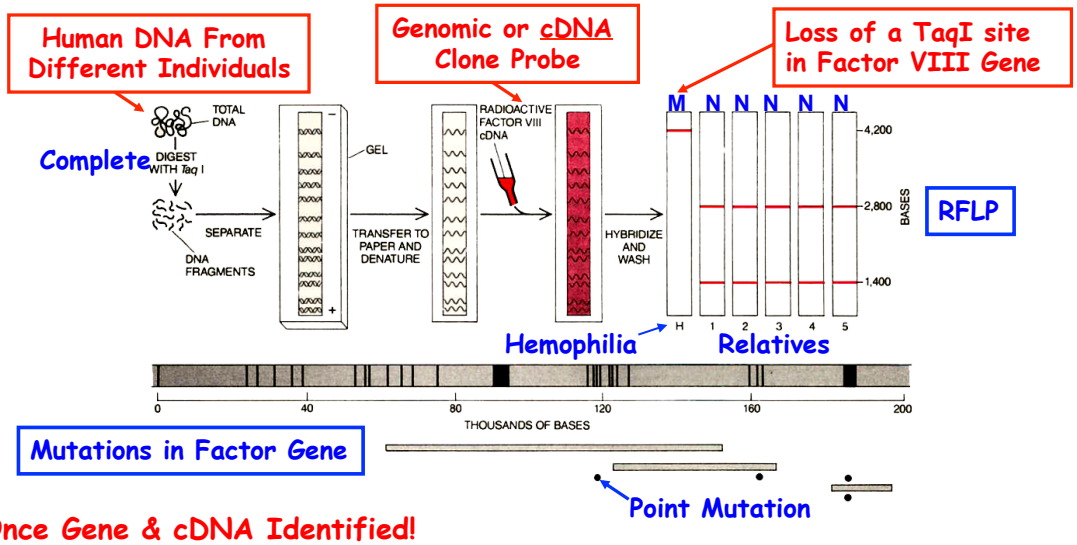
Factor VIII gene mutations in haemophilia A patients without intron 22 inversion.

