ATLAS of PROTEIN SEQUENC and STRUCTURE 1965

N66-23819

(ACCESSION NUMBER)

(THRU)

111

(PAGES)

1

(CODE)

CR-71805

(NASA CR OR TMX OR AD NUMBER)

04

(CATEGORY)

FACILITY FORM 602

GPO PRICE $ ____

CFSTI PRICE(S) $ ____

Hard copy (HC) 4.00

Microfiche (MF) .75

ff 653 July 65

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8600 16TH STREET

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Library of Congress Card Catalogue Number 65-29342

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8600 16th Street, Silver Spring, Maryland

DEDICATION

To all the investigators who have developed the techniques necessary for the grand accomplishments represented by this tabulation, and to all those who have spent so much tedious effort in their application.

We would gratefully appreciate receiving suggestions, corrections, new data (even if fragmentary or provisional), and references to any data omitted from this volume.

M. O. D.
R. V. E.
M. A. C.
M. R. S.

PREFACE

This Atlas voluminously illustrates the triumph of experimental technique over the secretiveness of nature. Perhaps nowhere has the power of the scientific method been more brilliantly demonstrated than in the development of procedures for the study of the chemistry of life. As recently as twenty years ago, it was customary for biologists to have a hopeless attitude about biochemistry. Some details might be elicited, perhaps, but living things were thought to be so very complex and intricate that there surely was no hope of fully "understanding" them in all their chemical detail. Who, if he really comprehended the difficulty of the problem, would dare to think of man's ever knowing the detailed structure of a protein, for example, much less be able to synthesize it? Who would ever understand the mechanism of an enzyme as clearly as a chemist understands the details of an inorganic reaction? How could we ever hope to know the atomic details of a protein crystal?

Today some of these ambitions have already been attained, and the others no longer seem out of reach. We now rationally hope to be able to discover and understand the finest chemical details of living processes. These accomplishments and hopes have been made possible by the combined effect of several new approaches.

Techniques which permit the separation of chemically similar compounds have been developed for microgram samples. Among these are ion-exchange columns, paper chromatography, electrophoresis, and counter-current distribution. Radioactive tracer techniques and other micro-quantitative analytical procedures, often dependent on electronics and automation, have aided the analyses. X-ray crystallography, starting with the art of protein crystal production and ending with the processing of great numbers of experimental observations in the high-speed computer, has permitted a glimpse of three-dimensional structure.

Confidence in our understanding of experimental procedures and relationships among proteins has grown so great that sequences of amino acids are inferred from those found in homologous proteins. This technique requires only a small proportion of the analytical work needed to sequence a protein with no known relatives. The effectiveness of laboratory effort is thus magnified.

Some of the insights which have been developed cannot be attributed to any particular worker or school. Perhaps the greatest of these insights is that nature always uses "building blocks." A living cell is extremely complex and almost unimaginably intricate in detail. But it consists of a limited, understandable number of types of processes, reduplicated with variations. To understand the cell, we must have a few examples of each type of process, from which we can see the overall principles. For understanding, we need not work out the details of all the variations on these principles, although we may eventually choose to do so for medical or other practical reasons. Similarly, the analysis of such large, complex chemical molecules as proteins has been made possible by the recognition of their essential modularity, their building-block nature. Proteins are precise chemical structures built from regular subunits, not statistical mixtures or hopelessly intricate molecular conglomerates as was once thought. It is by means of the discovery and utilization of such building block principles, combined with the large-scale application of new and improved techniques, that we now dare hope to make all of living nature accessible to our understanding.

Hidden in the amino acid sequence of a protein is the chemical information that produces its three-dimensional structure. In the case of an enzyme, this structure forms locks into which the proper keys—cell chemicals—fit. By these locks, the enzymes bring the proper reactants together quickly, efficiently, and selectively. Uncatalyzed reactions cannot complete with such specifically catalyzed reactions; therefore, the presence of enzymes determines which reactions can take place in living chemistry. In many cases, if not all, this three-dimensional structure is fully determined by the information in the one-dimensional sequence. The folding is the thermodynamically most stable result of all the possible intermolecular forces, such as hydrogen bonds and hydrophobic bonds, which can form between the various links of the chain. In principle, if we knew these forces in detail, and if we had appropriate computer routines, we should then be able to determine the three-dimensional structure of a protein, given only its amino acid sequence.

Also hidden in the sequences is information about the genes which directed their synthesis. For each amino acid there are a small number of possible corresponding nucleotide triplets in the gene. That is, each protein sequence corresponds to a limited number of possible nucleotide sequences. When nucleotide mutations occur, the substitution of alternative amino acids is not random. Analysis of amino acid sequence data, considered as a mathematical puzzle, can help elucidate both the mathematical details of the genetic code and the structural aspects of the genetic mechanism.

Hidden in each family of homologous sequences is the story of its evolution. Simple organisms, caught in their primitive ecological niches, still preserve even today enzymes performing primeval functions, held relatively fixed by natural selection. Even the older proteins of man are preserved as living "fossils" in his metabolism.

Enmeshed also in homologous sequences are the records of the many thousands of mutational steps by which we can quantify a phylogenetic tree. Each amino acid link is a trait by which we can trace species evolution. By comparison, the traditional taxonomic criteria are extremely vague and uncertain. In the case of distant relationships, they often break down completely. A truly quantitative and inclusive system of phylogenetic classification would be of great help to comparative physiologists and other students of evolution.

Conspicuous in comparative human protein sequences is information of great medical-diagnostic value. A long series of abnormalities has been found to be attributable to single amino acid replacements. One such tragically serious disease is sickle-cell anemia.

To facilitate the theoretical study of the protein sequences which have already been so ingeniously and laboriously determined, we have undertaken this compilation.

The information is kept in a compact, uniform format on punched cards. New information and corrections are easily inserted, while the text is kept accurate.

It is our intention to include the currently accepted amino acid sequence of every protein for which complete or substantial data is available. Uusally, only the definitive report giving the complete sequence from each laboratory will be referenced. If a substantial amount of work has been done on the same protein in other laboratories, their reports will also be referenced. We have also included some smaller peptides that have come to our attention. Unusual polypeptides which are presumably not produced by the genetic code have been omitted.

The format in which the Atlas is kept on punched cards is suitable for direct use in our computer programs. We use a three-letter code, which is a slight modification of the conventional notation, and also a mnemonic one-letter code which is clearer and much more suitable for certain comparative studies. We use a system of punctuation to describe the degree of confidence in each bond. Brief remarks are also included about the nature and function of the protein, and additional structural information such as the attachment of prosthetic groups, the location of S-S bonds, amino acids involved in active sites, and three-dimensional structures. In later editions we intend to include a section in which the alignment of all sequences of each family is given. Possibly we will also have sections on alleles and on mathematical methods and computer programs to treat the information.

This first edition is incomplete and imperfect and is intended mainly for distribution to investigators who have published protein sequence analyses, to acquaint them with the existence of this Atlas. We would gratefully appreciate their cooperation in making corrections, additions and suggestions for future editions. Since sequences are being reported in great numbers, we plan to bring out supplementary material in six months and a second edition in a year.

We thank all those who have assisted with this compilation, particularly Mr. Javier Albarran for his help with the computer aspects and Miss Lorrie Goldstein for her design of the cover.

The tabulations and computations were made at the University of Maryland Computer Science Center, College Park.

This work was supported by Grants GM-08710 and GM-12168 from the National Institutes of Health to the National Biomedical Research Foundation.

TABLE OF CONTENTS

THE MEANING OF THE PUNCTUATION IS AS FOLLOWS.

BLANK	SEQUENCE OF AMINO ACIDS HAS BEEN DETERMINED.
( )	ENCLOSE PORTION OF SEQUENCE NOT SPECIFICALLY DETERMINED. TO PRESERVE PROPER SPACING,
=	IS USED INSTEAD OF)(
,	SEPARATES AMINO ACIDS WITHIN PARENTHESES,
BUT .	SEPARATES AMINO ACIDS, WHERE THE SEQUENCE IS PRESUMED BY HOMOLOGY WITH A KNOWN SEQUENCE.
/ OR ///	FRAGMENT, CONNECTION UNDETERMINED
* OR ***	CARBOXYL END OF PROTEIN

* ASTERISK BEFORE REFERENCE INDICATES THAT THE SEQUENCE WAS COPIED FROM, AND PROOFREAD AGAINST, THE ORIGINAL ARTICLE.

= BEFORE REFERENCE INDICATES THAT WE HAVE NOT SEEN THE ORIGINAL ARTICLE.

NO MARK BEFORE REFERENCE INDICATES OTHER GROUPS WHICH HAVE ALSO REPORTED WORK ON THE SAME PROTEIN.

BOTH SINGLE- AND THREE-LETTER NOTATIONS ARE USED, AS FOLLOWS.

A = ALA = ALANINE	M = MET = METHIONINE
C = CYS = CYSTEINE	N = ASN = ASPARAGINE
D = ASP = ASPARTIC ACID	O = TYR = TYROSINE
E = GLU = GLUTAMIC ACID	P = PRO = PROLINE
F = PHE = PHENYLALANINE	Q = GLN = GLUTAMINE
G = GLY = GLYCINE	R = ARG = ARGININE
H = HIS = HISTIDINE	S = SER = SERINE
I = ILU = ISOLEUCINE	T = THR = THREONINE
K = LYS = LYSINE	W = TRP = TRYPTOPHAN
L = LEU = LEUCINE	V = VAL = VALINE

B = ASX = ASPARTIC ACID OR ASPARAGINE
Z = GLX = GLUTAMIC ACID OR GLUTAMINE
X = XXX = UNDETERMINED OR OTHERWISE UNUSUAL

MNEMONICS OF THE ONE-LETTER CODE

IF POSSIBLE, THE INITIAL LETTER OF THE AMINO ACID IS USED. IF MORE THAN ONE AMINO ACID BEGINS WITH THE SAME LETTER, THE MOST COMMONLY-OCCURRING ONE IS ASSIGNED THE INITIAL.

A = ALANINE	I = ISOLEUCINE	S = SERINE
C = CYSTEINE	L = LEUCINE	T = THREONINE
G = GLYCINE	M = METHIONINE	V = VALINE
H = HISTIDINE	P = PROLINE	

SOME OF THE OTHERS ARE PHONETICALLY SUGGESTIVE.

F = PHENYLALANINE
R = ARGININE
O = TYROSINE

DOUBLE RING IN THE SIDE CHAIN.

W = TRYPTOPHAN

THE TWO ACIDS ARE ADJACENT, IN ALPHABETICAL ORDER.

D = ASPARTIC ACID
E = GLUTAMIC ACID

THE TWO AMINES HAVE LETTERS FROM THE MIDDLE OF THE ALPHABET.

N = ASPARAGINE (CONTAINS N)
Q = GLUTAMINE ('Q-TAMINE')

NON-INITIAL LETTER AS CLOSE AS POSSIBLE TO ITS INITIAL.

K = LYSINE

CYTOCHROME C - BAKER'S YEAST

HEME BONDED TO CYSTEINES AT POSITIONS 19 AND 22.

```
   1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0
 1 T E F K A G S A K K G A T L F K T R C E L C H T V E K G G P
31 H K V G P N L H G I F G R H S G Q A Q G O S O T D A N I K K
61 N V L W D E N N M S E O L T N P K K O I P G T K M A F G G L
91 K K E K D R N D L I T O L K K A C E *
```

```
    1   2   3   4   5   6   7   8   9   10  11  12  13  14  15
 1 THR GLU PHE LYS ALA GLY SER ALA LYS LYS GLY ALA THR LEU PHE
   LYS THR ARG CYS GLU LEU CYS HIS THR VAL GLU LYS GLY GLY PRO
31 HIS LYS VAL GLY PRO ASN LEU HIS GLY ILU PHE GLY ARG HIS SER
   GLY GLN ALA GLN GLY TYR SER TYR THR ASP ALA ASN ILU LYS LYS
61 ASN VAL LEU TRP ASP GLU ASN ASN MET SER GLU TYR LEU THR ASN
   PRO LYS LYS TYR ILU PRO GLY THR LYS MET ALA PHE GLY GLY LEU
91 LYS LYS GLU LYS ASP ARG ASN ASP LEU ILU THR TYR LEU LYS LYS
   ALA CYS GLU ***
```

COMPOSITION

7	ALA	A	2	GLN	Q	8	LEU	L	4	SER	S
3	ARG	R	7	GLU	E	16	LYS	K	8	THR	T
7	ASN	N	12	GLY	G	2	MET	M	1	TRP	W
4	ASP	D	4	HIS	H	4	PHE	F	5	TYR	O
3	CYS	C	4	ILU	I	4	PRO	P	3	VAL	V

TOTAL NO. OF ACIDS = 108

* NARITA,K.,TITANI,K.,YAOI,Y.,MURAKAMI,H., BIOCHIM. BIOPHYS. ACTA,
VOL. 77, PP.688-690, 1963

CYTOCHROME C - CHICKEN

ACETYL AT AMINO END.
HEME BONDED TO CYSTEINES AT POSITIONS 14 AND 17.

```
   1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0

 1 G D I E K G K K I F V Q K C S Q C H T V E K G G K H K T G P

31 N L H G L F G R K T G Q A E G F S O T D A N K N K G I T W G

61 E D T L M E O L E N P K K O I P G T K M I F A G I K K K S E

91 R V D L I A O L K K A T N S *
```

```
    1   2   3   4   5   6   7   8   9   10  11  12  13  14  15

 1 GLY ASP ILU GLU LYS GLY LYS LYS ILU PHE VAL GLN LYS CYS SER

   GLN CYS HIS THR VAL GLU LYS GLY GLY LYS HIS LYS THR GLY PRO

31 ASN LEU HIS GLY LEU PHE GLY ARG LYS THR GLY GLN ALA GLU GLY

   PHE SER TYR THR ASP ALA ASN LYS ASN LYS GLY ILU THR TRP GLY

61 GLU ASP THR LEU MET GLU TYR LEU GLU ASN PRO LYS LYS TYR ILU

   PRO GLY THR LYS MET ILU PHE ALA GLY ILU LYS LYS LYS SER GLU

91 ARG VAL ASP LEU ILU ALA TYR LEU LYS LYS ALA THR ASN SER ***
```

COMPOSITION

5	ALA	A	3	GLN	Q	6	LEU	L	4	SER	S
2	ARG	R	7	GLU	E	18	LYS	K	8	THR	T
5	ASN	N	13	GLY	G	2	MET	M	1	TRP	W
4	ASP	D	3	HIS	H	4	PHE	F	4	TYR	O
2	CYS	C	7	ILU	I	3	PRO	P	3	VAL	V

TOTAL NO. OF ACIDS = 104

* MARGOLIASH,E.,NEEDLEMAN,S.B. AND STEWART,J.W., ACTA CHEM. SCAND., VOL.17, SUPPL.1, PP.250-256, 1963

CYTOCHROME C - HORSE

ACETYL AT AMINO END.
HEME BONDED TO CYSTEINES AT POSITIONS 14 AND 17.
OXIDATION-REDUCTION POTENTIAL EQUALS .250 V.