VIII:C (%)	Family history	Consanguinity*	Inversion	Codon†	Mutation	Amino acid change	Exon	Conservation‡
1	Sporadic	NC	Normal	51	TTT → TCT§	Phe → Ser	2	FFFF, identical
1.20	Sporadic	NC	Normal	80	GTT → GAT	Val → Asp	3	VVVV, identical
1	Sporadic	NC	Normal	102	GGT → GTT§	Gly → Val	3	GGGG, identical
2	Sporadic	NC	Normal	104	TCC → CCC§	Ser → Pro	3	SSSS, identical
6	Sporadic	NC	Normal	143	GAG → AAG§	Glu → Lys	4	EEEE, identical
1	Sporadic	NC	Normal	233	delCA§	Thr → fs (TGA-264)	6	
2.70	Inherited	NC	Normal	321	GAA → AAA	Glu → Lys	8	EEEE, identical
0	Sporadic	NC	Normal	372	CGC → CAC	Arg → His	8	RRRR, identical
3	Inherited	NC	Normal	527	CGG → TGG	Arg → Trp	11	RRRR, identical
1	Sporadic	NC	Normal	528	TGC → TAC§	Cys → Tyr	11	CCCC, identical
1	Inherited	NC	Normal	592	CAA → TAA	Gln → Stop	12	QQQQ, identical
1	Inherited	NC	Normal	864	delGACA insCAATTAAATGAGAA§	Gly → fs [TAA-867]	14	
1	Sporadic	NC	Normal	948	insA§	Lys → fs (TGA-984)	14	
1	Sporadic	NC	Intron 1	1107	AGG → TGG§	Arg → Trp	14	RGKK, dissimilar
1	Sporadic	NC	Normal	1107	AGG → TGG§	Arg → Trp	14	RGKK, dissimilar
1	Inherited	NC	Normal	1191–1194	delA	Ile → fs (TAG-1198)	14	
1.40	Sporadic	NC	Normal	1191–1194	insA	Ile → fs (TAA-1220)	14	
1	Sporadic	C	Normal	1227	delC§	Leu → fs (TGA-1231)	14	
2.10	Sporadic	NC	Normal	1241	GAC → GAG	Asp → Glu	14	DGGE, similar
1	Sporadic	NC	Normal	1392	1392del1418§	Pro → fs (TAG-1446)	14	
1	Inerited	C	Normal	1392	1392del1418§	Pro → fs (TAG-1446)	14	
1	Sporadic	NC	Normal	1441	insA§		14	
1	Inerited	C	Normal	1441	insA§			
1	Inherited	NC	Normal	1502	CAG → TAG§	Gln → Stop	14	QREQ, dissimilar
1	Inherited	NC	Normal	1504	delGT§	Val → fs (TGA-1517)	14	
1	Sporadic	NC	Normal	1535	TGG → TGA	Trp → Stop	14	WLWM, dissimilar
nhibitor 96 BU								
1	Sporadic	NC	Normal	1571	TAT → TAA§	Tyr → Stop	14	Y-YY, dissimilar
1	Sporadic	NC	Normal	1581	AAA → TAA§	Lys → Stop	14	KEKK, dissimilar
0.20	Sporadic	NC	Normal	1696	CGA → GGA	Arg → Gly	14	RRRR, identical
1.80	Sporadic	NC	Normal	1729	delA§	Gln → fs (TAA-1752)	15	
1	Inherited	NC	Normal	1751	GAA → AAA§	Glu → Lys	15	EEEE, identical
1	Sporadic	NC	Normal	1775	TTC → TCC§	Phe → Pro	16	FFFF, identical
1	Sporadic	NC	Normal	1835	TGG → TGA§	Trp → Stop	16	WWWW, identical
7.60	Sporadic	C	Normal	1882	ATC → ATA§	Ile → Ile	17	IIII, identical
3	Inherited	C	Normal	1966	CGA → CAA	Arg → Glu	18	RRRR, identical
1	Sporadic	NC	Normal	1966	CGA → TGA	Arg → Stop	18	RRRR, identical

FVIII GENE MUTATIONS IN INDIAN PATIE

Need To Screen Across the Gene for Markers -- Family Specific

Factor VIII Gene Probes/ Sequence Can Be Used to Characterize Mutant Genes & Do DNA Testing for Carriers



Once Gene & cDNA Identified!

Use DNA Gel Blots (or PCR) & Factor VIII Probes to Investigate Presence of Mutant Alleles in Families (carriers)

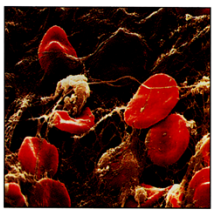
Mutations Arise Independently in Families

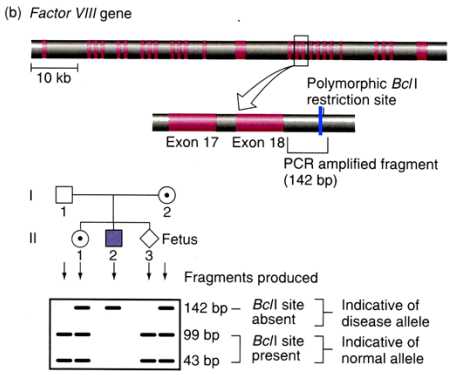
Using PCR and RFLPs (Markers) to Detect the Hemophilia A Disease Allele/Gene

1. Use PCR to amplify a specific Factor VIII gene region
2. Use restriction enzyme (BcL I) to distinguish between normal allele (1 site) & disease allele (no site)

= = Normal allele

– = Disease allele





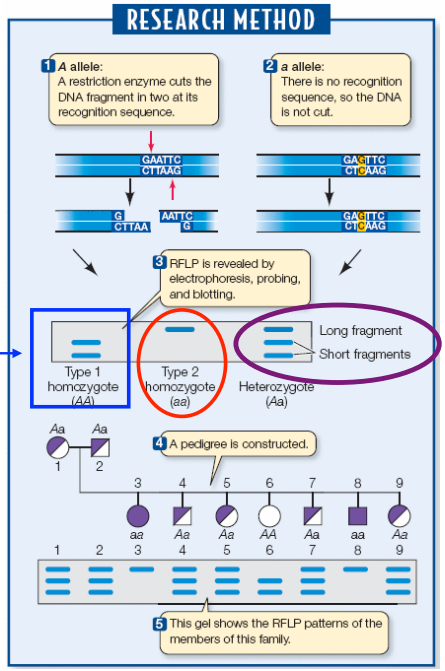
The 21st Century Approach!

1. Sequence the Entire Gene & Find Mutation
2. Then Synthesize Primers to Test Family Members Using PCR

Only Can Do This With a Knowledge of DNA Sequence of Wild-type (Normal) and Disease Genes (Can Vary family to Family)

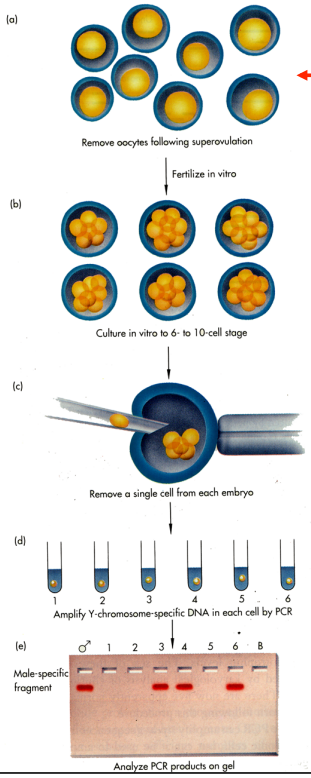
Genetic Diseases Can Also Be Followed in Families Using DNA Methods (e.g., PCR) & Pedigrees – With DNA Markers Linked to the Disease Phenotype