	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
1	G	D	V	E	K	G	K	K	I	F	V	Q	K	C	A	Q	C	H	T	V	E	K	G	G	K	H	K	T	G	P
31	N	L	H	G	L	F	G	R	K	T	G	Q	A	P	G	F	T	O	T	D	A	N	K	N	K	G	I	T	W	K
61	E	E	T	L	M	E	O	L	E	N	P	K	K	O	I	P	G	T	K	M	I	F	A	G	I	K	K	K	T	E
91	R	E	D	L	I	A	O	L	K	K	A	T	N	E	*															

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	GLY	ASP	VAL	GLU	LYS	GLY	LYS	LYS	ILU	PHE	VAL	GLN	LYS	CYS	ALA
	GLN	CYS	HIS	THR	VAL	GLU	LYS	GLY	GLY	LYS	HIS	LYS	THR	GLY	PRO
31	ASN	LEU	HIS	GLY	LEU	PHE	GLY	ARG	LYS	THR	GLY	GLN	ALA	PRO	GLY
	PHE	THR	TYR	THR	ASP	ALA	ASN	LYS	ASN	LYS	GLY	ILU	THR	TRP	LYS
61	GLU	GLU	THR	LEU	MET	GLU	TYR	LEU	GLU	ASN	PRO	LYS	LYS	TYR	ILU
	PRO	GLY	THR	LYS	MET	ILU	PHE	ALA	GLY	ILU	LYS	LYS	LYS	THR	GLU
91	ARG	GLU	ASP	LEU	ILU	ALA	TYR	LEU	LYS	LYS	ALA	THR	ASN	GLU	***

COMPOSITION

6	ALA	A	3	GLN	Q	6	LEU	L	0	SER	S
2	ARG	R	9	GLU	E	19	LYS	K	10	THR	T
5	ASN	N	12	GLY	G	2	MET	M	1	TRP	W
3	ASP	D	3	HIS	H	4	PHE	F	4	TYR	O
2	CYS	C	6	ILU	I	4	PRO	P	3	VAL	V

TOTAL NO. OF ACIDS = 104

* MARGOLIASH,E., SMITH,E.L., KREIL,G.,AND TUPPY, H., NATURE, VOL.192, NO.4808, PP.1121-1127, DEC.23, 1961

CYTOCHROME C - HUMAN

ACETYL AT AMINO END.
HEME BONDED TO CYSTEINES AT POSITIONS 14 AND 17.
LEU (L) REPLACES MET (M) AT POSITION 65 IN 10 PERCENT
YIELD IN POOLED PROTEIN.

```
    1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0

 1  G D V E K G K K I F I M K C S Q C H T V E K G G K H K T G P

31  N L H G L F G R K T G Q A P G O S O T A A N K N K G I I W G

61  E D T L M E O L E N P K K O I P G T K M I F V G I K K K E E

91  R A D L I A O L K K A T N E *
```

```
     1   2   3   4   5   6   7   8   9   10  11  12  13  14  15

 1  GLY ASP VAL GLU LYS GLY LYS LYS ILU PHE ILU MET LYS CYS SER

    GLN CYS HIS THR VAL GLU LYS GLY GLY LYS HIS LYS THR GLY PRO

31  ASN LEU HIS GLY LEU PHE GLY ARG LYS THR GLY GLN ALA PRO GLY

    TYR SER TYR THR ALA ALA ASN LYS ASN LYS GLY ILU ILU TRP GLY

61  GLU ASP THR LEU MET GLU TYR LEU GLU ASN PRO LYS LYS TYR ILU

    PRO GLY THR LYS MET ILU PHE VAL GLY ILU LYS LYS LYS GLU GLU

91  ARG ALA ASP LEU ILU ALA TYR LEU LYS LYS ALA THR ASN GLU ***
```

COMPOSITION

6	ALA	A	2	GLN	Q	6	LEU	L	2	SER	S
2	ARG	R	8	GLU	E	18	LYS	K	7	THR	T
5	ASN	N	13	GLY	G	3	MET	M	1	TRP	W
3	ASP	D	3	HIS	H	3	PHE	F	5	TYR	O
2	CYS	C	8	ILU	I	4	PRO	P	3	VAL	V

TOTAL NO. OF ACIDS = 104

* MATSUBARA, H., AND SMITH,E.L., J. BIOL. CHEM., VOL. 237, NO.11, PC3575-PC3576, NOV., 1962

CYTOCHROME - C PIG AND BOVINE

ACETYL AT AMINO END.
HEME BONDED TO CYSTEINES AT POSITIONS 14 AND 17.

	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
1	G	D	V	E	K	G	K	K	I	F	V	Q	K	C	A	Q	C	H	T	V	E	K	G	G	K	H	K	T	G	P
31	N	L	H	G	L	F	G	R	K	T	G	Q	A	P	G	F	S	O	T	D	A	N	K	N	K	G	I	T	W	G
61	E	E	T	L	M	E	O	L	E	N	P	K	K	O	I	P	G	T	K	M	I	F	A	G	I	K	K	K	G	E
91	R	E	D	L	I	A	O	L	K	K	A	T	N	E	*															

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	GLY	ASP	VAL	GLU	LYS	GLY	LYS	LYS	ILU	PHE	VAL	GLN	LYS	CYS	ALA
	GLN	CYS	HIS	THR	VAL	GLU	LYS	GLY	GLY	LYS	HIS	LYS	THR	GLY	PRO
31	ASN	LEU	HIS	GLY	LEU	PHE	GLY	ARG	LYS	THR	GLY	GLN	ALA	PRO	GLY
	PHE	SER	TYR	THR	ASP	ALA	ASN	LYS	ASN	LYS	GLY	ILU	THR	TRP	GLY
61	GLU	GLU	THR	LEU	MET	GLU	TYR	LEU	GLU	ASN	PRO	LYS	LYS	TYR	ILU
	PRO	GLY	THR	LYS	MET	ILU	PHE	ALA	GLY	ILU	LYS	LYS	LYS	GLY	GLU
91	ARG	GLU	ASP	LEU	ILU	ALA	TYR	LEU	LYS	LYS	ALA	THR	ASN	GLU	***

COMPOSITION

6	ALA	A	3	GLN	Q	6	LEU	L	1	SER	S
2	ARG	R	9	GLU	E	18	LYS	K	8	THR	T
5	ASN	N	14	GLY	G	2	MET	M	1	TRP	W
3	ASP	D	3	HIS	H	4	PHE	F	4	TYR	O
2	CYS	C	6	ILU	I	4	PRO	P	3	VAL	V

TOTAL NO. OF ACIDS = 104

* MARGOLIASH,E.,NEEDLEMAN,S.B. AND STEWART,J.W., ACTA CHEM. SCAND., VOL.17, SUPPL.1, PP.250-256, 1963 (PIG)

TUPPY H., AND PALEUS, S., ACTA CHEM. SCAND., VOL. 13, NO.4,
PP. 641-646, 1959, (HEME ATTACHEMENT REGION ONLY - BOVINE)

YASUNOBU, K. T., NAKASHIMA, T., HIGA, H., MATSUBARA, H., AND
BENSON, A. , BIOCHIM. BIOPHYS. ACTA VOL. 78, PN1324
PP. 791-794, 1963 (BOVINE)

CYTOCHROME C - PSEUDOMONAS

HEME BONDED TO CYSTEINES AT POSITIONS 12 AND 15.
THE AMINO END IS NOT ACETYLATED.

	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
1	E	D	P	E	V	L	F	K	N	K	G	C	V	A	C	H	A	I	D	T	K	M	V	G	P	A	O	K	D	V
31	A	A	K	F	A	G	Q	A	G	A	E	A	E	L	A	Q	R	I	K	N	G	S	Q	G	V	W	G	P	I	P
61	M	P	P	N	A	V	S	D	D	E	A	Q	T	L	A	K	W	V	L	S	Q	K	*							

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	GLU	ASP	PRO	GLU	VAL	LEU	PHE	LYS	ASN	LYS	GLY	CYS	VAL	ALA	CYS
	HIS	ALA	ILU	ASP	THR	LYS	MET	VAL	GLY	PRO	ALA	TYR	LYS	ASP	VAL
31	ALA	ALA	LYS	PHE	ALA	GLY	GLN	ALA	GLY	ALA	GLU	ALA	GLU	LEU	ALA
	GLN	ARG	ILU	LYS	ASN	GLY	SER	GLN	GLY	VAL	TRP	GLY	PRO	ILU	PRO
61	MET	PRO	PRO	ASN	ALA	VAL	SER	ASP	ASP	GLU	ALA	GLN	THR	LEU	ALA
	LYS	TRP	VAL	LEU	SER	GLN	LYS	***							

COMPOSITION

13	ALA	A	5	GLN	Q	4	LEU	L	3	SER	S
1	ARG	R	5	GLU	E	8	LYS	K	2	THR	T
3	ASN	N	7	GLY	G	2	MET	M	2	TRP	W
5	ASP	D	1	HIS	H	2	PHE	F	1	TYR	O
2	CYS	C	3	ILU	I	6	PRO	P	7	VAL	V

TOTAL NO. OF ACIDS = 82

* AMBLER, R. P., BIOCHEM. J., VOL.89, P.349-378. 1963

CYTOCHROME C - TUNA FISH

ACETYL AT AMINO END.
HEME BONDED TO CYSTEINES AT POSITIONS 14 AND 17.

```
   1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0

 1 G D V A K.G K K.T F V Q K.C A Q(C.H)T V E N G G K.H K(V.G.P.

31 N)L W.G L F.G R.K T(G.Q)A E G O.S O T(D.A.N)K.S K.G I V W(N,

61 N,D)T L M E O.L E N P K K.O(I.P.G)T K(M.I)F.A G I K K.K G E

91 R.Q D L(V.A)O.L K S T A S *
```

```
    1   2   3   4   5   6   7   8   9   10  11  12  13  14  15

 1 GLY ASP VAL ALA LYS.GLY LYS LYS.THR PHE VAL GLN LYS.CYS ALA

   GLN(CYS.HIS)THR VAL GLU ASN GLY GLY LYS.HIS LYS(VAL.GLY.PRO.

31 ASN)LEU TRP.GLY LEU PHE.GLY ARG.LYS THR(GLY.GLN)ALA GLU GLY

   TYR.SER TYR THR(ASP.ALA.ASN)LYS.SER LYS.GLY ILU VAL TRP(ASN,

61 ASN,ASP)THR LEU MET GLU TYR.LEU GLU ASN PRO LYS LYS.TYR(ILU.

   PRO.GLY)THR LYS.MET.ILU)PHE.ALA GLY ILU LYS LYS.LYS GLY GLU

91 ARG.GLN ASP LEU(VAL.ALA)TYR.LEU LYS SER THR ALA SER ***
```

COMPOSITION

7	ALA	A	4	GLN	Q	6	LEU	L	4	SER	S
2	ARG	R	5	GLU	E	16	LYS	K	7	THR	T
6	ASN	N	13	GLY	G	2	MET	M	2	TRP	W
4	ASP	D	2	HIS	H	3	PHE	F	5	TYR	O
2	CYS	C	4	ILU	I	3	PRO	P	6	VAL	V

TOTAL NO. OF ACIDS = 103

* KREIL,G., Z. PHYSIOL. CHEM., BD. 334, PP.154-166, 1963

CYTOCHROME C - BOMBYX MORI (SILKWORM)

HEME BONDED TO CYSTEINES AT POSITIONS 4 AND 7 OF FRAGMENT.

```
 1 2 3 4 5 6 7 8 9 0 1
/ V Q R C A Q C H T(V,E)/
```

```
     1   2   3   4   5   6   7   8   9  10  11
/// VAL GLN ARG CYS ALA GLN CYS HIS THR(VAL,GLU)///
```

COMPOSITION OF FRAGMENT

1	ALA	A	2	GLN	Q	0	LEU	L	0	SER	S
1	ARG	R	1	GLU	E	0	LYS	K	1	THR	T
0	ASN	N	0	GLY	G	0	MET	M	0	TRP	W
0	ASP	D	1	HIS	H	0	PHE	F	0	TYR	O
2	CYS	C	0	ILU	I	0	PRO	P	2	VAL	V

TOTAL NO. OF ACIDS IN FRAGMENT = 11

* TUPPY H., Z. NATURFORSCH., VOL.12, PP.784-788, 1957

CYTOCHROME C - RATTLESNAKE

ACETYL AT AMINO END.

```
   1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0
 1 G D V E K G K K I F(I.T.K.C.S.Q.C.H.T.V.E.K.G.G.K.H)K T G P
31 N L H.G L F.G R K T G Q A V G O.S O.T A A N K N.K G I I W.G
61 D D T L M E O.L E N P K K O.I P G T K M.V F.T G L.S K K K E
91 R T N L.I A O.L K E K T A A *
```

```
    1   2   3   4   5   6   7   8   9   10  11  12  13  14  15
 1 GLY ASP VAL GLU LYS GLY LYS LYS ILU PHE(ILU.THR.LYS.CYS.SER.
   GLN.CYS.HIS.THR.VAL.GLU.LYS.GLY.GLY.LYS.HIS)LYS THR GLY PRO
31 ASN LEU HIS.GLY LEU PHE.GLY ARG LYS THR GLY GLN ALA VAL GLY
   TYR.SER TYR.THR ALA ALA ASN LYS ASN.LYS GLY ILU ILU TRP.GLY
61 ASP ASP THR LEU MET GLU TYR.LEU GLU ASN PRO LYS LYS TYR.ILU
   PRO GLY THR LYS MET.VAL PHE.THR GLY LEU.SER LYS LYS LYS GLU
91 ARG THR ASN LEU.ILU ALA TYR.LEU LYS GLU LYS THR ALA ALA ***
```

COMPOSITION

6	ALA	A	2	GLN	Q	7	LEU	L	3	SER	S
2	ARG	R	6	GLU	E	18	LYS	K	10	THR	T
5	ASN	N	13	GLY	G	2	MET	M	1	TRP	W
3	ASP	D	3	HIS	H	3	PHE	F	5	TYR	O
2	CYS	C	6	ILU	I	3	PRO	P	4	VAL	V

TOTAL NO. OF ACIDS = 104

* BAHL, O. P. AND SMITH, E. L., J. BIOL. CHEM., VOL.240, NO.9, PP.3585-3593, SEPT., 1965

CYTOCHROME - C RHODOSPIRILLUM RUBRUM

HEME BONDED TO CYSTEINES AT POSITIONS 1 AND 4 OF FRAGMENT.

```
 1 2 3 4 5 6 7 8 9 0 1 2 3
/ C L A C H T F B Z G A N K /

      1   2   3   4   5   6   7   8   9  10  11  12  13
/// CYS LEU ALA CYS HIS THR PHE ASX GLX GLY ALA ASN LYS ///
```

COMPOSITION OF FRAGMENT

2	ALA	A	0	GLN	Q	1	LEU	L	0	SER	S
0	ARG	R	0	GLU	E	1	LYS	K	1	THR	T
1	ASN	N	1	GLY	G	0	MET	M	0	TRP	W
0	ASP	D	1	HIS	H	1	PHE	F	0	TYR	O
2	CYS	C	0	ILU	I	0	PRO	P	0	VAL	V
1	ASX	B	1	GLX	Z						

TOTAL NO. OF ACIDS IN FRAGMENT = 13

* TUPPY H., AND PALEUS, S., ACTA CHEM. SCAND., VOL. 13, NO.4, PP. 641-646, 1959

CYTOCHROME C - SALMON

HEME BONDED TO CYSTEINES AT POSITIONS 4 AND 7 OF FRAGMENT.

```
  1 2 3 4 5 6 7 8 9 0 1
/ V Q K C A Q H C T(V,E)/
```

```
       1   2   3   4   5   6   7   8   9  10  11
/// VAL GLN LYS CYS ALA GLN CYS HIS THR(VAL,GLU)///
```

COMPOSITION OF FRAGMENT

1 ALA A	2 GLN Q	0 LEU L	0 SER S
0 ARG R	1 GLU E	1 LYS K	1 THR T
0 ASN N	0 GLY G	0 MET M	0 TRP W
0 ASP D	1 HIS H	0 PHE F	0 TYR O
2 CYS C	0 ILU I	0 PRO P	2 VAL V

TOTAL NO. OF ACIDS IN FRAGMENT = 11

* TUPPY H., AND PALEUS, S., ACTA CHEM. SCAND., VOL. 9, P.353-364, 1955

GL HUHA 2.001

HEMOGLOBIN ALPHA - HUMAN

```
    1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0
  1 V L S P A D K T N V K A A W G K V G A H A G E O G A E A L E
 31 R M F L S F P T T K T O F P H F D L S H G S A Q V K G H G K
 61 K V A D A L T N A V A H V D D M P N A L S A L S D L H A H K
 91 L R V D P V N F K L L S H C L L V T L A A H L P A E F T P A
121 V H A S L D K F L A S V S T V L T S K O R *
```

```
     1   2   3   4   5   6   7   8   9   10  11  12  13  14  15
  1 VAL LEU SER PRO ALA ASP LYS THR ASN VAL LYS ALA ALA TRP GLY
    LYS VAL GLY ALA HIS ALA GLY GLU TYR GLY ALA GLU ALA LEU GLU
 31 ARG MET PHE LEU SER PHE PRO THR THR LYS THR TYR PHE PRO HIS
    PHE ASP LEU SER HIS GLY SER ALA GLN VAL LYS GLY HIS GLY LYS
 61 LYS VAL ALA ASP ALA LEU THR ASN ALA VAL ALA HIS VAL ASP ASP
    MET PRO ASN ALA LEU SER ALA LEU SER ASP LEU HIS ALA HIS LYS
 91 LEU ARG VAL ASP PRO VAL ASN PHE LYS LEU LEU SER HIS CYS LEU
    LEU VAL THR LEU ALA ALA HIS LEU PRO ALA GLU PHE THR PRO ALA
121 VAL HIS ALA SER LEU ASP LYS PHE LEU ALA SER VAL SER THR VAL
    LEU THR SER LYS TYR ARG ***
```

COMPOSITION

21	ALA	A	1	GLN	Q	18	LEU	L	11	SER	S
3	ARG	R	4	GLU	E	11	LYS	K	9	THR	T
4	ASN	N	7	GLY	G	2	MET	M	1	TRP	W
8	ASP	D	10	HIS	H	7	PHE	F	3	TYR	O
1	CYS	C	0	ILU	I	7	PRO	P	13	VAL	V

TOTAL NO. OF ACIDS = 141

* HILL,R.J., AND KONIGSBERG, W., J. BIOL. CHEM., VOL. 237, NO.10, PP. 3151-3156, OCT., 1962

BRAUNITZER, G., GEHRING-MULLER, R., HILSCHMANN, N., HILSE, K., HOBOM, G., RUDLOFF, V., AND WITTMANN-LIEBOLD, B., Z. PHYSIOL. CHEM., VOL. BD 325, PP.283-286, 1961

THE SAME SEQUENCE, WITHOUT DISTINGUISHING AMINES, ALSO REPORTED IN THE ARTICLE.

SCHROEDER,W.A., J.R.SHELTON, J.B.SHELTON, AND J.CORMICK BIOCHEMISTRY, VOL. 2, NO.6, PP.1353-1357, NOV.-DEC., 1963

FETAL ALPHA CHAIN IS VERY PROBABLY IDENTICAL WITH ADULT ALPHA CHAIN. TRYPTIC AND CHYMOTRYPTIC PEPTIDES, MOST OF WHICH WERE COMPLETELY SEQUENCED, WERE SHOWN TO FIT EXACTLY INTO THE ADULT ALPHA CHAIN SEQUENCE.