DNA Fingerprints



RFLP – Restriction Fragment Length Polymorphism

Using PGD to Detect Hemophilia A Disease Alleles

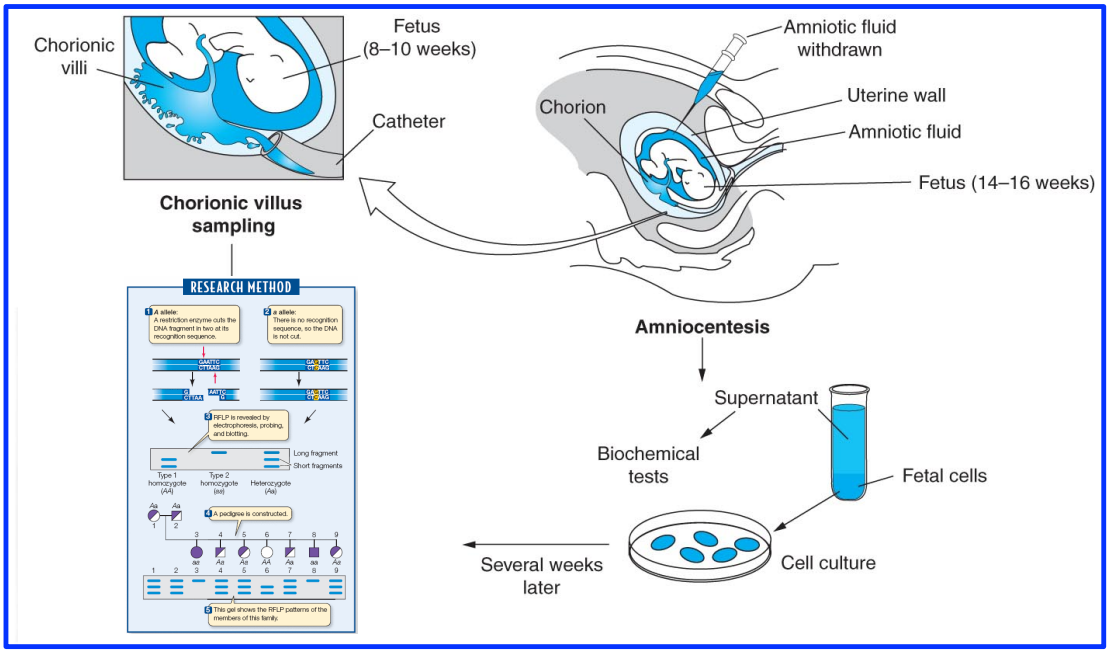


Mother is a Carrier X^HX^h

1. Test for Male Embryos
2. Test for Presence of Hemophilia A Disease Alleles!

X^hY

DNA Testing Can Be Carried Out Before Child Birth During Pregnancy



RESEARCH ARTICLE **New Non-Invasive DNA Tests Are Available Based on PCR**

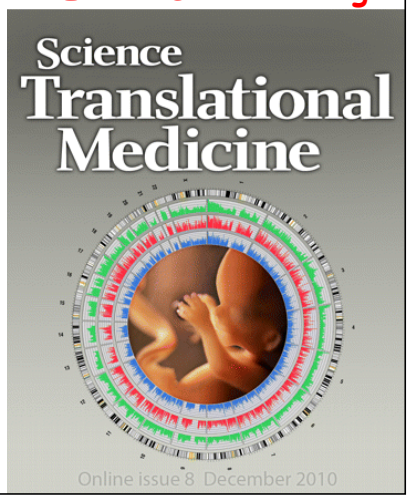
PRENATAL DIAGNOSIS

Maternal Plasma DNA Sequencing Reveals the Genome-Wide Genetic and Mutational Profile of the Fetus

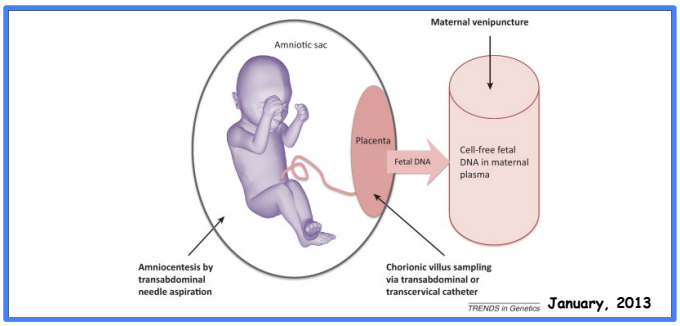
Science Translational Medicine, December 8, 2010 (61,1-12)

Sequencing DNA From the Blood of a Pregnant Woman Allows the Complete Genome Of the Fetus to Be Decoded!

A New Era in DNA Testing!!



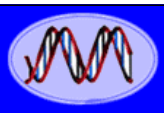
~10% of DNA in Maternal Plasma is From the Fetus



DNA Tests Can Now Be Used To Detects Hundreds of Genetic Disease Alleles

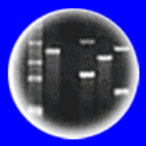
TABLE 11.1 GENETIC DISEASE TESTING

Genetic Disease Condition	Genetic Basis for Disease and Symptoms
Cancers (brain tumors; urinary bladder, prostate, ovarian, breast, brain, lung, and colorectal cancers)	A variety of different mutant genes can serve as markers for genetic testing.
Cystic fibrosis	Large number of mutations in the cystic fibrosis transmembrane conductance regulator (CFTR) gene on chromosome 7. Causes lung infections and problems with pancreatic, digestive, and pulmonary functions.
Duchenne muscular dystrophy	Defective gene (dystrophin) on the X chromosome causes muscle weakness and muscle degeneration.
Familial hypercholesterolemia	Mutant gene on chromosome 19 causes extremely high levels of blood cholesterol.
Hemophilia	Defective gene on the X chromosome makes it difficult for blood to clot when there is bleeding.
Huntington disease	Mutation in gene on chromosome 4 causes neurodegenerative disease in adults.
Phenylketonuria (PKU)	Mutation in gene required for converting the amino acid phenylalanine into the amino acid tyrosine. Causes severe neurological damage, including mental retardation.
Severe combined immunodeficiency (SCID)	Immune system disorder caused by mutation of the adenosine deaminase gene.
Sickle cell disease	Mutation in ß-globin gene on chromosome 11 affects hemoglobin structure and shape of red blood cells, which disrupts oxygen transport in blood and causes joint pain.
Tay-Sachs disease	Rare mutation of a gene on chromosome 5 causes certain types of lipids to accumulate in the brain. Causes paralysis, blindness, retardation, and respiratory infections.



DNA
Genetic Code of Life

Entire Genetic Code of a Bacteria



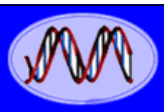
DNA Fingerprinting

Cloning: Ethical Issues and Future Consequences

Plants of Tomorrow

Genetic Screening Issues

- Why Screen For Genes?
- When is a Test Accurate Enough?
- Mandatory or Voluntary Screening?
- Who Should Be Tested?
- Employer & Insurance Company Testing?
- Protection From Genotype Discrimination?
- Testing for Genetic Diseases With No Cures?
- How Ensure Privacy & Confidentiality?
- Obligations to Inform Others (Spouse/Sibling) of Genetic Disorder Knowledge?
- Genetic Databases??
- Patents on Tests?



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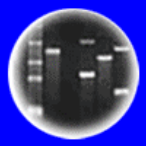

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Step Four

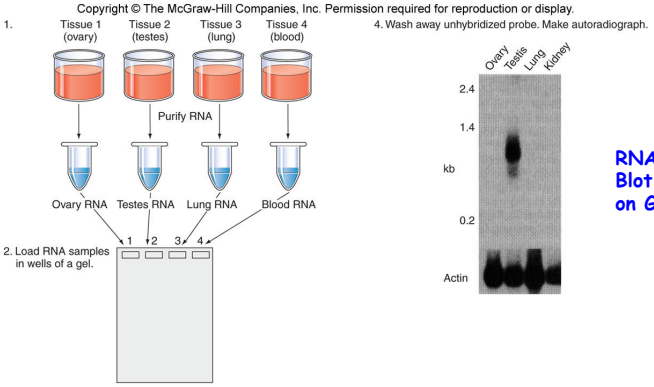
How Find Factor VIII mRNA to Generate a cDNA for Protein Production in Host Cells?

Recall: Eukaryotic Genes Provide Obstacles for Efficient Protein Production in Genetically Engineered Cells! Reasons???

Making the Drug

Need cDNA Not Gene

Factor VIII Gene Can Be Used to Find Out Where It is Active Using RNA Blots

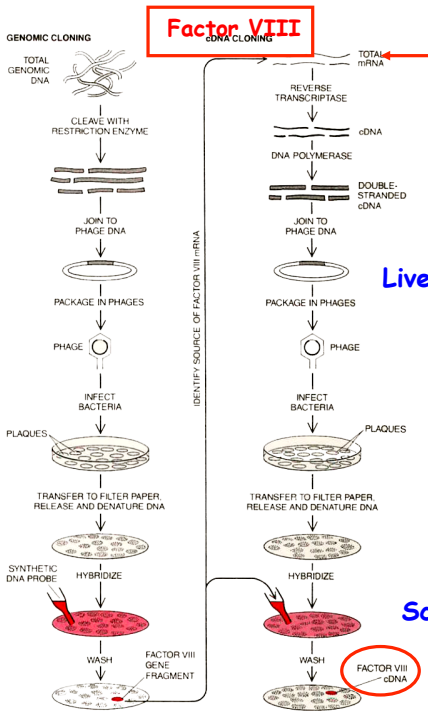


RNA Blot Is Like a DNA Blot Except That RNA is on Gel & Blotted

Factor VIII Gene Is Highly Active in Liver!