HEMOGLOBIN BETA - HUMAN

	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
1	V	H	L	T	P	E	E	K	S	A	V	T	A	L	W	G	K	V	D	V	D	E	V	G	G	E	A	L	G	R
31	L	L	V	V	O	P	W	T	E	R	F	F	E	S	F	G	D	L	S	T	P	D	A	V	M	G	D	P	K	V
61	K	A	H	G	K	K	V	L	G	A	F	S	D	G	L	A	H	L	D	D	L	K	G	T	F	A	T	L	S	E
91	L	H	C	D	K	L	H	V	D	P	E	D	F	R	L	L	G	D	V	L	V	C	V	L	A	H	H	F	G	K
121	E	F	T	P	P	V	E	A	A	O	E	K	V	V	A	G	V	A	D	A	L	A	H	K	O	H	*			

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	VAL	HIS	LEU	THR	PRO	GLU	GLU	LYS	SER	ALA	VAL	THR	ALA	LEU	TRP
	GLY	LYS	VAL	ASP	VAL	ASP	GLU	VAL	GLY	GLY	GLU	ALA	LEU	GLY	ARG
31	LEU	LEU	VAL	VAL	TYR	PRO	TRP	THR	GLU	ARG	PHE	PHE	GLU	SER	PHE
	GLY	ASP	LEU	SER	THR	PRO	ASP	ALA	VAL	MET	GLY	ASP	PRO	LYS	VAL
61	LYS	ALA	HIS	GLY	LYS	LYS	VAL	LEU	GLY	ALA	PHE	SER	ASP	GLY	LEU
	ALA	HIS	LEU	ASP	ASP	LEU	LYS	GLY	THR	PHE	ALA	THR	LEU	SER	GLU
91	LEU	HIS	CYS	ASP	LYS	LEU	HIS	VAL	ASP	PRO	GLU	ASP	PHE	ARG	LEU
	LEU	GLY	ASP	VAL	LEU	VAL	CYS	VAL	LEU	ALA	HIS	HIS	PHE	GLY	LYS
121	GLU	PHE	THR	PRO	PRO	VAL	GLU	ALA	ALA	TYR	GLU	LYS	VAL	VAL	ALA
	GLY	VAL	ALA	ASP	ALA	LEU	ALA	HIS	LYS	TYR	HIS	***			

COMPOSITION

15	ALA	A	0	GLN	Q	18	LEU	L	5	SER	S
3	ARG	R	11	GLU	E	11	LYS	K	7	THR	T
0	ASN	N	13	GLY	G	1	MET	M	2	TRP	W
13	ASP	D	9	HIS	H	8	PHE	F	3	TYR	O
2	CYS	C	0	ILU	I	7	PRO	P	18	VAL	V

TOTAL NO. OF ACIDS = 146

* BRAUNITZER, G., GEHRING-MULLER, R., HILSCHMANN, N., HILSE, K., HOBOM, G., RUDLOFF, V., AND WITTMANN-LIEBOLD, B., Z. PHYSIOL. CHEM., VOL. BD 325, PP.283-286, 1961

HEMOGLOBIN GAMMA - HUMAN

	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
1	G	H	F	T	E	E	D	K	A	T	I	T	S	L	W	G	K	V	N	V	E	D	A	G	G	E	T	L	G	R
31	L	L	V	V	O	P	W	T	Q	R	F	F	D	S	F	G	N	L	S	S	A	S	A	I	M	G	N	P	K	V
61	K	A	H	G	K	K	V	L	T	S	L	G	D	A	I	K	H	L	D	D	L	K	G	T	F	A	Q	L	S	E
91	L	H	C	D	K	L	H	V	D	P	E	N	F	K	L	L	G	N	V	L	V	T	V	L	A	I	H	F	G	K
121	E	F	T	P	E	V	Q	A	S	W	Q	K	M	V	T	G	V	A	S	A	L	S	S	R	O	H	*			

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	GLY	HIS	PHE	THR	GLU	GLU	ASP	LYS	ALA	THR	ILU	THR	SER	LEU	TRP
	GLY	LYS	VAL	ASN	VAL	GLU	ASP	ALA	GLY	GLY	GLU	THR	LEU	GLY	ARG
31	LEU	LEU	VAL	VAL	TYR	PRO	TRP	THR	GLN	ARG	PHE	PHE	ASP	SER	PHE
	GLY	ASN	LEU	SER	SER	ALA	SER	ALA	ILU	MET	GLY	ASN	PRO	LYS	VAL
61	LYS	ALA	HIS	GLY	LYS	LYS	VAL	LEU	THR	SER	LEU	GLY	ASP	ALA	ILU
	LYS	HIS	LEU	ASP	ASP	LEU	LYS	GLY	THR	PHE	ALA	GLN	LEU	SER	GLU
91	LEU	HIS	CYS	ASP	LYS	LEU	HIS	VAL	ASP	PRO	GLU	ASN	PHE	LYS	LEU
	LEU	GLY	ASN	VAL	LEU	VAL	THR	VAL	LEU	ALA	ILU	HIS	PHE	GLY	LYS
121	GLU	PHE	THR	PRO	GLU	VAL	GLN	ALA	SER	TRP	GLN	LYS	MET	VAL	THR
	GLY	VAL	ALA	SER	ALA	LEU	SER	SER	ARG	TYR	HIS	***			

COMPOSITION

11	ALA	A	4	GLN	Q	17	LEU	L	11	SER	S
3	ARG	R	8	GLU	E	12	LYS	K	10	THR	T
5	ASN	N	13	GLY	G	2	MET	M	3	TRP	W
8	ASP	D	7	HIS	H	8	PHE	F	2	TYR	O
1	CYS	C	4	ILU	I	4	PRO	P	13	VAL	V

TOTAL NO. OF ACIDS = 146

* SCHROEDER,W.A., SHELTON, J.R., SHELTON,J.B., CORMICK, J., AND JONES,R.T., BIOCHEMISTRY, VOL.2, NO.5, PP.992-1008, SEPT.-OCT., 1963

HEMOGLOBIN BETA - GORILLA

```
     1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0
  1  V H L T P E E K S A V T A L W G K V D V D E V G G E A L G R
 31  L L V V O P W T E R F F E S F G D L S T P D A V M G D P K V
 61  K A H G K K V L G A F S D G L A H L D D L K G T F A T L S E
 91  L H C D K L H V D P E D F L L L G D V L V C V L A H H F G K
121  E F T P P V E A A O E K V V A G V A D A L A H K O H *
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```
      1   2   3   4   5   6   7   8   9   10  11  12  13  14  15
  1  VAL HIS LEU THR PRO GLU GLU LYS SER ALA VAL THR ALA LEU TRP
     GLY LYS VAL ASP VAL ASP GLU VAL GLY GLY GLU ALA LEU GLY ARG
 31  LEU LEU VAL VAL TYR PRO TRP THR GLU ARG PHE PHE GLU SER PHE
     GLY ASP LEU SER THR PRO ASP ALA VAL MET GLY ASP PRO LYS VAL
 61  LYS ALA HIS GLY LYS LYS VAL LEU GLY ALA PHE SER ASP GLY LEU
     ALA HIS LEU ASP ASP LEU LYS GLY THR PHE ALA THR LEU SER GLU
 91  LEU HIS CYS ASP LYS LEU HIS VAL ASP PRO GLU ASP PHE LEU LEU
     LEU GLY ASP VAL LEU VAL CYS VAL LEU ALA HIS HIS PHE GLY LYS
121  GLU PHE THR PRO PRO VAL GLU ALA ALA TYR GLU LYS VAL VAL ALA
     GLY VAL ALA ASP ALA LEU ALA HIS LYS TYR HIS ***
```

COMPOSITION

15	ALA	A	0	GLN	Q	19	LEU	L	5	SER	S
2	ARG	R	11	GLU	E	11	LYS	K	7	THR	T
0	ASN	N	13	GLY	G	1	MET	M	2	TRP	W
13	ASP	D	9	HIS	H	8	PHE	F	3	TYR	O
2	CYS	C	0	ILU	I	7	PRO	P	18	VAL	V

TOTAL NO. OF ACIDS = 146

= ZUCKERKANDL, E., SCIENTIFIC AMERICAN, VOL. 212, NO. 5,
PP. 110-118, MAY 1965

HEMOGLOBIN BETA - HORSE

```
     1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0
  1  V E L S G E E K A A L(V,A,L,W,D)K V D E E E V G(G.E.A)L G R
 31  L L V V O P W T E R F(F.E.S.F.G.D.L.S.G.P.D.A.V)M(G.D.P)K V
 61  K A H G K K V L H S F G E G V H H(L.D.D.L)K G T F A(A.L.S.E.
 91  L.H.C.D.K.L.H.V.D.P.E.D.F)R L L G D V L A L V V A R H F G K
121  D F T P E L E A S O E K V V A G V A D A L A H K O H *
```

```
      1   2   3   4   5   6   7   8   9   10  11  12  13  14  15
  1  VAL GLU LEU SER GLY GLU GLU LYS ALA ALA LEU(VAL,ALA,LEU,TRP,
     ASP)LYS VAL ASP GLU GLU GLU VAL GLY(GLY.GLU.ALA)LEU GLY ARG
 31  LEU LEU VAL VAL TYR PRO TRP THR GLU ARG PHE(PHE.GLU.SER.PHE.
     GLY.ASP.LEU.SER.GLY.PRO.ASP.ALA.VAL)MET(GLY.ASP.PRO)LYS VAL
 61  LYS ALA HIS GLY LYS LYS VAL LEU HIS SER PHE GLY GLU GLY VAL
     HIS HIS(LEU.ASP.ASP.LEU)LYS GLY THR PHE ALA(ALA.LEU.SER.GLU.
 91  LEU.HIS.CYS.ASP.LYS.LEU.HIS.VAL.ASP.PRO.GLU.ASP.PHE)ARG LEU
     LEU GLY ASP VAL LEU ALA LEU VAL VAL ALA ARG HIS PHE GLY LYS
121  ASP PHE THR PRO GLU LEU GLU ALA SER TYR GLU LYS VAL VAL ALA
     GLY VAL ALA ASP ALA LEU ALA HIS LYS TYR HIS ***
```

COMPOSITION

15	ALA	A	0	GLN	Q	19	LEU	L	6	SER	S
4	ARG	R	15	GLU	E	11	LYS	K	3	THR	T
0	ASN	N	14	GLY	G	1	MET	M	2	TRP	W
13	ASP	D	9	HIS	H	8	PHE	F	3	TYR	O
1	CYS	C	0	ILU	I	5	PRO	P	17	VAL	V

TOTAL NO. OF ACIDS = 146

* SMITH, D. B., CAN. J. BIOCHEM., VOL.42, NO.5, PP.755-762, 1964

HEMOGLOBIN ALPHA - HORSE

	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
1	V	L	S	A	A	D	K	T	N	V	K	A	A	W	S	K	V	G	G	H	A	G	E	O	G	A	E	A	L	E
31	R	M	F	L	G	F	P	T	T	K	T	O	F	P	H	F	D	L	S	H	G	S	A	Q	V	K	A	H	G	K
61	K	V	A	D	G	L	T	L	A	V	G	H	L	D	D	L	P	G	A	L	S	N	L	S	D	L	H	A	H	K
91	L	R	V	D	P	V	N	F	K	L	L	S	H	C	L	L	S	T	L	A	V	H	L	P	N	D	F	T	P	A
121	V	H	A	S	L	D	K	F	L	S	S	V	S	T	V	L	T	S	K	O	R	*								

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	VAL	LEU	SER	ALA	ALA	ASP	LYS	THR	ASN	VAL	LYS	ALA	ALA	TRP	SER
	LYS	VAL	GLY	GLY	HIS	ALA	GLY	GLU	TYR	GLY	ALA	GLU	ALA	LEU	GLU
31	ARG	MET	PHE	LEU	GLY	PHE	PRO	THR	THR	LYS	THR	TYR	PHE	PRO	HIS
	PHE	ASP	LEU	SER	HIS	GLY	SER	ALA	GLN	VAL	LYS	ALA	HIS	GLY	LYS
61	LYS	VAL	ALA	ASP	GLY	LEU	THR	LEU	ALA	VAL	GLY	HIS	LEU	ASP	ASP
	LEU	PRO	GLY	ALA	LEU	SER	ASN	LEU	SER	ASP	LEU	HIS	ALA	HIS	LYS
91	LEU	ARG	VAL	ASP	PRO	VAL	ASN	PHE	LYS	LEU	LEU	SER	HIS	CYS	LEU
	LEU	SER	THR	LEU	ALA	VAL	HIS	LEU	PRO	ASN	ASP	PHE	THR	PRO	ALA
121	VAL	HIS	ALA	SER	LEU	ASP	LYS	PHE	LEU	SER	SER	VAL	SER	THR	VAL
	LEU	THR	SER	LYS	TYR	ARG	***								

COMPOSITION

16	ALA	A	1	GLN	Q	21	LEU	L	13	SER	S
3	ARG	R	3	GLU	E	11	LYS	K	9	THR	T
4	ASN	N	10	GLY	G	1	MET	M	1	TRP	W
9	ASP	D	10	HIS	H	7	PHE	F	3	TYR	O
1	CYS	C	0	ILU	I	6	PRO	P	12	VAL	V

TOTAL NO. OF ACIDS = 141

* BRAUNITZER, G. AND MATSUDA, G., J. BIOCHEM. (TOKYO), VOL.53, NO.3, PP.262-263, 1963
THIS SEQUENCE WAS DETERMINED PARTIALLY BY HOMOLOGY WITH HUMAN ALPHA.

HEMOGLOBIN BETA - LEMUR FULVUS

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     1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0
  1  T L L S A E E D A H V T S L W G K V N V E K V G G E A L G R
 31  L L V V(O,P,W,T,E,R,F,F,E,S,F,G,D=L,S,S,P,S,A,V,M,G,D,P,K,V,
 61  K,A,H,G,K,K,V,L,S,A,F,S,E,G=L,H,H,L,D,D,L,K,G,T,F,A,A,L,S,E,
 91  L,H,C,V,A,L,H,V,D,P,E,D,F,K,L,L,G,D,S,L,S,D,V,L,A,D,H,F,G,K)
121  X X X X X X X X X X X X V V A G V(A,D,A,L,A,H,K,O,H)*