Could Also Use PCR (RT-PCR)

Using Factor VIII Gene Probe to Identify Factor VIII cDNA clone



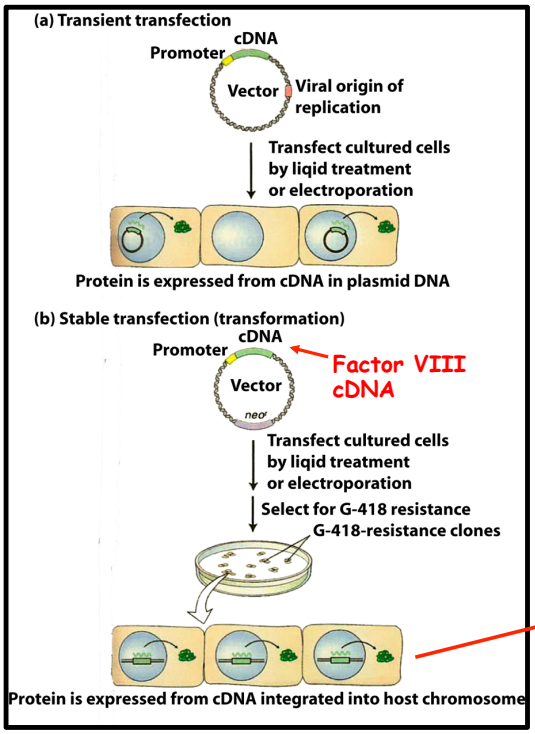
Liver mRNA

Liver cDNA Library

Factor VIII cDNA → Used to Make Drug !

Screen Liver cDNA Library

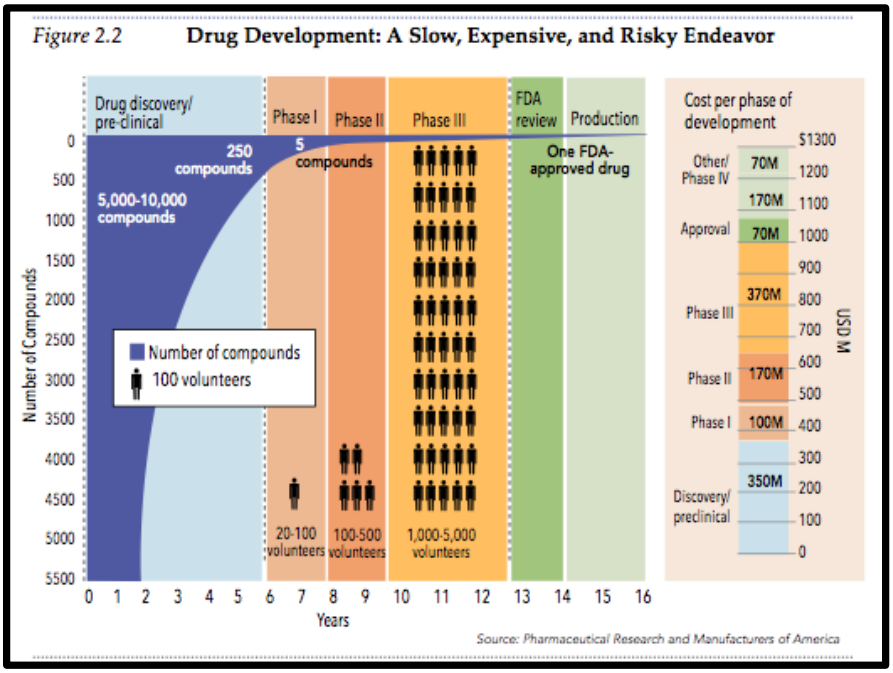
Engineer Factor VIII cDNA to Produce Protein in Host Cell & Synthesize Factor VIII in Mammalian Cells



Why Mammalian Cells?

Purify Factor VIII Protein!

Need FDA Approval Before Recombinant DNA Drug Can Be Marketed and Used to Treat Patients



A Long and Expensive Process!

Recombinant Factor VIII

Bayer Biological Products EU

Bayer HealthCare
Biological Products Division
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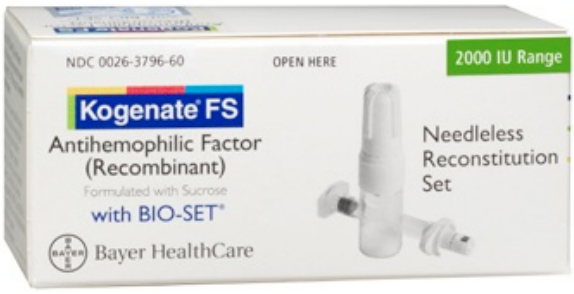
- Recombinant Factor VIII
- More Resources
- Haemophilia Centres in Europe

Related Links
- Haemo-QoL Project
- Hemophilia Research Awards

Recombinant factor VIII

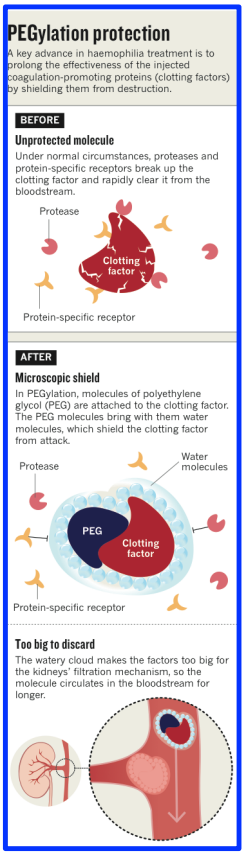
Recombinant factor VIII (rFVIII) is the antihaemophilic factor A, obtained using recombinant DNA technology. With this technology, pure protein is synthesized in the laboratory instead of being extracted from blood. In the following pages, it will be explained in detail how the knowledge and analysis of DNA, using the new instruments of molecular genetics, have represented both the beginning and follow-up stages in the development of recombinant FVIII.



Prophylactic Treatment Costs $300,000/ Year! Most Hemophiliacs Use "On Demand" or As Needed

Factor VIII gene cloned in 1983

Factor VIII (recombinant) approved as drug in 1993!
Ten years from gene → drug! (Off Patent in 2011)



New Longer Lasting Factor VIII and Factor IX Drugs

DRUGS TO HELP THE BLOOD

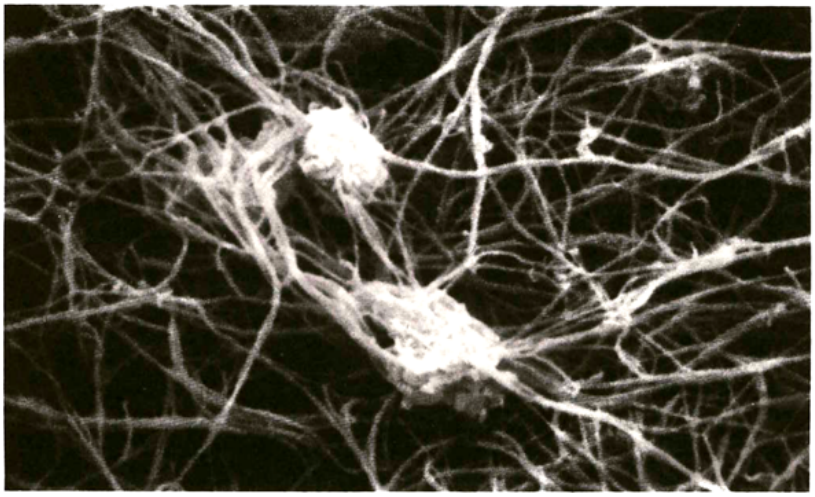
A number of treatments to aid blood clotting are in clinical trials or have been approved this year.