      1   2   3   4   5   6   7   8   9   10  11  12  13  14  15
  1  THR LEU LEU SER ALA GLU GLU ASP ALA HIS VAL THR SER LEU TRP
     GLY LYS VAL ASN VAL GLU LYS VAL GLY GLY GLU ALA LEU GLY ARG
 31  LEU LEU VAL VAL(TYR,PRO,TRP,THR,GLU,ARG,PHE,PHE,GLU,SER,PHE,
     GLY,ASP=LEU,SER,SER,PRO,SER,ALA,VAL,MET,GLY,ASP,PRO,LYS,VAL,
 61  LYS,ALA,HIS,GLY,LYS,LYS,VAL,LEU,SER,ALA,PHE,SER,GLU,GLY=LEU,
     HIS,HIS,LEU,ASP,ASP,LEU,LYS,GLY,THR,PHE,ALA,ALA,LEU,SER,GLU,
 91  LEU,HIS,CYS,VAL,ALA,LEU,HIS,VAL,ASP,PRO,GLU,ASP,PHE,LYS,LEU,
     LEU,GLY,ASP,SER,LEU,SER,ASP,VAL,LEU,ALA,ASP,HIS,PHE,GLY,LYS)
121  XXX XXX XXX XXX XXX XXX XXX XXX XXX XXX XXX XXX VAL VAL ALA
     GLY VAL(ALA,ASP,ALA,LEU,ALA,HIS,LYS,TYR,HIS)***
```

COMPOSITION

14 ALA A	0 GLN Q	19 LEU L	11 SER S
2 ARG R	9 GLU E	10 LYS K	4 THR T
1 ASN N	12 GLY G	1 MET M	2 TRP W
11 ASP D	9 HIS H	7 PHE F	2 TYR O
1 CYS C	0 ILU I	4 PRO P	15 VAL V
12 XXX X			

TOTAL NO. OF ACIDS = 146

* BUETTNER-JANUSCH, J. AND HILL, R. L., SCIENCE, VOL. 147, PP. 836-842, FEB. 19, 1965

ABNORMAL HUMAN HEMOGLOBIN

Normal adult human hemoglobin (hemoglobin A) contains two pairs of polypeptide chains, termed alpha and beta. Each pair is identical. Some modified beta chains have been given other Greek letters, for example, normal fetal hemoglobin is composed of two alpha chains and two "gamma" chains. Usually, however, altered hemoglobins are different in only a single amino acid. A number of hemoglobins bearing these altered amino acid sequences in their polypeptide chains have been described. For example, one of the early reports by Ingram (1957) shows the chemical difference between normal human hemoglobin and sickle cell hemoglobin. By comparison of amino acid sequences of tryptic peptide digests of the two hemoglobins, it was established that hemoglobin A (normal) contains a GLU residue in the locus where hemoglobin S (sickle cell) contains VAL. This replacement of two charged GLU residues for two uncharged VAL residues in the hemoglobin tetramer is sufficient to account for the "sickling" phenomenon in the abnormal hemoglobin. Listed below are a number of known amino acid replacements in abnormal human hemoglobins.

HEMOGLOBIN NAME	CHANGES CHAIN	POS.	FROM TO	REFERENCE
A NORMAL				
F NORMAL FETAL	BETA (CALLED GAMMA)			1
I	ALPHA	16	LYS-ASP	2
NORFOLK	ALPHA	57	GLY-ASP	3
M BOSTON	ALPHA	58	HIS-TYR	4
M SASKATOON	BETA	63	HIS-TYR	4
M MILWAUKEE	BETA	67	VAL-GLU	4
D PUNJAB	BETA	121	GLU-GLN	5
G SAN JOSE	BETA	7	GLU-GLY	6
ZURICH	BETA	63	HIS-ARG	7
C	BETA	6	GLU-LYS	8
O ARABIA	BETA	121	GLU-LYS	9
O INDONESIA	ALPHA	116	GLU-LYS	9
X	ALPHA	68	ASN-LYS	
	and BETA	6	GLU-LYS	10
S	BETA	6	GLU-VAL	11
D IBADAN	BETA	87	THR-LYS	12
F TEXAS	GAMMA	5 or 6	GLU-LYS	13
KENWOOD	BETA	143	HIS-ASP	14
G	BETA	7	GLU-GLY	15

1. Rhinesmith, H. W., Schroeder, W. A., and Pauling, L., J. Am. Chem. Soc., Vol. 79, p. 4682, 1957

Rhinesmith, H. W., Schroeder, W. A., and Martin, N., J. Am. Chem. Soc., Vol. 80, p. 3358, 1958

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3. Baglioni, C., J. Biol. Chem., Vol. 237, pp. 69-74, 1962
4. Gerald, P. S. and Efron, M. L., Proc. Natl. Acad. Sci. U.S., Vol. 47, pp. 1758-1767, 1958
5. Baglioni, C., Biochim. Biophys. Acta, Vol. 59, pp. 437-440, 1962
6. Hill, R. L. and Schwartz, H. C., Nature, Vol. 184, pp. 641-642, 1959
7. Muller, C. J. and Kingma, S., Biochim. Biophys. Acta, Vol. 50, p. 595, 1961
8. Hunt, J. A. and Ingram, V. M., Nature, Vol. 184, p. 640, 1959

Ingram, V. M., Nature, Vol. 180, pp. 326-328, 1957

9. Baglioni, C. and Lehmann, H., Nature, Vol. 196, pp. 229-232, 1962
10. Baglioni, C. and Ingram, V. M., Nature, Vol. 189, pp. 465-467, 1961
11. Ingram, V. M., Nature, Vol. 180, pp. 326-328, 1957
12. Watson-Williams, E. J., Nature, Vol. 205, pp. 1273-1276, 1965
13. Schneider, R. G., Science, Vol. 148, pp. 240-242, 1965
14. Beale, D. and Lehmann, H., Nature, Vol. 207, pp. 249-261, 1965
15. Hill, R. L., Swenson, R. T., and Schwartz, H. C., J. Biol. Chem., Vol. 235, pp. 3182-3187, 1960

MYOGLOBIN - WHALE

	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
1	V	L	S	E	G	E	W	Q	L	V	L	H	V	W	A	K	V	E	A	D	V	A	G	H	G	Q	D	I	L	I
31	R	L	F	K	S	H	P	E	T	L	E	K	F	D	R	F	K	H	L	K	T	E	A	E	M	K	A	S	E	D
61	L	K	K	H	G	V	T	V	L	T	A	L	G	A	I	L	K	K	K	G	H	H	E	A	E	L	K	P	L	A
91	Q	S	H	A	T	K	H	K	I	P	I	K	O	L	E	F	I	S	E	A	I	I	H	V	L	H	S	R	H	P
121	G	N	F	G	A	D	A	Q	G	A	M	N	K	A	L	E	L	F	R	K	D	I	A	A	K	O	K	E	L	G
151	O	Q	G	*																										

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	VAL	LEU	SER	GLU	GLY	GLU	TRP	GLN	LEU	VAL	LEU	HIS	VAL	TRP	ALA
	LYS	VAL	GLU	ALA	ASP	VAL	ALA	GLY	HIS	GLY	GLN	ASP	ILU	LEU	ILU
31	ARG	LEU	PHE	LYS	SER	HIS	PRO	GLU	THR	LEU	GLU	LYS	PHE	ASP	ARG
	PHE	LYS	HIS	LEU	LYS	THR	GLU	ALA	GLU	MET	LYS	ALA	SER	GLU	ASP
61	LEU	LYS	LYS	HIS	GLY	VAL	THR	VAL	LEU	THR	ALA	LEU	GLY	ALA	ILU
	LEU	LYS	LYS	LYS	GLY	HIS	HIS	GLU	ALA	GLU	LEU	LYS	PRO	LEU	ALA
91	GLN	SER	HIS	ALA	THR	LYS	HIS	LYS	ILU	PRO	ILU	LYS	TYR	LEU	GLU
	PHE	ILU	SER	GLU	ALA	ILU	ILU	HIS	VAL	LEU	HIS	SER	ARG	HIS	PRO
121	GLY	ASN	PHE	GLY	ALA	ASP	ALA	GLN	GLY	ALA	MET	ASN	LYS	ALA	LEU
	GLU	LEU	PHE	ARG	LYS	ASP	ILU	ALA	ALA	LYS	TYR	LYS	GLU	LEU	GLY
151	TYR	GLN	GLY	***											

COMPOSITION

17	ALA	A	5	GLN	Q	18	LEU	L	6	SER	S
4	ARG	R	14	GLU	E	19	LYS	K	5	THR	T
2	ASN	N	11	GLY	G	2	MET	M	2	TRP	W
6	ASP	D	12	HIS	H	6	PHE	F	3	TYR	O
0	CYS	C	9	ILU	I	4	PRO	P	8	VAL	V

TOTAL NO. OF ACIDS = 153

* EDMUNDSON, A. B., NATURE, VOL.205, NO.4974, PP.883-887, FEBRUARY 27, 1965

DIHEME PEPTIDE - CHROMATIUM

THE PEPTIDE CONTAINS TWO HEME GROUPS. THE FIRST IS COVALENTLY BONDED TO CYSTEINES 5 AND 8. THERE IS ONLY ONE OTHER CYSTEINE AVAILABLE FOR THE OBSERVED COVALENT BONDING OF THE SECOND HEME.

```
  1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7
/ F A G K C S Q C H T L V A D E G S A K C H T F D E G S /

     1   2   3   4   5   6   7   8   9  10  11  12  13  14  15
/// PHE ALA GLY LYS CYS SER GLN CYS HIS THR LEU VAL ALA ASP GLU
    GLY SER ALA LYS CYS HIS THR PHE ASP GLU GLY SER ///
```

COMPOSITION

3	ALA	A	1	GLN	Q	1	LEU	L	3	SER	S
0	ARG	R	2	GLU	E	2	LYS	K	2	THR	T
0	ASN	N	3	GLY	G	0	MET	M	0	TRP	W
2	ASP	D	2	HIS	H	2	PHE	F	0	TYR	O
3	CYS	C	0	ILU	I	0	PRO	P	1	VAL	V

TOTAL NO. OF ACIDS IN FRAGMENT = 27

* DUS,K., BARTSCH, R.G., AND KAMEN,M.D., J. BIOL. CHEM., VOL.237, NO.10, PP.3083-3093, OCT., 1962

FERREDOXIN - CLOSTRIDIUM PASTEURIANUM

THE PROTEIN CONTAINS 7 SULPHIDE AND 7 IRON ATOMS PER MOLECULE.
IT DOES NOT CONTAIN HEME.

```
   1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0
 1 A O K I A D S C V S C/G A C/A S E C P V N A I S Q G D S I F/
31 V I D A D T C I D C G N C A N V C P V G A P V Q E *
```

```
    1   2   3   4   5   6   7   8   9   10  11  12  13  14  15
 1  ALA TYR LYS ILU ALA ASP SER CYS VAL SER CYS/GLY ALA CYS/ALA
    SER GLU CYS PRO VAL ASN ALA ILU SER GLN GLY ASP SER ILU PHE/
31  VAL ILU ASP ALA ASP THR CYS ILU ASP CYS GLY ASN CYS ALA ASN
    VAL CYS PRO VAL GLY ALA PRO VAL GLN GLU ***
```

COMPOSITION

8	ALA	A	2	GLN	Q	0	LEU	L	5	SER	S
0	ARG	R	2	GLU	E	1	LYS	K	1	THR	T
3	ASN	N	4	GLY	G	0	MET	M	0	TRP	W
5	ASP	D	0	HIS	H	1	PHE	F	1	TYR	O
8	CYS	C	5	ILU	I	3	PRO	P	6	VAL	V

TOTAL NO. OF ACIDS = 55

* TANAKA,M.,NAKASHIMA,T.,BENSON,A.,MOWER,H.F.,AND YASUNOBU,K.T.,
BIOCHEM. BIOPHYS. RES. COMMUN., VOL. 16, NO.5,
PP.422-427, 1964

AZURIN - PSEUDOMONAS FLUORESCENS

THE BLUE PROTEIN CONTAINS ONE COPPER ATOM PER MOLECULE.

```
     1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0
   1 A E C S V D I Q G N D Q M Q F N T N A I T V D K S C K Q F T
  31 V N L S H P G N L P K N V M G H N W V L S T A A D M Q G V V
  61 T D G M A S G L D K D O L K P D D S R V I A H T K L I G S G
  91 E K D S V T F D V S K L K E G E Q O M F F C T F P G H S A L
 121 M K G T L T L K *
```

```
      1   2   3   4   5   6   7   8   9  10  11  12  13  14  15
   1 ALA GLU CYS SER VAL ASP ILU GLN GLY ASN ASP GLN MET GLN PHE
     ASN THR ASN ALA ILU THR VAL ASP LYS SER CYS LYS GLN PHE THR
  31 VAL ASN LEU SER HIS PRO GLY ASN LEU PRO LYS ASN VAL MET GLY
     HIS ASN TRP VAL LEU SER THR ALA ALA ASP MET GLN GLY VAL VAL
  61 THR ASP GLY MET ALA SER GLY LEU ASP LYS ASP TYR LEU LYS PRO
     ASP ASP SER ARG VAL ILU ALA HIS THR LYS LEU ILU GLY SER GLY
  91 GLU LYS ASP SER VAL THR PHE ASP VAL SER LYS LEU LYS GLU GLY
     GLU GLN TYR MET PHE PHE CYS THR PHE PRO GLY HIS SER ALA LEU
 121 MET LYS GLY THR LEU THR LEU LYS ***
```

COMPOSITION

7	ALA	A	6	GLN	Q	10	LEU	L	10	SER	S
1	ARG	R	4	GLU	E	11	LYS	K	10	THR	T
7	ASN	N	11	GLY	G	6	MET	M	1	TRP	W
11	ASP	D	4	HIS	H	6	PHE	F	2	TYR	O
3	CYS	C	4	ILU	I	4	PRO	P	10	VAL	V

TOTAL NO. OF ACIDS = 128

* AMBLER,R.P.,AND BROWN,L.H., J. MOL. BIOL., VOL. 9, NO.3,
PP. 825-828, SEPT., 1964

RIBONUCLEASE - BOVINE

DISULPHIDE BONDS ARE FORMED BETWEEN CYSTEINES AT POSITIONS 26 AND 84, 40 AND 95, 58 AND 110, AND 65 AND 72.

	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
1	K	E	T	A	A	A	K	F	E	R	Q	H	M	D	S	S	T	S	A	A	S	S	S	N	O	C	N	Q	M	M
31	K	S	R	N	L	T	K	D	R	C	K	P	V	N	T	F	V	H	E	S	L	A	D	V	Q	A	V	C	S	Q
61	K	N	V	A	C	K	N	G	Q	T	N	C	O	Q	S	O	S	T	M	S	I	T	D	C	R	E	T	G	S	S
91	K	O	P	N	C	A	O	K	T	T	Q	A	N	K	H	I	I	V	A	C	E	G	N	P	O	V	P	V	H	F
121	D	A	S	V	*																									

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	LYS	GLU	THR	ALA	ALA	ALA	LYS	PHE	GLU	ARG	GLN	HIS	MET	ASP	SER
	SER	THR	SER	ALA	ALA	SER	SER	SER	ASN	TYR	CYS	ASN	GLN	MET	MET
31	LYS	SER	ARG	ASN	LEU	THR	LYS	ASP	ARG	CYS	LYS	PRO	VAL	ASN	THR
	PHE	VAL	HIS	GLU	SER	LEU	ALA	ASP	VAL	GLN	ALA	VAL	CYS	SER	GLN
61	LYS	ASN	VAL	ALA	CYS	LYS	ASN	GLY	GLN	THR	ASN	CYS	TYR	GLN	SER
	TYR	SER	THR	MET	SER	ILU	THR	ASP	CYS	ARG	GLU	THR	GLY	SER	SER
91	LYS	TYR	PRO	ASN	CYS	ALA	TYR	LYS	THR	THR	GLN	ALA	ASN	LYS	HIS
	ILU	ILU	VAL	ALA	CYS	GLU	GLY	ASN	PRO	TYR	VAL	PRO	VAL	HIS	PHE
121	ASP	ALA	SER	VAL	***										

COMPOSITION

12	ALA	A	7	GLN	Q	2	LEU	L	15	SER	S
4	ARG	R	5	GLU	E	10	LYS	K	10	THR	T
10	ASN	N	3	GLY	G	4	MET	M	0	TRP	W
5	ASP	D	4	HIS	H	3	PHE	F	6	TYR	O
8	CYS	C	3	ILU	I	4	PRO	P	9	VAL	V

TOTAL NO. OF ACIDS = 124

* SMYTH, D.G., STEIN,W.H. AND MOORE, S., J. BIOL. CHEM., VOL.238, NO.1, PP.227-234, JAN., 1963

TRYPSIN INHIBITOR - BOVINE

DISULPHIDE BONDS ARE FORMED BETWEEN CYSTEINES AT POSITIONS 5-55, 14-38, AND 30-51.

	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
1	R	P	D	F	C	L	E	P	P	O	T	G	P	C	K	A	R	I	I	R	O	F	O	N	A	K	A	G	L	C
31	Q	T	F	V	O	G	G	C	R	A	K	R	N	N	F	K	S	A	E	D	C	M	R	T	C	G	G	A	*	

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	ARG	PRO	ASP	PHE	CYS	LEU	GLU	PRO	PRO	TYR	THR	GLY	PRO	CYS	LYS
	ALA	ARG	ILU	ILU	ARG	TYR	PHE	TYR	ASN	ALA	LYS	ALA	GLY	LEU	CYS
31	GLN	THR	PHE	VAL	TYR	GLY	GLY	CYS	ARG	ALA	LYS	ARG	ASN	ASN	PHE
	LYS	SER	ALA	GLU	ASP	CYS	MET	ARG	THR	CYS	GLY	GLY	ALA	***	

COMPOSITION

6	ALA	A	1	GLN	Q	2	LEU	L	1	SER	S
6	ARG	R	2	GLU	E	4	LYS	K	3	THR	T
3	ASN	N	6	GLY	G	1	MET	M	0	TRP	W
2	ASP	D	0	HIS	H	4	PHE	F	4	TYR	O
6	CYS	C	2	ILU	I	4	PRO	P	1	VAL	V

TOTAL NO. OF ACIDS = 58

* KASSELL, B., RADICEVIC, M., ANSFIELD,M. J., AND LASKOWSKI, M., BIOCHEM. BIOPHYS. RES. COMMUN., VOL. 18, NO,2, PP.255-258, 1965

DLOUHA, V., POSPISILOVA, D., MELOUN, B. AND SORM, F., COLLECTION CZECH. CHEM. COMMUN., VOL. 30, PP.1311-1325, 1965

THE SEQUENCE REPORTED HERE DIFFERS FROM THE ABOVE IN HAVING THE ILU (I) DELETED AT POSITION 19.

CHAUVET, J., NOUVEL, G., AND ACHER, R., BIOCHIM. BIOPHYS.
ACTA , VOL. 92, PP. 200-201, 1964

THE SEQUENCE REPORTED HERE DIFFERS FROM THE ABOVE IN THE FOLLOWING RESPECTS.
THE ARG (R) FROM POSITION 42 HAS BEEN REMOVED AND INSERTED BETWEEN POSITIONS 20 AND 21. THE GLN (Q) AT POSITION 31 HAS BEEN DELETED AND A GLU (E) ADDED BETWEEN POSITIONS 32 AND 33.

KASSELL, B., AND LASKOWSKI, M., BIOCHEM. BIOPHYS. RES.
COMMUN. VOL 20, NO.4, PP.463-468, 1965

TOBACCO MOSAIC VIRUS

ACETYL - AT AMINO END

	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
1	S	O	S	I	T	T	P	S	Q	F	V	F	L	S	S	A	W	A	D	P	I	E	L	I	N	L	C	T	N	A
31	L	G	N	Q	F	Q	T	Q	Q	A	R	T	V	Q	V	R	Q	F	S	Q	V	W	K	P	S	P	Q	V	T	V
61	R	F	P	D	S	D	F	K	V	O	R	O	N	A	V	L	D	P	L	V	T	A	L	L	G	A	F	D	T	R
91	N	R	I	I	Q	V	Q	D	Q	A	N	P	T	T	A	Q	T	L	D	A	T	R	R	V	D	D	A	T	V	A
121	I	R	S	A	D	I	N	L	I	V	E	L	I	R	G	T	G	S	Q	N	R	S	S	F	E	S	S	S	G	L
151	V	W	T	S	G	P	A	T	•																					

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	SER	TYR	SER	ILU	THR	THR	PRO	SER	GLN	PHE	VAL	PHE	LEU	SER	SER
	ALA	TRP	ALA	ASP	PRO	ILU	GLU	LEU	ILU	ASN	LEU	CYS	THR	ASN	ALA
31	LEU	GLY	ASN	GLN	PHE	GLN	THR	GLN	GLN	ALA	ARG	THR	VAL	GLN	VAL
	ARG	GLN	PHE	SER	GLN	VAL	TRP	LYS	PRO	SER	PRO	GLN	VAL	THR	VAL
61	ARG	PHE	PRO	ASP	SER	ASP	PHE	LYS	VAL	TYR	ARG	TYR	ASN	ALA	VAL
	LEU	ASP	PRO	LEU	VAL	THR	ALA	LEU	LEU	GLY	ALA	PHE	ASP	THR	ARG
91	ASN	ARG	ILU	ILU	GLN	VAL	GLN	ASP	GLN	ALA	ASN	PRO	THR	THR	ALA
	GLN	THR	LEU	ASP	ALA	THR	ARG	ARG	VAL	ASP	ASP	ALA	THR	VAL	ALA
121	ILU	ARG	SER	ALA	ASP	ILU	ASN	LEU	ILU	VAL	GLU	LEU	ILU	ARG	GLY
	THR	GLY	SER	TYR	ASN	ARG	SER	SER	PHE	GLU	SER	SER	SER	GLY	LEU
151	VAL	TRP	THR	SER	GLY	PRO	ALA	THR	***						

COMPOSITION

14	ALA	A	13	GLN	Q	12	LEU	L	16	SER	S
11	ARG	R	3	GLU	E	2	LYS	K	16	THR	T
8	ASN	N	6	GLY	G	0	MET	M	3	TRP	W
10	ASP	D	0	HIS	H	8	PHE	F	4	TYR	O
1	CYS	C	9	ILU	I	8	PRO	P	14	VAL	V

TOTAL NO. OF ACIDS = 158

• ANDERER, F.A., Z. NATURFORSCH., VOL. 17, PP.526-543, 1962

STRUCTURE REVISIONS AND CONFIRMATIONS.

ANDERER, F.A., UHLIG, H., WEBER, E., AND SCHRAMM, G., NATURE, VOL. 186, NO.4729, PP.922-925, JUNE 18, 1960

FUNATSU, G., TSUGITA, A., AND FRAENKEL-CONRAT, H., ARCH. BIOCHEM. BIOPHYS., VOL. 105, NO.1, PP.25-41, APR. 1964

TOBACCO MOSAIC VIRUS STRAIN DAHLMENSE

ACETYL- AT AMINO END

```
     1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0
  1  S O S I T S P S Q F V F L S S V W A D P I E L L N V C T S S
 31  L G N Q F Q T Q Q A R T T Q V Q Q F S E V W K P F P Q S T V
 61  R F P G D V O K V O R O N A V L D P L I T A L L G T F D T R
 91  N R I I E V E N Q Q S P T T A E T L D A T R R V D D A T V A
121  I R S A N I N L V N E L V R G T G L O N Q N T F E S M S G L
151  V W T S A P A S •

      1   2   3   4   5   6   7   8   9   10  11  12  13  14  15
  1  SER TYR SER ILU THR SER PRO SER GLN PHE VAL PHE LEU SER SER
     VAL TRP ALA ASP PRO ILU GLU LEU LEU ASN VAL CYS THR SER SER
 31  LEU GLY ASN GLN PHE GLN THR GLN GLN ALA ARG THR THR GLN VAL
     GLN GLN PHE SER GLU VAL TRP LYS PRO PHE PRO GLN SER THR VAL
 61  ARG PHE PRO GLY ASP VAL TYR LYS VAL TYR ARG TYR ASN ALA VAL
     LEU ASP PRO LEU ILU THR ALA LEU LEU GLY THR PHE ASP THR ARG
 91  ASN ARG ILU ILU GLU VAL GLU ASN GLN GLN SER PRO THR THR ALA
     GLU THR LEU ASP ALA THR ARG ARG VAL ASP ASP ALA THR VAL ALA
121  ILU ARG SER ALA ASN ILU ASN LEU VAL ASN GLU LEU VAL ARG GLY
     THR GLY LEU TYR ASN GLN ASN THR PHE GLU SER MET SER GLY LEU
151  VAL TRP THR SER ALA PRO ALA SER ***
```

COMPOSITION

11	ALA	A	12	GLN	Q	13	LEU	L	16	SER	S
9	ARG	R	7	GLU	E	2	LYS	K	17	THR	T
10	ASN	N	6	GLY	G	1	MET	M	3	TRP	W
7	ASP	D	0	HIS	H	8	PHE	F	5	TYR	O
1	CYS	C	7	ILU	I	8	PRO	P	15	VAL	V

TOTAL NO. OF ACIDS = 158

• WITTMANN-LIEBOLD,B. AND WITTMANN, H. G., Z. VERERBUNGS.,
VOL. 94, PP. 427-435, 1963

CHYMOTRYPSINOGEN-A - BOVINE

```
    1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0
  1 C G V P A I Q P V L S G L S R I V G D E E A V P G S W P W Q
 31 V S L Q D K T G F H F C G G S L I N E N W V V T A A H C G V
 61 T T S D V V V A G E F D Q G S S S E K I Q K L K I A K V F K
 91 N S K O N S L T I N N N I T L L K L S T A A S F S Q T V S A
121 V C L P S A S D D F A A G T T C V T T G W G L T R O T N A N
151 T P D R L Q Q A S L P L L S N T N C K K O W G T K I K D A M
181 I C A G A S G V S S C M G D S G G P L V C K K N G A W T L V
211 G I V S W G S S T C S T S T P G V O A R V T A L V N W V Q Q
241 T L A A N •
```

```
     1   2   3   4   5   6   7   8   9   10  11  12  13  14  15
  1 CYS GLY VAL PRO ALA ILU GLN PRO VAL LEU SER GLY LEU SER ARG
    ILU VAL GLY ASP GLU GLU ALA VAL PRO GLY SER TRP PRO TRP GLN
 31 VAL SER LEU GLN ASP LYS THR GLY PHE HIS PHE CYS GLY GLY SER
    LEU ILU ASN GLU ASN TRP VAL VAL THR ALA ALA HIS CYS GLY VAL
 61 THR THR SER ASP VAL VAL VAL ALA GLY GLU PHE ASP GLN GLY SER
    SER SER GLU LYS ILU GLN LYS LEU LYS ILU ALA LYS VAL PHE LYS
 91 ASN SER LYS TYR ASN SER LEU THR ILU ASN ASN ASN ILU THR LEU
    LEU LYS LEU SER THR ALA ALA SER PHE SER GLN THR VAL SER ALA
121 VAL CYS LEU PRO SER ALA SER ASP ASP PHE ALA ALA GLY THR THR
    CYS VAL THR THR GLY TRP GLY LEU THR ARG TYR THR ASN ALA ASN
151 THR PRO ASP ARG LEU GLN GLN ALA SER LEU PRO LEU LEU SER ASN
    THR ASN CYS LYS LYS TYR TRP GLY THR LYS ILU LYS ASP ALA MET
181 ILU CYS ALA GLY ALA SER GLY VAL SER SER CYS MET GLY ASP SER
    GLY GLY PRO LEU VAL CYS LYS LYS ASN GLY ALA TRP THR LEU VAL
211 GLY ILU VAL SER TRP GLY SER SER THR CYS SER THR SER THR PRO
    GLY VAL TYR ALA ARG VAL THR ALA LEU VAL ASN TRP VAL GLN GLN
241 THR LEU ALA ALA ASN ***
```

COMPOSITION

22	ALA	A	10	GLN	Q	19	LEU	L	28	SER	S
4	ARG	R	5	GLU	E	14	LYS	K	23	THR	T
14	ASN	N	23	GLY	G	2	MET	M	8	TRP	W
9	ASP	D	2	HIS	H	6	PHE	F	4	TYR	O
10	CYS	C	10	ILU	I	9	PRO	P	23	VAL	V

TOTAL NO. OF ACIDS = 245

● HARTLEY, B.S., BROWN, J.R., KAUFFMAN, D.L., AND SMILLIE,L.B., NATURE, VOL.207, NO.5002, PP.1157-1159, SEPT.11, 1965

THIS SEQUENCE HAS BEEN CORRECTED BY DELETING SER (S) WHICH WAS AT POSITION 215.

BROWN, J.R., AND HARTLEY, B. S., BIOCHEM J., VOL. 89, 59P, 1963

THE ACTIVE SITE SERINE IS AT POSITION 195

KEIL, B., PRUSIK, Z., AND SORM, F., BIOCHIM. BIOPHYS. ACTA, VOL. 78, P. 559-561, 1963

DISULPHIDE BRIDGES LINK POSITIONS 1-122, 42-58, 136-201, 168-182 AND 191-220.

KOSTKA, V., MELOUN, B., AND SORM,F., COLLECTION CZECH. CHEM. COMMUN., VOL. 28, PP.2779-2805, 1963 .

HARTLEY,B.S., NATURE, VOL. 201, NO. 4962, PP.1284-1287, MARCH 28,1964

TRYPSINOGEN

1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0

1 V D D D D K I V G G O T C G A N T V P O Q V S L N S G O H F

31 C G G S L I N S Q W V V S A A H C O K S G I Q V R L G E D N

61 I N V V E G D E Q F I S A S K S I V H P S O N(P,L,T,N)N N D

91 I M L I K L K S A A S L N S R V A S I S L P T S C A S A G T

121 Q C L I S G W G N T K S S G T S O P D V L K C L K A P I L S

151 D S S C K S A O P G Q I T S N M F C A G O L E G G K N S C Q

181 G D S G G P V V C S G K L Q G I V S W G S G C A Q K N K P G

211 V O T K V C N O V S W I K Q T I A S N *

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

1 VAL ASP ASP ASP ASP LYS ILU VAL GLY GLY TYR THR CYS GLY ALA

ASN THR VAL PRO TYR GLN VAL SER LEU ASN SER GLY TYR HIS PHE

31 CYS GLY GLY SER LEU ILU ASN SER GLN TRP VAL VAL SER ALA ALA

HIS CYS TYR LYS SER GLY ILU GLN VAL ARG LEU GLY GLU ASP ASN

61 ILU ASN VAL VAL GLU GLY ASP GLU GLN PHE ILU SER ALA SER LYS

SER ILU VAL HIS PRO SER TYR ASN(PRO,LEU,THR,ASN)ASN ASN ASP

91 ILU MET LEU ILU LYS LEU LYS SER ALA ALA SER LEU ASN SER ARG

VAL ALA SER ILU SER LEU PRO THR SER CYS ALA SER ALA GLY THR

121 GLN CYS LEU ILU SER GLY TRP GLY ASN THR LYS SER SER GLY THR

SER TYR PRO ASP VAL LEU LYS CYS LEU LYS ALA PRO ILU LEU SER

151 ASP SER SER CYS LYS SER ALA TYR PRO GLY GLN ILU THR SER ASN

MET PHE CYS ALA GLY TYR LEU GLU GLY GLY LYS ASN SER CYS GLN

181 GLY ASP SER GLY GLY PRO VAL VAL CYS SER GLY LYS LEU GLN GLY

ILU VAL SER TRP GLY SER GLY CYS ALA GLN LYS ASN LYS PRO GLY

211 VAL TYR THR LYS VAL CYS ASN TYR VAL SER TRP ILU LYS GLN THR

ILU ALA SER ASN ***

COMPOSITION

14	ALA	A	10	GLN	Q	14	LEU	L	33	SER	S
2	ARG	R	4	GLU	E	15	LYS	K	10	THR	T
16	ASN	N	25	GLY	G	2	MET	M	4	TRP	W
10	ASP	D	3	HIS	H	3	PHE	F	10	TYR	O
12	CYS	C	15	ILU	I	9	PRO	P	18	VAL	V

TOTAL NO. OF ACIDS = 229

• WALSH, K., AND NEURATH, H., PROC. NATL. ACAD. SCI. U.S., VOL. 52, NO.4, PP.884-889, 1964

KAUFFMAN, D. L., J. MOL. BIOL., VOL.12, PP.929-932, 1965

DISULPHIDE BRIDGES WERE FOUND BETWEEN LINKS 13-143, 31-47
115-216, 122-189, 154-168, AND 179-203.
THE ACTIVE SERINE IS AT LINK 183.

PAPAIN

1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0

1/I P E O V D W R Q K G A V T P V K N Q G S C G S C W/A F/I I/

31 R N T P O O E G V Q R O C R S R E K G P O A A K T D G V R Q

61 V Q P O N Q G A L L O S I A N Q P S V V L Q A A G K D F Q L

91 O R G G I F V G P C G N K V D H A V A A V G O N P G O I L I

121 K N S W G T G W G E N G O I R I K T G N L N Q O S E Q E L L

151 D C D R R S O G C O P G D G W/S A L/V A Q O G I H O R G T G

181 N S O G V C G L O T S S F O P V K N •

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

1/ILU PRO GLU TYR VAL ASP TRP ARG GLN LYS GLY ALA VAL THR PRO

VAL LYS ASN GLN GLY SER CYS GLY SER CYS TRP/ALA PHE/ILU ILU/

31 ARG ASN THR PRO TYR TYR GLU GLY VAL GLN ARG TYR CYS ARG SER

ARG GLU LYS GLY PRO TYR ALA ALA LYS THR ASP GLY VAL ARG GLN

61 VAL GLN PRO TYR ASN GLN GLY ALA LEU LEU TYR SER ILU ALA ASN

GLN PRO SER VAL VAL LEU GLN ALA ALA GLY LYS ASP PHE GLN LEU

91 TYR ARG GLY GLY ILU PHE VAL GLY PRO CYS GLY ASN LYS VAL ASP

HIS ALA VAL ALA ALA VAL GLY TYR ASN PRO GLY TYR ILU LEU ILU

121 LYS ASN SER TRP GLY THR GLY TRP GLY GLU ASN GLY TYR ILU ARG

ILU LYS THR GLY ASN LEU ASN GLN TYR SER GLU GLN GLU LEU LEU

151 ASP CYS ASP ARG ARG SER TYR GLY CYS TYR PRO GLY ASP GLY TRP/

SER ALA LEU/VAL ALA GLN TYR GLY ILU HIS TYR ARG GLY THR GLY

181 ASN SER TYR GLY VAL CYS GLY LEU TYR THR SER SER PHE TYR PRO

VAL LYS ASN ***

COMPOSITION

13	ALA	A	12	GLN	Q	10	LEU	L	12	SER	S
11	ARG	R	6	GLU	E	9	LYS	K	7	THR	T
12	ASN	N	27	GLY	G	0	MET	M	5	TRP	W
7	ASP	D	2	HIS	H	4	PHE	F	19	TYR	O
7	CYS	C	10	ILU	I	10	PRO	P	15	VAL	V

TOTAL NO. OF ACIDS = 198

• LIGHT, A., FRATER, R., KIMMEL, J., AND SMITH, E.L., PROC. NATL. ACAD. SCI. U.S., VOL.52, NO.5, PP.1276-1283, NOV. 1964

DISULPHIDE BRIDGES ARE FORMED BETWEEN CYSTEINES AT POSITIONS 43 AND 152, 100 AND 186, AND 22 AND 159.

THE ACTIVE SULFHYDRYL GROUP IS AT POSITION 25.

LYSOZYME - CHICKEN

LYSOZYME HAS A BETA (1-4) GLUCOSAMINIDASE ACTIVITY WITH THE ABILITY TO HYDROLYSE A MUCOPOLYSACCHARIDE COMPONENT OF SOME BACTERIAL CELL WALLS RELEASING N-ACETYL AMINO SUGARS DERIVED FROM GLUCOSAMINE AND MURAMIC ACID.

	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0
1	K	V	F	G	R	C	E	L	A	A	A	M	K	R	H	G	L	D	N	O	R	G	O	S	L	G	N	W	V	C
31	A	A	K	F	E	S	N	F	N	T	Q	A	T	N	R	N	T	D	G	S	T	D	O	G	I	L	Q	I	N	S
61	R	W	W	C	N	D	G	R	T	P	G	S	R	N	L	C	N	I	P	C	S	A	L	L	S	S	D	I	T	A
91	S	V	N	C	A	K	K	I	V	S	D	G	D	G	M	N	A	W	V	A	W	R	N	R	C	K	G	T	D	V
121	Q	A	W	I	R	G	C	R	L	*																				

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	LYS	VAL	PHE	GLY	ARG	CYS	GLU	LEU	ALA	ALA	ALA	MET	LYS	ARG	HIS
	GLY	LEU	ASP	ASN	TYR	ARG	GLY	TYR	SER	LEU	GLY	ASN	TRP	VAL	CYS
31	ALA	ALA	LYS	PHE	GLU	SER	ASN	PHE	ASN	THR	GLN	ALA	THR	ASN	ARG
	ASN	THR	ASP	GLY	SER	THR	ASP	TYR	GLY	ILU	LEU	GLN	ILU	ASN	SER
61	ARG	TRP	TRP	CYS	ASN	ASP	GLY	ARG	THR	PRO	GLY	SER	ARG	ASN	LEU
	CYS	ASN	ILU	PRO	CYS	SER	ALA	LEU	LEU	SER	SER	ASP	ILU	THR	ALA
91	SER	VAL	ASN	CYS	ALA	LYS	LYS	ILU	VAL	SER	ASP	GLY	ASP	GLY	MET
	ASN	ALA	TRP	VAL	ALA	TRP	ARG	ASN	ARG	CYS	LYS	GLY	THR	ASP	VAL
121	GLN	ALA	TRP	ILU	ARG	GLY	CYS	ARG	LEU	***					

COMPOSITION

12	ALA	A	3	GLN	Q	8	LEU	L	10	SER	S
11	ARG	R	2	GLU	E	6	LYS	K	7	THR	T
13	ASN	N	12	GLY	G	2	MET	M	6	TRP	W
8	ASP	D	1	HIS	H	3	PHE	F	3	TYR	O
8	CYS	C	6	ILU	I	2	PRO	P	6	VAL	V

TOTAL NO. OF ACIDS = 129

• CANFIELD, R., J. BIOL. CHEM., VOL.238, NO.8, PP.2698-2707, AUG., 1963

CANFIELD, R., LIU, A.K., J. BIOL. CHEM., VOL.240, NO.5, PP. 1997-2002, MAY 1965

ABOVE SEQUENCE CONFIRMED IN THIS WORK.
DISULPHIDE BONDS ARE FOUND BETWEEN 6 AND 127, 30 AND 115, 64 AND 80, AND 76 AND 94.

JOLLES, J., JAUREGUI-ADELL, J., BERNIER, I., AND JOLLES, P., BIOCHIM. BIOPHYS. ACTA, VOL.78, PP.668-689, 1963

THIS SEQUENCE DIFFERS FROM THE ABOVE AS FOLLOWS, 40-GLN, 41-ALA, 42-THR, 43-THR, 46-ASP, 58-ASN, 59-ILU, 92-ASN, AND 93-VAL.

BLAKE, C.C.F., KOENING, D.F., MAIR, G.A., NORTH, A.C.T., PHILLIPS, D.C., AND SARMA, V.R., NATURE, NO. 4986, PP. 757-761, MAY 22, 1965

A 2 ANGSTROM RESOLUTION FOURIER SYNTHESIS HAS BEEN PERFORMED BY X-RAY CRYSTALLOGRAPHIC METHODS. THE LOCATION OF THE FOUR DISULPHIDE BRIDGES HAS BEEN CONFIRMED. THE BINDING SITE OF THE INHIBITOR N-ACETYL-GLUCOSAMINE AND ITS DIMER HAS BEEN FOUND TO BE VERY EXTENSIVE INVOLVING RESIDUES AT POSITIONS 44, 46, 47, 48, 50, 52, 57, 59, 61-63, 72, 73, 97, 99-101, 103, 107-110, 113, AND 114.

GLUCAGON - BOVINE