	Product	Approach	Company	Half-life (hours)	Status
Factor VIII infusions (for haemophilia A) Conventional infusion half-life: 8-12 hours	Eloctate	Fc fusion protein	Biogen Idec	20	FDA approved in June 2014
	BAX 855	PEGylation	Baxter International	19	Submission for approval planned for late 2014
	BAY94-9027	PEGylation	Bayer	19	Submission for approval planned for mid-2015
	N8-GP	PEGylation	Novo Nordisk	19	Submission for approval planned for 2018
Factor IX infusions (for haemophilia B) Conventional infusion half-life: 18–24 hours	rIX-FP	Albumin fusion	CSL Behring	92	In clinical trials
	N9-GP	PEGylation	Novo Nordisk	110	Submission for approval planned for 2015
	Alprolix	Fc fusion protein	Biogen Idec	87	FDA approved in March 2014

FDA, US Food and Drug Administration.

Using Factor VIII to Treat Hemophilia

Formation of a Blood Clot



FIBRIN STRANDS stabilize a blood clot at the site of a wound by trapping the platelets that form the bulk of the clot. The electron micrograph, which was made by Jon C. Lewis of Wake Forest University, shows a clot formed in a suspension of platelets and fibrin.

A clot in the bloodstream is the result of a complex cascade of enzymatic reactions culminating in the conversion of fibrinogen, a soluble protein, into insoluble fibrin strands. In hemophiliacs a crucial protein in the blood-clotting cascade is either missing or defective.

A Triumph of Genetic Engineering

The Future: Gene Therapy – A Permanent "Cure"

December 10, 2011

Treatment for Blood Disease Is Gene Therapy Landmark

By NICHOLAS WADE

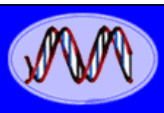
TIME Partners with CNN

Gene Therapy Shows Promise for Treating Hemophilia

By ALICE PARK Monday, December 12, 2011

The First Ever In-Human Gene Editing Will Try and Combat Hemophilia

Factor IX – Hemoglobin B
FDA-Approved Clinical Trial
2016



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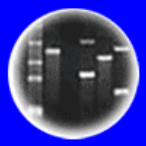

DNA Fingerprinting

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Plants of Tomorrow

The Factor VIII Story -- A Summary

1. Purify Small Amounts of Factor VIII
2. Obtain Partial or Complete Amino Acid Sequence
3. Use the Genetic Code to Synthesize Degenerate DNA Probes
4. Isolate Factor VIII DNA Clones Complementary to Probe in Genome Library
5. Determine if Factor VIII Clones Contain the Complete Gene By Sequencing and Comparing With Protein Sequence
6. If Not, "Walk" to Obtain Overlapping DNA Clones That Collectively Contain the Factor VIII Gene
7. Sequence Clones To Determine Where the Factor VIII Gene Starts and Stops
8. Use Factor VIII Genome Probe to Find Out What Body Organ/Tissue Expresses the Factor VIII Gene
9. Make a cDNA Library From the Target Organ/Tissue and Isolate a Factor VIII cDNA Clone
10. Sequence the Factor VIII cDNA Clone and Compare With Factor VIII Gene Sequence to Map its Anatomy (I.e., introns, exons, swtiches) and Ensure That it Contains the Complete Protein Coding Sequence
11. Use Factor VIII cDNA and/or Genome Fragments as a Probe to Find RFLP Markers For Disease Alleles -- Or Sequence Disease Alleles to Find Relevant RFLP Markers By Comparison With Wild-Type Sequence
12. Insert Factor VIII cDNA Into an Expression Vector and Synthesize Factor VIII Protein in Host Cells (e.g., Mammalian Cells)