```
  1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9
1 H S Q G T F T S D O S K O L D S R R A Q D F V Q W L M N T *

   1   2   3   4   5   6   7   8   9  10  11  12  13  14  15
1 HIS SER GLN GLY THR PHE THR SER ASP TYR SER LYS TYR LEU ASP
  SER ARG ARG ALA GLN ASP PHE VAL GLN TRP LEU MET ASN THR ***
```

COMPOSITION

1	ALA	A	3	GLN	Q	2	LEU	L	4	SER	S
2	ARG	R	0	GLU	E	1	LYS	K	3	THR	T
1	ASN	N	1	GLY	G	1	MET	M	1	TRP	W
3	ASP	D	1	HIS	H	2	PHE	F	2	TYR	O
0	CYS	C	0	ILU	I	0	PRO	P	1	VAL	V

TOTAL NO. OF ACIDS = 29

• BROMER, W.W., SINN, L.G., AND BEHRENS, O.K., J. AM. CHEM. SOC., VOL. 79, PP. 2807-2810, JUNE 5, 1957

ARGININE VASOPRESSIN - BOVINE

THE C TERMINAL GLYCINE IS PRESENT AS THE AMIDE.
THE TWO CYSTEINES ARE LINKED BY A DISULPHIDE BOND.

```
  1 2 3 4 5 6 7 8 9

1 C O F Q N C P R G *


   1   2   3   4   5   6   7   8   9

1 CYS TYR PHE GLN ASN CYS PRO ARG GLY ***
```

COMPOSITION

0	ALA	A	1	GLN	Q	0	LEU	L	0	SER	S
1	ARG	R	0	GLU	E	0	LYS	K	0	THR	T
1	ASN	N	1	GLY	G	0	MET	M	0	TRP	W
0	ASP	D	0	HIS	H	1	PHE	F	1	TYR	O
2	CYS	C	0	ILU	I	1	PRO	P	0	VAL	V

TOTAL NO. OF ACIDS = 9

* DU VIGNEAUD, V., LAWLER, H. C., AND POPENOE, E. A., J. AM. CHEM. SOC., VOL.75, PP.4880-4881, OCT. 5, 1953

ACHER, R., AND CHAUVET, J., BIOCHIM. BIOPHYS. ACTA, VOL. 12, PP.487-488, 1953

THIS WORK CONFIRMED THE SEQUENCE ABOVE, HOWEVER GLU (E) AND ASP (D) WERE NOT DISTINGUISHED FROM GLN (Q) AND ASN (N).

LYSINE VASOPRESSIN - PIG

THE C TERMINAL GLYCINE IS PRESENT AS THE AMIDE.
THE TWO CYSTEINES ARE LINKED BY A DISULPHIDE BOND.

```
  1 2 3 4 5 6 7 8 9

1 C.O.F.Q.N.C.P.K.G.*


   1   2   3   4   5   6   7   8   9

1 CYS.TYR.PHE.GLN.ASN.CYS.PRO.LYS.GLY ***
```

COMPOSITION

0	ALA	A	1	GLN	Q	0	LEU	L	0	SER	S
0	ARG	R	0	GLU	E	1	LYS	K	0	THR	T
1	ASN	N	1	GLY	G	0	MET	M	0	TRP	W
0	ASP	D	0	HIS	H	1	PHE	F	1	TYR	O
2	CYS	C	0	ILU	I	1	PRO	P	0	VAL	V

TOTAL NO. OF ACIDS = 9

* POPENOE, E. A., LAWLER, H. C., AND DU VIGNEAUD, V.,
J. AM. CHEM. SOC., VOL.74, P.3713, JULY 20, 1952

OXYTOCIN - BOVINE

THE C TERMINAL GLYCINE IS PRESENT AS THE AMIDE.
THE TWO CYSTEINES ARE LINKED BY A DISULPHIDE BOND.
OXYTOCIN IS THE PRINCIPAL UTERINE CONTRACTING AND MILK EJECTING HORMONE OF THE POSTERIOR PITUITARY.

```
  1 2 3 4 5 6 7 8 9

1 C O I Q N C P L G *


   1   2   3   4   5   6   7   8   9

1 CYS TYR ILU GLN ASN CYS PRO LEU GLY ***
```

COMPOSITION

0	ALA	A	1	GLN	Q	1	LEU	L	0	SER	S
0	ARG	R	0	GLU	E	0	LYS	K	0	THR	T
1	ASN	N	1	GLY	G	0	MET	M	0	TRP	W
0	ASP	D	0	HIS	H	0	PHE	F	1	TYR	O
2	CYS	C	1	ILU	I	1	PRO	P	0	VAL	V

TOTAL NO. OF ACIDS = 9

* DU VIGNEAUD, V., RESSLER, C., TRIPPETT, S., J. BIOL. CHEM., VOL.205, PP.949-957, 1953

TUPPY, H. AND MICHL, H., MONATSH. CHEM., VOL.84, PP.1011-1020, 1953

HYPERTENSIN - BOVINE

```
  1 2 3 4 5 6 7 8 9 0
1 D R V O V H P F H L *
```

```
   1   2   3   4   5   6   7   8   9   10
1 ASP ARG VAL TYR VAL HIS PRO PHE HIS LEU ***
```

COMPOSITION

0	ALA	A	0	GLN	Q	1	LEU	L	0	SER	S
1	ARG	R	0	GLU	E	0	LYS	K	0	THR	T
0	ASN	N	0	GLY	G	0	MET	M	0	TRP	W
1	ASP	D	2	HIS	H	1	PHE	F	1	TYR	O
0	CYS	C	0	ILU	I	1	PRO	P	2	VAL	V

TOTAL NO. OF ACIDS = 10

* ELLIOT, D. F., AND PEART, W. S., BIOCHEM. J., VOL.65, PP.246-254, 1957

ALPHA MELANOCYTE-STIMULATING HORMONE - BOVINE, PIG, AND HORSE

ACETYL AT AMINO END.
C-TERMINAL VALINE IS AMINATED.

1 2 3 4 5 6 7 8 9 0 1 2 3

S O S M E H F R W G K P V *

1	2	3	4	5	6	7	8	9	10	11	12	13	
SER	TYR	SER	MET	GLU	HIS	PHE	ARG	TRP	GLY	LYS	PRO	VAL	***

COMPOSITION

0	ALA	A	0	GLN	Q	0	LEU	L	2	SER	S
1	ARG	R	1	GLU	E	1	LYS	K	0	THR	T
0	ASN	N	1	GLY	G	1	MET	M	1	TRP	W
0	ASP	D	1	HIS	H	1	PHE	F	1	TYR	O
0	CYS	C	0	ILU	I	1	PRO	P	1	VAL	V

TOTAL NO. OF ACIDS = 13

* HARRIS, J. I. AND LERNER, A. B., NATURE, VOL.179, NO.4574, PP.1346-1347, JUNE 29, 1957 (PIG)

LI, C. H., LABORATORY INVESTIGATION, VOL. 8, NO.2, PP.574-587, 1959 (BOVINE)

DIXON, J. S. AND LI, C. H., J. AM. CHEM. SOC., VOL.82, PP.4568-4572, SEPT. 5, 1960 (HORSE)

BETA MELANOCYTE-STIMULATING HORMONE - BOVINE

```
  1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8
1 D S G P O K M E H F R W G S P P K D *

   1   2   3   4   5   6   7   8   9  10  11  12  13  14  15
1 ASP SER GLY PRO TYR LYS MET GLU HIS PHE ARG TRP GLY SER PRO
  PRO LYS ASP ***
```

COMPOSITION

0	ALA	A	0	GLN	Q	0	LEU	L	2	SER	S
1	ARG	R	1	GLU	E	2	LYS	K	0	THR	T
0	ASN	N	2	GLY	G	1	MET	M	1	TRP	W
2	ASP	D	1	HIS	H	1	PHE	F	1	TYR	O
0	CYS	C	0	ILU	I	3	PRO	P	0	VAL	V

TOTAL NO. OF ACIDS = 18

* GESCHWIND, I.I., LI, C. H., AND BARNAFI, L., J. AM. CHEM. SOC., VOL. 79, PP.1003-1004, FEB. 20, 1957

BETA MELANOCYTE-STIMULATING HORMONE - PIG

```
  1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8
1 D E G P O K M E H F R W G S P P K D *

   1   2   3   4   5   6   7   8   9  10  11  12  13  14  15
1 ASP GLU GLY PRO TYR LYS MET GLU HIS PHE ARG TRP GLY SER PRO
  PRO LYS ASP ***
```

COMPOSITION

0	ALA	A	0	GLN	Q	0	LEU	L	1	SER	S
1	ARG	R	2	GLU	E	2	LYS	K	0	THR	T
0	ASN	N	2	GLY	G	1	MET	M	1	TRP	W
2	ASP	D	1	HIS	H	1	PHE	F	1	TYR	O
0	CYS	C	0	ILU	I	3	PRO	P	0	VAL	V

TOTAL NO. OF ACIDS = 18

* HARRIS, J. I. AND ROOS, P., NATURE, VOL.178, NO.4524, P. 90, JULY 14, 1956

GESCHWIND, I.I., LI, C. H., AND BARNAFI, L., J. AM. CHEM. SOC., VOL. 79, PP.620-625, FEB. 5, 1957

BETA MELANOCYTE-STIMULATING HORMONE - HORSE

```
  1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8
1 D E G P O K M E H F R W G S P R K D *
```

```
   1   2   3   4   5   6   7   8   9  10  11  12  13  14  15
1 ASP GLU GLY PRO TYR LYS MET GLU HIS PHE ARG TRP GLY SER PRO
  ARG LYS ASP ***
```

COMPOSITION

0	ALA	A	0	GLN	Q	0	LEU	L	1	SER	S
2	ARG	R	2	GLU	E	2	LYS	K	0	THR	T
0	ASN	N	2	GLY	G	1	MET	M	1	TRP	W
2	ASP	D	1	HIS	H	1	PHE	F	1	TYR	O
0	CYS	C	0	ILU	I	2	PRO	P	0	VAL	V

TOTAL NO. OF ACIDS = 18

* DIXON, J. S. AND LI, C. H., GEN. COMP. ENDOCRINOL., VOL.1, PP.161-169, 1961

BETA MELANOCYTE-STIMULATING HORMONE - HUMAN

```
  1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2
1 A E K K D E G P O R M E H F R W G S P P K D *
```

```
    1   2   3   4   5   6   7   8   9  10  11  12  13  14  15
1 ALA GLU LYS LYS ASP GLU GLY PRO TYR ARG MET GLU HIS PHE ARG
  TRP GLY SER PRO PRO LYS ASP ***
```

COMPOSITION

1 ALA A	0 GLN Q	0 LEU L	1 SER S
2 ARG R	3 GLU E	3 LYS K	0 THR T
0 ASN N	2 GLY G	1 MET M	1 TRP W
2 ASP D	1 HIS H	1 PHE F	1 TYR O
0 CYS C	0 ILU I	3 PRO P	0 VAL V

TOTAL NO. OF ACIDS = 22

• HARRIS, J. I., NATURE, VOL. 184, NO. 4681, PP.167-169,
JULY 18, 1959

BETA CORTICOTROPIN - PIG

```
   1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0
 1 S O S M E H F R W G K P V G K K R R P V K V O P G A E D D Q
31 L A E A F P L E F *
```

```
    1   2   3   4   5   6   7   8   9  10  11  12  13  14  15
 1 SER TYR SER MET GLU HIS PHE ARG TRP GLY LYS PRO VAL GLY LYS
   LYS ARG ARG PRO VAL LYS VAL TYR PRO GLY ALA GLU ASP ASP GLN
31 LEU ALA GLU ALA PHE PRO LEU GLU PHE ***
```

COMPOSITION

3	ALA	A	1	GLN	Q	2	LEU	L	2	SER	S
3	ARG	R	4	GLU	E	4	LYS	K	0	THR	T
0	ASN	N	3	GLY	G	1	MET	M	1	TRP	W
2	ASP	D	1	HIS	H	3	PHE	F	2	TYR	O
0	CYS	C	0	ILU	I	4	PRO	P	3	VAL	V

TOTAL NO. OF ACIDS = 39

* WHITE, W. F., AND LANDMANN, W. A., J. AM. CHEM. SOC., VOL. 77, PP.1711-1712, MARCH 20, 1955

HOWARD, K. S., SHEPHERD, R. G., EIGNER, E. A., DAVIS, D. S., AND BELL, P. H., J. AM. CHEM. SOC., VOL.77, PP.3419-3420, JUNE 20, 1955

BELL, P. H., J. AM. CHEM. SOC., VOL.76, PP.5565-5567, NOV. 1954

THIS SEQUENCE DIFFERS FROM THAT SHOWN ABOVE BY REMOVING THE ASP (D) FROM POSITION 29 AND INSERTING IT BETWEEN POSITIONS 24 AND 25.

ALPHA CORTICOTROPIN - SHEEP AND BOVINE

```
   1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0
 1 S O S M E H F R W G K P V G K K R R P V K V O P D G E A E D
31 S A Q A F P L E F *
```

```
     1   2   3   4   5   6   7   8   9  10  11  12  13  14  15
 1 SER TYR SER MET GLU HIS PHE ARG TRP GLY LYS PRO VAL GLY LYS
   LYS ARG ARG PRO VAL LYS VAL TYR PRO ASP GLY GLU ALA GLU ASP
31 SER ALA GLN ALA PHE PRO LEU GLU PHE ***
```

COMPOSITION

3	ALA	A	1	GLN	Q	1	LEU	L	3	SER	S
3	ARG	R	4	GLU	E	4	LYS	K	0	THR	T
0	ASN	N	3	GLY	G	1	MET	M	1	TRP	W
2	ASP	D	1	HIS	H	3	PHE	F	2	TYR	O
0	CYS	C	0	ILU	I	4	PRO	P	3	VAL	V

TOTAL NO. OF ACIDS = 39

* LI, C.H., GESCHWIND, I. I., COLE, D., RAACK, I. D., HARRIS, J.I., AND DIXON, J. S., NATURE, VOL.176, NO.4484, PP.687-689, OCT. 8, 1955 (SHEEP)

LI, C. H., DIXON, J. S., AND CHUNG, D., J. AM. CHEM. SOC., VOL. 80, P.2587, 1958 (BOVINE)

INSULIN A - BOVINE

```
  1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
1 G I V E Q C C A S V C S L O Q L E N O C N *
```

```
   1   2   3   4   5   6   7   8   9  10  11  12  13  14  15
1 GLY ILU VAL GLU GLN CYS CYS ALA SER VAL CYS SER LEU TYR GLN
  LEU GLU ASN TYR CYS ASN ***
```

COMPOSITION

1	ALA	A	2	GLN	Q	2	LEU	L	2	SER	S
0	ARG	R	2	GLU	E	0	LYS	K	0	THR	T
2	ASN	N	1	GLY	G	0	MET	M	0	TRP	W
0	ASP	D	0	HIS	H	0	PHE	F	2	TYR	O
4	CYS	C	1	ILU	I	0	PRO	P	2	VAL	V

TOTAL NO. OF ACIDS = 21

* SANGER, F. AND THOMPSON, E. O. P., BIOCHEM J., VOL.53, PP. 353-374, 1953

THE AMIDE GROUPS WERE SUBSEQUENTLY DETERMINED.

RYLE, A. P., SANGER, F., SMITH, L.F., AND KITAI, R., BIOCHEM. J., VOL. 60, PP. 541-556, 1955

INSULIN A - BONITO

```
   1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
1  G I(H,E,E,C(C,K,P,H)C,D,L)F E L E D O C N *

    1   2   3   4   5   6   7   8   9  10  11  12  13  14  15
1  GLY ILU(HIS,GLU,GLU,CYS(CYS,LYS,PRO,HIS)CYS,ASP,LEU)PHE GLU
   LEU GLU ASP TYR CYS ASN ***
```

COMPOSITION

0	ALA	A	0	GLN	Q	2	LEU	L	0	SER	S
0	ARG	R	4	GLU	E	1	LYS	K	0	THR	T
1	ASN	N	1	GLY	G	0	MET	M	0	TRP	W
2	ASP	D	2	HIS	H	1	PHE	F	1	TYR	O
4	CYS	C	1	ILU	I	1	PRO	P	0	VAL	V

TOTAL NO. OF ACIDS = 21

* KOTAKI, A., J. BIOCHEM. (TOKYO), VOL.53, NO.1, PP.61-70, 1963

INSULIN A - HORSE

```
  1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
1 G I V E Q C C T G I C S L O Q L E N O C N *
```

```
     1   2   3   4   5   6   7   8   9  10  11  12  13  14  15
1  GLY ILU VAL GLU GLN CYS CYS THR GLY ILU CYS SER LEU TYR GLN
   LEU GLU ASN TYR CYS ASN ***
```

COMPOSITION

0	ALA	A	2	GLN	Q	2	LEU	L	1	SER	S
0	ARG	R	2	GLU	E	0	LYS	K	1	THR	T
2	ASN	N	2	GLY	G	0	MET	M	0	TRP	W
0	ASP	D	0	HIS	H	0	PHE	F	2	TYR	O
4	CYS	C	2	ILU	I	0	PRO	P	1	VAL	V

TOTAL NO. OF ACIDS = 21

* HARRIS, J. I., SANGER, F., AND NAUGHTON, M. A., ARCH. BIOCHEM. BIOPHYS., VOL.65, PP.427-438, 1956

SOME EVIDENCE FOR THE SEQUENCE WAS DERIVED FROM HOMOLOGY WITH BOVINE INSULIN.

INSULIN A - SHEEP

```
  1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
1 G I V E Q C C A G V C S L O Q L E N O C N *

   1   2   3   4   5   6   7   8   9  10  11  12  13  14  15
1 GLY ILU VAL GLU GLN CYS CYS ALA GLY VAL CYS SER LEU TYR GLN
  LEU GLU ASN TYR CYS ASN ***
```

COMPOSITION

1	ALA	A	2	GLN	Q	2	LEU	L	1	SER	S
0	ARG	R	2	GLU	E	0	LYS	K	0	THR	T
2	ASN	N	2	GLY	G	0	MET	M	0	TRP	W
0	ASP	D	0	HIS	H	0	PHE	F	2	TYR	O
4	CYS	C	1	ILU	I	0	PRO	P	2	VAL	V

TOTAL NO. OF ACIDS = 21

* BROWN, H., SANGER, F., AND KITAI, R., BIOCHEM. J., VOL.60, PP.556-565, 1955

SOME EVIDENCE FOR THE SEQUENCE WAS DERIVED FROM HOMOLOGY WITH BOVINE INSULIN.

INSULIN A - SPERM WHALE, FIN-WHALE, PIG, AND HUMAN

```
  1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
1 G I V E Q C C T S I C S L O Q L E N O C N *

   1   2   3   4   5   6   7   8   9  10  11  12  13  14  15
1 GLY ILU VAL GLU GLN CYS CYS THR SER ILU CYS SER LEU TYR GLN
  LEU GLU ASN TYR CYS ASN ***
```

COMPOSITION

0 ALA A	2 GLN Q	2 LEU L	2 SER S
0 ARG R	2 GLU E	0 LYS K	1 THR T
2 ASN N	1 GLY G	0 MET M	0 TRP W
0 ASP D	0 HIS H	0 PHE F	2 TYR O
4 CYS C	2 ILU I	0 PRO P	1 VAL V

TOTAL NO. OF ACIDS = 21

* BROWN, H., SANGER, F., AND KITAI, R., BIOCHEM. J., VOL.60, PP.556-565, 1955 (PIG)

SOME EVIDENCE FOR THE SEQUENCE WAS DERIVED FROM HOMOLOGY WITH BOVINE INSULIN.

HARRIS, J. I., SANGER, F., AND NAUGHTON, M. A., ARCH. BIOCHEM. BIOPHYS., VOL.65, PP.427-438, 1956 (SPERM WHALE)

HAMA, H., TITANI, K., SAKAKI, S., AND NARITA, K., J. BIOCHEM. (TOKYO), VOL.56, NO.3, PP.285-293, 1964 (FIN-WHALE)

THIS WORK CONFIRMED THE SEQUENCE ABOVE, EXCEPT GLU (E) AND GLN (Q) WERE INTERCHANGED AT POSITIONS 15 AND 17.

NICOL, D. S. H. AND SMITH, L. F., NATURE, VOL.187, NO.4736, PP.483-485, AUG. 6, 1960 (HUMAN)

INSULIN A - SEI-WHALE

|

```
  1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
1 G I V E Q C C A S T C S L O Q L E N O C N *
```

```
    1   2   3   4   5   6   7   8   9  10  11  12  13  14  15
1 GLY ILU VAL GLU GLN CYS CYS ALA SER THR CYS SER LEU TYR GLN
  LEU GLU ASN TYR CYS ASN ***
```

COMPOSITION

1	ALA	A	2	GLN	Q	2	LEU	L	2	SER	S
0	ARG	R	2	GLU	E	0	LYS	K	1	THR	T
2	ASN	N	1	GLY	G	0	MET	M	0	TRP	W
0	ASP	D	0	HIS	H	0	PHE	F	2	TYR	O
4	CYS	C	1	ILU	I	0	PRO	P	1	VAL	V

TOTAL NO. OF ACIDS = 21

ISHIHARA, Y., SAITO, T., ITO, Y., AND FUJINO, M., NATURE, VOL.181, NO.4621, PP.1461-1469, MAY 24, 1958 (SEI-WHALE)

INSULIN B - BOVINE, SHEEP, HORSE, HUMAN, PIG, AND SPERM WHALE

TWO DISULPHIDE BONDS CONNECT THE A AND B CHAINS.
A7 IS BONDED TO B7 AND A20 IS BONDED TO B19. IN ADDITION THERE IS A BOND FROM A6 TO A11.

```
  1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0

1 F V N Q H L C G S H L V E A L O L V C G E R G F F O T P K A

  *

   1   2   3   4   5   6   7   8   9   10  11  12  13  14  15

1 PHE VAL ASN GLN HIS LEU CYS GLY SER HIS LEU VAL GLU ALA LEU

  TYR LEU VAL CYS GLY GLU ARG GLY PHE PHE TYR THR PRO LYS ALA

  ***
```

COMPOSITION

2	ALA	A	1	GLN	Q	4	LEU	L	1	SER	S
1	ARG	R	2	GLU	E	1	LYS	K	1	THR	T
1	ASN	N	3	GLY	G	0	MET	M	0	TRP	W
0	ASP	D	2	HIS	H	3	PHE	F	2	TYR	O
2	CYS	C	0	ILU	I	1	PRO	P	3	VAL	V

TOTAL NO. OF ACIDS = 30

* RYLE, A. P., SANGER, F., SMITH, L.F., AND KITAI, R., BIOCHEM. J., VOL. 60, PP.541-556, 1955 (BOVINE, SHEEP, AND PIG)

SANGER, F. AND TUPPY, H., BIOCHEM. J., VOL.49, PP.481-490, 1951 (BOVINE)
THE AMIDE GROUPS WERE SUBSEQUENTLY DETERMINED.

HARRIS, J. I., SANGER, F., AND NAUGHTON, M. A., ARCH. BIOCHEM. BIOPHYS., VOL.65, PP.427-438, 1956 (SPERM WHALE AND HORSE)

ISHIHARA, Y., SAITO, T., ITO, Y., AND FUJINO, M., NATURE, VOL.181, NO.4621, PP.1461-1469, MAY 24,1958 (SPERM AND SEI-WHALE)

NICOL, D. S. H. AND SMITH, L. F., NATURE, VOL.187, NO.4736, PP.483-485, AUG. 6, 1960 (HUMAN)

HUMAN INSULIN B CHAIN IS IDENTICAL WITH ABOVE EXCEPT THAT POSITION 30 IS THR (T).

INSULIN B - BONITO

```
  1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0
1 A A N(P,H,L)C(G,S,H,L,V,E,A,L)O L(V,C,G,E)R G F F O Q P K •

   1   2   3   4   5   6   7   8   9  10  11  12  13  14  15
1 ALA ALA ASN(PRO,HIS,LEU)CYS(GLY,SER,HIS,LEU,VAL,GLU,ALA,LEU)
  TYR LEU(VAL,CYS,GLY,GLU)ARG GLY PHE PHE TYR GLN PRO LYS ***
```

COMPOSITION

3	ALA	A	1	GLN	Q	4	LEU	L	1	SER	S
1	ARG	R	2	GLU	E	1	LYS	K	0	THR	T
1	ASN	N	3	GLY	G	0	MET	M	0	TRP	W
0	ASP	D	2	HIS	H	2	PHE	F	2	TYR	O
2	CYS	C	0	ILU	I	2	PRO	P	2	VAL	V

TOTAL NO. OF ACIDS = 29

• KOTAKI, A., J. BIOCHEM.(TOKYO), VOL.51, NO.4, PP.301-309, 1962

FIBRINOPEPTIDE A - BOVINE

FIBRINOPEPTIDES ARE THOSE PORTIONS OF VERTEBRATE FIBRINOGEN MOLECULES WHICH ARE PROTEOLYTICALLY REMOVED BY THE ENZYME THROMBIN. THEIR REMOVAL PERMITS SPONTANEOUS POLYMERIZATION OF THE PARENT MOLECULES TO FORM AN INSOLUBLE FIBRINOGEL. SINCE THE FUNCTION OF THE FIBRINOPEPTIDES IS RATHER NON-SPECIFIC, LARGE SEQUENCE CHANGES ARE OBSERVED AMONG CLOSELY RELATED SPECIES.

```
  1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9

1 E D G S D P P S G D F L T E G G G V R /


   1   2   3   4   5   6   7   8   9  10  11  12  13  14  15

1 GLU ASP GLY SER ASP PRO PRO SER GLY ASP PHE LEU THR GLU GLY

  GLY GLY VAL ARG ///
```

COMPOSITION

0	ALA	A	0	GLN	Q	1	LEU	L	2	SER	S
1	ARG	R	2	GLU	E	0	LYS	K	1	THR	T
0	ASN	N	5	GLY	G	0	MET	M	0	TRP	W
3	ASP	D	0	HIS	H	1	PHE	F	0	TYR	O
0	CYS	C	0	ILU	I	2	PRO	P	1	VAL	V

TOTAL NO. OF ACIDS = 19

* DOOLITTLE, R. F. AND BLOMBACK, B., NATURE, VOL. 202, NO. 4928, PP. 147-152, APRIL 11, 1964

FIBRINOPEPTIDE A - SHEEP

```
  1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9
1 A D D S D P V G G E F L A E G G G V R /

    1   2   3   4   5   6   7   8   9  10  11  12  13  14  15
1 ALA ASP ASP SER ASP PRO VAL GLY GLY GLU PHE LEU ALA GLU GLY
  GLY GLY VAL ARG ///
```

COMPOSITION

2	ALA	A	0	GLN	Q	1	LEU	L	1	SER	S
1	ARG	R	2	GLU	E	0	LYS	K	0	THR	T
0	ASN	N	5	GLY	G	0	MET	M	0	TRP	W
3	ASP	D	0	HIS	H	1	PHE	F	0	TYR	O
0	CYS	C	0	ILU	I	1	PRO	P	2	VAL	V

TOTAL NO. OF ACIDS = 19

• DOOLITTLE, R. F. AND BLOMBACK, B., NATURE, VOL. 202, NO. 4928, PP. 147-152, APRIL 11, 1964

FIBRINOPEPTIDE A - GOAT

```
  1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9
1 A D D S D P V G G E F L A E G G G V R /

   1   2   3   4   5   6   7   8   9  10  11  12  13  14  15
1 ALA ASP ASP SER ASP PRO VAL GLY GLY GLU PHE LEU ALA GLU GLY
  GLY GLY VAL ARG ///
```

COMPOSITION

2 ALA A	0 GLN Q	1 LEU L	1 SER S
1 ARG R	2 GLU E	0 LYS K	0 THR T
0 ASN N	5 GLY G	0 MET M	0 TRP W
3 ASP D	0 HIS H	1 PHE F	0 TYR O
0 CYS C	0 ILU I	1 PRO P	2 VAL V

TOTAL NO. OF ACIDS = 19

• DOOLITTLE, R. F. AND BLOMBACK, B., NATURE, VOL. 202, NO. 4928, PP. 147-152, APRIL 11, 1964

FIBRINOPEPTIDE A - REINDEER

```
  1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9
1 A D G S D P A G G E F(L,A,E,G,G,G,V)R /

   1   2   3   4   5   6   7   8   9  10  11  12  13  14  15
1 ALA ASP GLY SER ASP PRO ALA GLY GLY GLU PHE(LEU,ALA,GLU,GLY,
  GLY,GLY,VAL)ARG ///
```

COMPOSITION

3	ALA	A	0	GLN	Q	1	LEU	L	1	SER	S
1	ARG	R	2	GLU	E	0	LYS	K	0	THR	T
0	ASN	N	6	GLY	G	0	MET	M	0	TRP	W
2	ASP	D	0	HIS	H	1	PHE	F	0	TYR	O
0	CYS	C	0	ILU	I	1	PRO	P	1	VAL	V

TOTAL NO. OF ACIDS = 19

• DOOLITTLE, R. F. AND BLOMBACK, B., NATURE, VOL. 202, NO. 4928, PP. 147-152, APRIL 11, 1964

PIBRINOPEPTIDE A - PIG

```
  1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7
1 A E V Q D K G E F L A E G G G V R /

    1   2   3   4   5   6   7   8   9  10  11  12  13  14  15
1 ALA GLU VAL GLN ASP LYS GLY GLU PHE LEU ALA GLU GLY GLY GLY
  VAL ARG ///
```

COMPOSITION

2	ALA	A	1	GLN	Q	1	LEU	L	0	SER	S
1	ARG	R	3	GLU	E	1	LYS	K	0	THR	T
0	ASN	N	4	GLY	G	0	MET	M	0	TRP	W
1	ASP	D	0	HIS	H	1	PHE	F	0	TYR	O
0	CYS	C	0	ILU	I	0	PRO	P	2	VAL	V

TOTAL NO. OF ACIDS = 17

* DOOLITTLE, R. F. AND BLOMBACK, B., NATURE, VOL. 202, NO. 4928, PP. 147-152, APRIL 11, 1964

FIBRINOPEPTIDE A - HUMAN

```
  1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6
1 A D S G E G D F L A E G G G V R /

   1   2   3   4   5   6   7   8   9  10  11  12  13  14  15
1 ALA ASP SER GLY GLU GLY ASP PHE LEU ALA GLU GLY GLY GLY VAL
  ARG ///
```

COMPOSITION

2	ALA	A	0	GLN	Q	1	LEU	L	1	SER	S
1	ARG	R	2	GLU	E	0	LYS	K	0	THR	T
0	ASN	N	5	GLY	G	0	MET	M	0	TRP	W
2	ASP	D	0	HIS	H	1	PHE	F	0	TYR	O
0	CYS	C	0	ILU	I	0	PRO	P	1	VAL	V

TOTAL NO. OF ACIDS = 16

* DOOLITTLE, R. F. AND BLOMBACK, B., NATURE,* VOL. 202, NO. 4928, PP. 147-152, APRIL 11, 1964

PHOSPHO-SERINE OCCURS AT POSITION 3 IN ABOUT HALF THE MOLECULES. A MINOR COMPONENT FRAGMENT, WITH THE N TERMINAL ALANINE MISSING, HAS BEEN DETECTED IN ALL INDIVIDUALS.

FIBRINOPEPTIDE A - RABBIT

```
  1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6
1 V D P G E T S F L(T,E,G,G)D A R /

   1   2   3   4   5   6   7   8   9  10  11  12  13  14  15
1 VAL ASP PRO GLY GLU THR SER PHE LEU(THR,GLU,GLY,GLY)ASP ALA
  ARG ///
```

COMPOSITION

1	ALA	A	0	GLN	Q	1	LEU	L	1	SER	S
1	ARG	R	2	GLU	E	0	LYS	K	2	THR	T
0	ASN	N	3	GLY	G	0	MET	M	0	TRP	W
2	ASP	D	0	HIS	H	1	PHE	F	0	TYR	O
0	CYS	C	0	ILU	I	1	PRO	P	1	VAL	V

TOTAL NO. OF ACIDS = 16

• DOOLITTLE, R. F. AND BLOMBACK, B., NATURE, VOL. 202,
NO. 4928, PP. 147-152, APRIL 11, 1964

FIBRINOPEPTIDE B - BOVINE

PYRROLIDONE CARBOXYLIC ACID - AT AMINO END
SO4 ATTACHED TO TYROSINE AT POSITION 5

```
  1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0

1 F P T D O D E G Q D D R P K V G L G A R /
```

```
   1   2   3   4   5   6   7   8   9   10  11  12  13  14  15

1 PHE PRO THR ASP TYR ASP GLU GLY GLN ASP ASP ARG PRO LYS VAL

  GLY LEU GLY ALA ARG ///
```

COMPOSITION

1 ALA A	1 GLN Q	1 LEU L	0 SER S
2 ARG R	1 GLU E	1 LYS K	1 THR T
0 ASN N	3 GLY G	0 MET M	0 TRP W
4 ASP D	0 HIS H	1 PHE F	1 TYR O
0 CYS C	0 ILU I	2 PRO P	1 VAL V

TOTAL NO. OF ACIDS = 20

* DOOLITTLE, R. F. AND BLOMBACK, B., NATURE, VOL. 202,
NO. 4928, PP. 147-152, APRIL 11, 1964

FIBRINOPEPTIDE B - SHEEP

SO4 ATTACHED TO TYROSINE AT POSITION 5

```
  1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0
1 G O L D O D E V D D N R A K L P L D A R /
```

```
   1   2   3   4   5   6   7   8   9   10  11  12  13  14  15
1 GLY TYR LEU ASP TYR ASP GLU VAL ASP ASP ASN ARG ALA LYS LEU
  PRO LEU ASP ALA ARG ///
```

COMPOSITION

2	ALA	A	0	GLN	Q	3	LEU	L	0	SER	S
2	ARG	R	1	GLU	E	1	LYS	K	0	THR	T
1	ASN	N	1	GLY	G	0	MET	M	0	TRP	W
5	ASP	D	0	HIS	H	0	PHE	F	2	TYR	O
0	CYS	C	0	ILU	I	1	PRO	P	1	VAL	V

TOTAL NO. OF ACIDS = 20

* DOOLITTLE, R. F. AND BLOMBACK, B., NATURE, VOL. 202,
NO. 4928, PP. 147-152, APRIL 11, 1964

FIBRINOPEPTIDE B - GOAT

SO4 ATTACHED TO TYROSINE AT POSITION 5

```
  1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0
1 G O L D O D E V D D N R A K L P L D A R /
```

```
   1   2   3   4   5   6   7   8   9  10  11  12  13  14  15
1 GLY TYR LEU ASP TYR ASP GLU VAL ASP ASP ASN ARG ALA LYS LEU
  PRO LEU ASP ALA ARG ///
```

COMPOSITION

2	ALA	A	0	GLN	Q	3	LEU	L	0	SER	S
2	ARG	R	1	GLU	E	1	LYS	K	0	THR	T
1	ASN	N	1	GLY	G	0	MET	M	0	TRP	W
5	ASP	D	0	HIS	H	0	PHE	F	2	TYR	O
0	CYS	C	0	ILU	I	1	PRO	P	1	VAL	V

TOTAL NO. OF ACIDS = 20

• DOOLITTLE, R. F. AND BLOMBACK, B., NATURE, VOL. 202,
NO. 4928, PP.147-152, APRIL 11, 1964

FIBRINOPEPTIDE B - REINDEER

PYRROLIDONE CARBOXYLIC ACID - AT AMINO END
SO4 ATTACHED TO TYROSINE AT POSITION 4
A MUTANT HAS BEEN FOUND WHERE GLYCINE REPLACES HISTIDINE
IN POSITION 9.

```
  1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9

1 L A D O D E V(E,H,D)R A K L H L D A R /


   1   2   3   4   5   6   7   8   9  10  11  12  13  14  15

1 LEU ALA ASP TYR ASP GLU VAL(GLU,HIS,ASP)ARG ALA LYS LEU HIS

  LEU ASP ALA ARG ///
```

COMPOSITION

3	ALA	A	0	GLN	Q	3	LEU	L	0	SER	S
2	ARG	R	2	GLU	E	1	LYS	K	0	THR	T
0	ASN	N	0	GLY	G	0	MET	M	0	TRP	W
4	ASP	D	2	HIS	H	0	PHE	F	1	TYR	O
0	CYS	C	0	ILU	I	0	PRO	P	1	VAL	V

TOTAL NO. OF ACIDS = 19

* DOOLITTLE, R. F. AND BLOMBACK, B., NATURE, VOL. 202,
NO. 4928, PP. 147-152, APRIL 11, 1964

FIBRINOPEPTIDE B - PIG

SO4 ATTACHED TO TYROSINE AT POSITION 4

```
  1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9
1 A I D O D E D E D G R P K V H V D A R /

   1   2   3   4   5   6   7   8   9  10  11  12  13  14  15
1 ALA ILU ASP TYR ASP GLU ASP GLU ASP GLY ARG PRO LYS VAL HIS
  VAL ASP ALA ARG ///
```

COMPOSITION

2	ALA	A	0	GLN	Q	0	LEU	L	0	SER	S
2	ARG	R	2	GLU	E	1	LYS	K	0	THR	T
0	ASN	N	1	GLY	G	0	MET	M	0	TRP	W
5	ASP	D	1	HIS	H	0	PHE	F	1	TYR	O
0	CYS	C	1	ILU	I	1	PRO	P	2	VAL	V

TOTAL NO. OF ACIDS = 19

• DOOLITTLE, R. F. AND BLOMBACK, B., NATURE, VOL. 202, NO. 4928, PP. 147-152, APRIL 11, 1964

FIBRINOPEPTIDE B - HUMAN

PYRROLIDONE CARBOXYLIC ACID - AT AMINO END
PHOSPHO-SERINE OCCURS IN POSITION 11.

```
  1 2 3 4 5 6 7 8 9 0 1 2 3

1 G V N D N E E G F F S A R /
```

```
   1   2   3   4   5   6   7   8   9  10  11  12  13

1 GLY VAL ASN ASP ASN GLU GLU GLY PHE PHE SER ALA ARG ///
```

COMPOSITION

1	ALA	A	0	GLN	Q	0	LEU	L	1	SER	S
1	ARG	R	2	GLU	E	0	LYS	K	0	THR	T
2	ASN	N	2	GLY	G	0	MET	M	0	TRP	W
1	ASP	D	0	HIS	H	2	PHE	F	0	TYR	O
0	CYS	C	0	ILU	I	0	PRO	P	1	VAL	V

TOTAL NO. OF ACIDS = 13

• DOOLITTLE, R. F. AND BLOMBACK, B., NATURE, VOL. 202,
NO. 4928, PP. 147-152, APRIL 11, 1964

FIBRINOPEPTIDE B - RABBIT

SO4 ATTACHED TO TYROSINE AT POSITION 4

```
  1 2 3 4 5 6 7 8 9 0 1 2 3
1 A D D O(D,E,P,L,D,V)D A R /

   1   2   3   4   5   6   7   8   9  10  11  12  13
1 ALA ASP ASP TYR(ASP,GLU,PRO,LEU,ASP,VAL)ASP ALA ARG ///
```

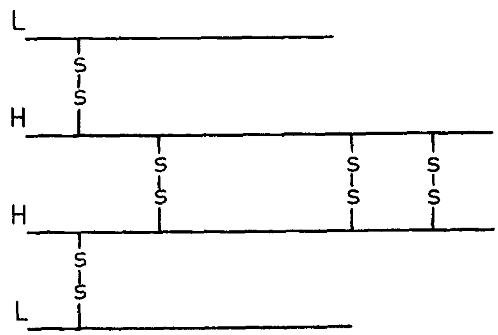
COMPOSITION

2	ALA	A	0	GLN	Q	1	LEU	L	0	SER	S
1	ARG	R	1	GLU	E	0	LYS	K	0	THR	T
0	ASN	N	0	GLY	G	0	MET	M	0	TRP	W
5	ASP	D	0	HIS	H	0	PHE	F	1	TYR	O
0	CYS	C	0	ILU	I	1	PRO	P	1	VAL	V

TOTAL NO. OF ACIDS = 13

* DOOLITTLE, R. F. AND BLOMBACK, B., NATURE, VOL. 202, NO. 4928, PP. 147-152, APRIL 11, 1964

Immunoglobulins are serum proteins distinguishable by electrophoretic mobilities, sedimentation coefficients and differential solubilities in variable ethanol-salt solutions. Of these, the gamma globulins are associated with normal antibody function. A proposal for the structure of gamma globulin has been made by Porter (1959) and Fleishman *et al*, (1963).



Gamma globulin is thought to be a tetramer consisting of two pairs of identical polypeptide chains held in a particular configuration by disulfide bonds. There are two L (m.w. 20-25,000 each) and two H chains (m.w. 50,000-55,000 each). Because of the chemical problems associated with elucidation of gamma globulin structure, attention has turned to the abundantly produced, structurally similar globulins found in multiple myeloma.

Bence-Jones proteins are found exclusively in the urine of all multiple myeloma patients, and probably represent abnormal protein synthesized by the multiple myeloma tumor cell. They are thought to be made exclusively of L chains, related to gamma globulins, (Edelman and Gally, 1962, S. Cohen, 1963, Putnam 1962). It is thought that determination of the amino acid sequence of a particular individual's Bence-Jones protein would reflect a homologous sequence in that individual's antibody structure, thereby partially elucidating the structure of gamma globulin.

Cohen, S. Biochem. J. Vol. 89, p. 334 (1963)
Edelman, G. M. and Gally, J. A. J. Exp. Med. Vol. 116, p. 207 (1962)
Fleishman, J. B. *et al.* Biochem. J. Vol. 88, p. 220 (1963)
Porter, R. R. Biochem. J. Vol. 73, p. 119 (1959)
Putnam, F. W. Biochim. Biophys. Acta. Vol. 63, p. 539 (1962)

BENCE-JONES PROTEIN

```
     1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0
  1  D(T,S,S,S,E,E,P,M,I)L S(S,G,A,V)D R(D,T,T,S,S,E,E,A,V,I,I,I,
 31  F,C)L(O,D,W,E,E,P,G)K K A P K L L I O D A S K L E(S,P,G,A,V)
 61  R F S(D,T,T,S,G,G,G)F T(D,S,S,E,E,P,I,L)I A T O(D,D,T,E,E,P,
 91  L,L,C,O,F,F)G(T,G,G)K V D F K R T(S,P,A,A,V)V F I(D,S,E,E,P,
121  P,F)L K S(T,S,G,A)V(V,C)L L D(D,P,F)O R E A K V E W K V(D,D,
151  D,S,S,E,E,G,A,L)E S(D,T,S,E,E,V)K D(T,S)O S S S T L L T L S
181  K A D O E K H K L O A C E V(T,E,G,H)L S(T,S,P,V)K S F D R G
211  E C *
```

```
       1   2   3   4   5   6   7   8   9   10  11  12  13  14  15
  1  ASP(THR,SER,SER,SER,GLU,GLU,PRO,MET,ILU)LEU SER(SER,GLY,ALA,
     VAL)ASP ARG(ASP,THR,THR,SER,SER,GLU,GLU,ALA,VAL,ILU,ILU,ILU,
 31  PHE,CYS)LEU(TYR,ASP,TRP,GLU,GLU,PRO,GLY)LYS LYS ALA PRO LYS
     LEU LEU ILU TYR ASP ALA SER LYS LEU GLU(SER,PRO,GLY,ALA,VAL)
 61  ARG PHE SER(ASP,THR,THR,SER,GLY,GLY,GLY)PHE THR(ASP,SER,SER,
     GLU,GLU,PRO,ILU,LEU)ILU ALA THR TYR(ASP,ASP,THR,GLU,GLU,PRO,
 91  LEU,LEU,CYS,TYR,PHE,PHE)GLY(THR,GLY,GLY)LYS VAL ASP PHE LYS
     ARG THR(SER,PRO,ALA,ALA,VAL)VAL PHE ILU(ASP,SER,GLU,GLU,PRO,
121  PRO,PHE)LEU LYS SER(THR,SER,GLY,ALA)VAL(VAL,CYS)LEU LEU ASP
    (ASP,PRO,PHE)TYR ARG GLU ALA LYS VAL GLU TRP LYS VAL(ASP,ASP,
151  ASP,SER,SER,GLU,GLU,GLY,ALA,LEU)GLU SER(ASP,THR,SER,GLU,GLU,
     VAL)LYS ASP(THR,SER)TYR SER SER SER THR LEU LEU THR LEU SER
181  LYS ALA ASP TYR GLU LYS HIS LYS LEU TYR ALA CYS GLU VAL(THR,
     GLU,GLY,HIS)LEU SER(THR,SER,PRO,VAL)LYS SER PHE ASP ARG GLY
211  GLU CYS ***
```

COMPOSITION

13	ALA	A	0	GLN	Q	17	LEU	L	29	SER	S
5	ARG	R	24	GLU	E	14	LYS	K	17	THR	T
0	ASN	N	13	GLY	G	1	MET	M	2	TRP	W
20	ASP	D	2	HIS	H	10	PHE	F	8	TYR	O
5	CYS	C	8	ILU	I	11	PRO	P	13	VAL	V

TOTAL NO. OF ACIDS = 212

• HILSCHMANN, N. AND CRAIG, L.C., PROC. NATL. ACAD. SCI. U.S., VOL.53, NO.6, PP.1403-1409, 1965

AUTHOR INDEX

MOORE, S.	RN	BO	4.001
MOWER, H. F.	FE	CP	3.002
MULLER, C. J.	GL	HUH	2.020
MURAKAMI, H.	CY	BY	1.001
MURAYAMA, M.	GL	HUH	2.020
NAKASHIMA, T.	CY	PG	1.005
	FE	CP	3.002
NARITA, K.	CY	BY	1.001
	IS	WPA	8.305
NAUGHTON, M. A.	IS	HOA	8.303
	IS	WPA	8.305
	IS	BOB	8.321
NEEDLEMAN, S. B.	CY	CH	1.002
	CY	PG	1.005
NEURATH, H.	TR	BOTR	7.002
NICOL, D. S. H.	IS	WPA	8.305
	IS	BOB	8.321
NORTH, A. C. T.	LS	CH	7.201
NOUVEL, G.	TI	BOPA	5.001
PALEUS, S.	CY	PG	1.005
	CY	RR	1.010
	CY	SM	1.011
PAULING, L.	GL	HUH	2.020
PHILLIPS, D. C.	LS	CH	7.201
PEART, W. S.	PR	BOHY	8.104
PORTER, R. R.			10.000
POPENOE, E. A.	PR	BOAR	8.101
	PR	PGLS	8.102
POSPISILOVA, D.	TI	BOPA	5.001
PRUSIK, Z.	TR	BOCH	7.001
PUTNAM F. W.			10.000
RAACK, I. D.	TN	SBAC	8.207
RADICEVIC, M.	TI	BOPA	5.001
RESSLER, C.	PR	BOOX	8.103
RHINESMITH, H. W.	GL	HUH	2.020
ROOS, P.	TN	PGBM	8.203
RUDLOFF, V.	GL	HUHA	2.001
	GL	HUHB	2.002
RYLE, A. P.	IS	BOA	8.301
	IS	BOB	8.321
SAITO, T.	IS	WHA	8.306
	IS	BOB	8.321
SAKAKI, S.	IS	WPA	8.305
SANGER, F.	IS	BOA	8.301
	IS	HOA	8.303
	IS	SHA	8.304
	IS	WPA	8.305
	IS	BOB	8.321
SARMA, V. R.	LS	CH	7.201
SCHNEIDER, R. G.	GL	HUH	2.020
SCHRAMM, G.	TM	TM	6.001
SCHROEDER, W. A.	GL	HUHA	2.001
	GL	HUHG	2.003
	GL	HUH	2.020
SCHWARTZ, H. C.	GL	HUH	2.020